A LONGITUDINAL STUDY OF AGEING PERSONS

by

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"Discern of the coming on of years ... for age will not be defied."

Francis Bacon.

C O N T E N T S

1. Declaration
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DECLARATION

In accordance with the regulations of the University of Edinburgh I declare that the work on which this submission is based was done while I was a member of a research group and that my contribution to this was substantial. Most of the data used in the papers submitted were collected by me. The use of data collected by others is described in detail in the introduction.

Data about sampling, body weight, skinfold thickness, height, spinal curves and body diameters were reported in a thesis for the degree of Doctor of Medicine accepted by the University of Edinburgh in 1973. This material was used in papers numbered 2, 24, 25, 26, 27 and 30 in this submission. Of these numbers 2 and 30 were included as reprints in my MD thesis.

ABSTRACT OF THESIS (Regulation 6.9)

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Title of Thesis A LONGITUDINAL STUDY OF AGEING PERSONS

This submission is composed of papers based upon a longitudinal study of ageing persons carried on in Edinburgh from 1968 to 1974. The subjects were 215 men and 272 women aged 63-90 years who formed a simple random sample of the 27,000 older people living in ten city wards in north Edinburgh in 1968. Examinations, relevant to this submission, were made by a physician, a psychiatrist and a dietician.

The first examination was made in 1968-69 with reviews after one (1969-70) and five (1973-74) years. The project was designed to study physical and mental health over this period and to record certain measurements. The year 1967 was spent planning the study, validating the questionnaire and learning to make reproducible measurements.

The first examination yielded papers describing cross-sectional data in respect of respiratory symptoms and function, ischaemic heart disease, heart size, peripheral vascular disease, spinal curvature, vision, hearing, haematological variables, plasma urea, bowel habit, feet, urinary signs and symptoms, the ankle jerk, the androgyny score and diet related to health.

The review examinations provided papers describing longitudinal aspects of respiratory studies, ischaemic heart disease, heart size, blood pressure and stroke, vision, hearing, bone mass, height, body weight and skinfold thickness.

Other papers were concerned with sampling, methods, the fate of the sample, factors related to mortality and the use of medical services.

Use this side only

LIST OF PAPERS

A. Methods, Sampling and Use of Services

1. MILNE, J.S., HOPE, K. and WILLIAMSON, J.
Variability in replies to a questionnaire on symptoms of physical illness.
Journal of Chronic Diseases 1970, 22, 805.

2. MILNE, J.S., MAULE, M.M. and WILLIAMSON, J.
Method of sampling in a study of older people with a comparison of respondents and non-respondents.
British Journal of Preventive and Social Medicine 1971, 25, 37.

3. MILNE, J.S., MAULE, M.M., CORMACK, S. and WILLIAMSON, J.
The design and testing of a questionnaire and examination to assess physical and mental health in older people, using a staff nurse as the observer.
Journal of Chronic Diseases 1972, 25, 385.

4. MILNE, J.S. and CHOPIN, J.
Reviews after one and five years in a longitudinal study of ageing persons.
Age and Ageing 1975, 4, 152.

5. MILNE, J.S. and LAUDER, I.J.
Factors associated with mortality in older people.
Age and Ageing 1978, 7, 129.

6. MILNE, J.S. and WILLIAMSON, J.
Comparison of teaching machine with an observer in the detection of angina pectoris by questionnaire.
British Journal of Preventive and Social Medicine 1971, 25, 105.

7. MILNE, J.S. and WILLIAMSON, J.
The use of medical services by older people.
Health Bulletin 1972, 31, 263.

B. Cardiovascular and Respiratory

8. MILNE, J.S. and WILLIAMSON, J.
Respiratory function tests in older people.
Clinical Science 1972, 42, 371.

9. MILNE, J.S. and WILLIAMSON, J.
Respiratory symptoms and smoking habits in older people, with age and sex differences.
Respiration 1972, 29, 359.

10. MILNE, J.S. and WILLIAMSON, J.
The relationship of respiratory function tests to respiratory symptoms and smoking in older people.
Respiration 1972, 29, 206.

11. MILNE, J.S.
Longitudinal respiratory studies in older people.
Thorax 1978, 33, 547.

12. KITCHIN, A.H., LOWTHER, C.P. and MILNE, J.S.
Prevalence of clinical and electrocardiographic evidence of ischaemic heart disease in the older population.
British Heart Journal 1973, 35, 946.

13. MILNE, J.S. and LAUDER, I.J.
Heart size in older people.
British Heart Journal 1974, 36, 352.

14. KITCHIN, A.H. and MILNE, J.S.
Longitudinal survey of ischaemic heart disease in randomly selected sample of older population.
British Heart Journal 1977, 39, 889.

15. LAUDER, I.J. and MILNE, J.S.
Longitudinal study of heart size in older people.
British Heart Journal 1976, 38, 1286.

16. MILNE, J.S.
A longitudinal study of blood pressure and stroke in older people.
Journal of Clinical and Experimental Gerontology. 1981 in the press.

17. MILNE, J.S. and WILLIAMSON, J.
Intermittent claudication and peripheral pulses in older people.
Age and Ageing 1972, 1, 146.

C. <u>Special Senses</u>

18. MILNE, J.S. and WILLIAMSON, J.
Visual acuity in older people.
Gerontologia Clinica 1972, 14, 249.

19. MILNE, J.S.
Longitudinal studies of vision in older people.
Age and Ageing 1979, 8, 160.

20. MILNE, J.S. and LAUDER, I.J.
Pure tone audiometry in older people.
British Journal of Audiology 1975, 9, 50.

21. MILNE, J.S.
Hearing loss related to some signs and symptoms in older people.
British Journal of Audiology 1976, 10, 65.

22. MILNE, J.S.
The air-bone gap in older people.
British Journal of Audiology 1977, 11, 1.

23. MILNE, J.S.
A longitudinal study of hearing loss in older people.
British Journal of Audiology 1977, 11, 7.

D. Anthropometry

24. MILNE, J.S.
Longitudinal studies of body weight and skinfold thickness in older people.
Journal of Clinical and Experimental Gerontology 1979, 1, 101.

25. MILNE, J.S.
A longitudinal study of height in older people.
Journal of Clinical and Experimental Gerontology. 1981 in the press.

26. MILNE, J.S. and LAUDER, I.J.
Age effects in kyphosis and lordosis in adults.
Annals of Human Biology, 1974, 1, 327.

27. MILNE, J.S. and LAUDER, I.J.
The relationship of kyphosis to the shape of vertebral bodies.
Annals of Human Biology 1976, 3, 173.

28. MILNE, J.S. and LONERGAN, M.E.
A five-year follow-up study of bone mass in older people.
Annals of Human Biology 1977, 4, 243.

29. LAUDER, I.J. and MILNE, J.S.
Bone mass in men with Klinefelter's syndrome and in normal subjects, estimated by the cortical thickness of bone.
Clinical Genetics 1975, 8, 48.

30. MILNE, J.S.
Age differences in the Androgyny Score.
British Journal of Preventive and Social Medicine 1972, 26, 231.

31. MILNE, J.S., LAUDER, I.J. and PRICE, W.H.
Anthropometry in sex chromosome abnormality.
Clinical Genetics 1974, 5, 96.

E. Blood Examination

32. MILNE, J.S. and WILLIAMSON, J.
The ESR in older people.
Gerontologia Clinica 1972, 14, 36.

33. MILNE, J.S. and WILLIAMSON, J.
Plasma urea concentration in older people.
Gerontologia Clinica 1972, 14, 32.

34. MILNE, J.S. and WILLIAMSON, J.
Haemoglobin, Haematocrit, leukocyte count and blood grouping in older people.
Geriatrics 1972, 27, 118.

F. Miscellaneous

35. MILNE, J.S. and WILLIAMSON, J.
Bowel habit in older people.
Gerontologia Clinica 1972, 14, 56.

36. MILNE, J.S. and WILLIAMSON, J.
The feet of older people.
The Chiropodist 1972, 27, 142.

37. MILNE, J.S., WILLIAMSON, J., MAULE, M.M. and WALLACE, E.T.
Urinary symptoms in older people.
Modern Geriatrics 1972, 2, 198.

38. MILNE, J.S. and WILLIAMSON, J.
The ankle jerk in older people.
Gerontologia Clinica 1972, 14, 86.

G. Dietary

39. MILNE, J.S., LONERGAN, M.E., WILLIAMSON, J., MOORE, F.M.L., McMASTER, R. and PERCY, N.
Leucocyte ascorbic acid levels and vitamin C intake in older people.
British Medical Journal 1971, 4, 383.

40. LONERGAN, M.E., MILNE, J.S., MAULE, M.M. and WILLIAMSON, J.
A dietary survey of older people in Edinburgh.
British Journal of Nutrition 1975, 34, 517.

H. Review

41. MILNE, J.S.
Prevalence of incontinence in the elderly age groups: in Incontinence in the Elderly edited by WILLINGTON, F.L.
Academic Press. London. New York. San Francisco. 1976 pp 9-21.

42. MILNE, J.S.
Mesure de la densité osseuse chez le viellard.
Médecine et Hygiène 1973, 31, 35.
(The format of the journal differs from that of the reprint and hence page numbers do not correspond).

INTRODUCTION

The study on which this submission is based was originally planned in 1966 by Dr James Williamson (now Professor of Geriatric Medicine in the University of Edinburgh). He was then the consultant physician in charge of the geriatric service in north Edinburgh. The purpose of the study was to obtain data about the elderly population, particularly in respect of physical and mental health and of measurements of a number of variables. The dangers of cross-sectional examination of a sample for such a purpose were to be reduced by making the study longitudinal.

A grant was obtained by Professor Williamson from the Secretary of State for Scotland via the Advisory Committee on Medical Research. This grant supported the author, who was appointed as physician in charge of the day to day running of the project under the general direction of Professor Williamson, a psychiatrist (Dr Margaret Maule) and a secretary (Miss E J Nelson). Grants from elsewhere supported other workers including a dietician (Miss M E Lonergan) and a sociologist (Mrs Una Flett). This submission concerns mainly the work of the physician but some of the papers report data collected by Dr Maule and Miss Lonergan.

One year (1967) was spent constructing, testing and validating a questionnaire on physical health, deciding which items to include in the physical examination, practising the various measurements and testing their reproducibility. A pilot study was then made, of patients of a general practitioner (Dr Douglas Bell) whose practice lay outside the area to be sampled. The pilot study was used not only as a dress rehearsal but also to test the reproducibility of the questionnaire.

During 1967 statistical advice was obtained from Dr Keith Hope, now Fellow of Nuffield College, Oxford. He advised that the main study should be made on a simple random sample of the older population of north Edinburgh. Meetings were held to which the general practitioners were invited whose surgeries were situated in the ten city wards in north Edinburgh in which Professor Williamson then provided a geriatric service. The plan of the study was explained at these meetings and, once the approval of the general practitioners had been obtained, a simple random sample was drawn from the lists of patients of fifty practices held by the Edinburgh Executive Council.

Examinations of persons from the sample began on 1st February 1968 in buildings generously provided at the Royal Victoria Hospital, Edinburgh by the Board of Management. Each person spent about four hours with the team, of which two hours were used for the examination by the physician. Further examinations e.g. by the dietician were made later in the homes of the persons taking part. Participants attending the hospital were collected and later taken home by car. During 1968-1969 a total of 551 persons were examined, of whom 487 formed the simple random sample and the remainder a special group used by the sociologist to study retirement.

Further examinations were offered to the same persons after one year (1969-70) and five years (1973-74). These examinations were made as near as possible to the anniversary of the first examination. Little alteration was made in methods in the one year and five year reviews, apart from omission of some sections in order to reduce the time spent with the physician to one hour. This was done because one cause of refusal to attend the review examinations was the length of the first examination.

At the five year review 261 persons were examined, and 138 had died, leaving 88 persons who for various reasons were not re-examined.

The papers in this submission are mainly based on data collected by the author in this longitudinal study of ageing persons. Arabic numerals in brackets in the text below refer to the papers as numbered in the list of contents. Some papers included material collected by Dr Maule (2, 3, 37, 40) and Miss Lonergan (28, 39, 40). In those papers in which Mr I J Lauder is a co-author (5, 13, 15, 20, 26, 27, 29, 31) the statistical analysis was carried further by him than it would otherwise have been. When these papers were written he was working as a statistician at the MRC Clinical and Population Cytogenetics Unit. Apart from these papers and some others where help with data processing was acknowledged at the end of the text (8, 26, 28, 30, 39, 40), the statistical work was done by the author. Most of the calculations were made using the SPSS computer programme (Statistical Package for the Social Sciences) provided by the Edinburgh Regional Computing Centre (ERCC). Much help and advice was obtained from ERCC staff particularly Mr R L Middleton and Mrs Sandra Rice.

The papers were written by the author, with modifications suggested by other authors included in the published versions. The two papers concerning ischaemic heart disease (12, 14) were largely composed by Dr A H Kitchin and the paper describing the dietary survey (40) was mainly the work of Miss M E Lonergan, although it includes data collected by Dr M M Maule and by the author.

Electrocardiograms were read by Dr C P Lowther and Dr A H Kitchin who coded them using the Minnesota Code. Haematological measurements except the erythrocyte sedimentation rate which was measured by the author, were made by Dr S H Davies and his staff in the Department of Haematology in the Royal Infirmary of Edinburgh. Biochemical tests were made by the staff of Professor L G Whitby in the University Department of Clinical Chemistry in the Royal Infirmary, Edinburgh. Other help received has been acknowledged at the end of the published papers.

The papers in this submission have been arranged as follows:

A. Methods, sampling and use of services

The first two papers described the reproducibility of the questionnaire (1), the method of sampling and a study of the non-respondents (2). When the first examination was completed, analysis of the data allowed the construction of a shorter questionnaire and examination, suitable for use by nurses and appropriate for the study of larger samples of the elderly (3). After the five year examination the fate of the numbers of the sample was described, causes of death were analysed and difficulties encountered were recorded (4). At the same time the association between variables recorded at the first examination and mortality during the subsequent five years was examined (5). A comparison of a teaching machine with the author in the detection of angina pectoris by questionnaire was made at the one year review (6). The questionnaire at the first examination provided a description of the use of the National Health Service by older people (7).

B. Cardio-vascular and respiratory

Cross sectional data from the first examination were used to describe respiratory function tests, respiratory symptoms and the relationship between tests and symptoms (8, 9, 10). After five years the results from the longitudinal study of these variables emerged (11).

Ischaemic heart disease was examined both cross-sectionally and longitudinally (12, 14) as was heart size (13, 15). One paper described blood pressure and its relation to stroke both cross-sectionally and longitudinally (16). The relationship between symptoms of peripheral vascular disease and foot pulses was also recorded (17).

C. Special Senses

Visual acuity and its association with cataract were reported from the first examination (18) and after longitudinal study (19). Data from the first examination were analysed in respect of pure tone audiometry (20), symptoms and hearing loss (21) and the air-bone gap (22). Longitudinal audiometric changes in hearing were described and related to subjective changes (23).

D. Anthropometry

Height, body weight and skin-fold thickness were examined longitudinally (24, 25). Cross-sectional data were used to relate kyphosis to age (26), in a study which included younger subjects, and to the shape of vertebral bodies (27). Changes in bone mass were described longitudinally using measurements of metocarpal cortical thickness (28). Data from the longitudinal study of ageing persons were used in a comparison of bone in 46 XY men with bone in 47 XXY men with

Klinefelter's syndrome (29). A study of the Androgyny Score at the first examination also included younger subjects (30). The last paper in this section (31) compared anthropometric data from subjects with sex chromosome abnormality with those from subjects whose chromosome complements were presumed to be normal. Older people were not included in this report but the techniques used were learned by the author when preparing for the longitudinal study.

E. Blood examination

This was from the first examination only and included the erythrocyte sedimentation rate (32), other haematological data (34) and plasma urea (33).

F. Miscellaneous

Four papers from the first examination reported data concerning bowel habit (35), feet (36), urinary symptoms (37) and the ankle jerk (38).

G. Dietary data

Leucocyte ascorbic acid levels were reported and related to vitamin C intake (34). A dietary survey made by Miss M E Lonergan was analysed. Dietary intakes were related to variables recorded by the physician and the psychiatrist (40).

H. Review articles

The first of these (41) reviewed studies of the prevalence and incidence of incontinence in older people and was requested by Dr F L Willington who was editing a book entitled "Incontinence in the

Elderly". The second (42) reviewed methods of measuring bone mass in the elderly and was requested by Professor B Steinmann of Berne following a paper given by the author at the VIth European Congress of Gerontology. Professor Steinmann had been asked to edit one number of Médecine et Hygiène which was being devoted to Geriatric Medicine.

Longitudinal material has been included in eleven papers covering the fate of the sample (4), factors associated with mortality (5), respiratory studies (11), cardio-vascular studies (14, 15, 16), vision (19), hearing (23), height and weight (24, 25) and bone mass (28).

The study was not carried on longer than five years for two reasons. First the reduction in numbers over five years suggested that by ten years standard errors would be large and changes might be missed. Secondly the linear regression of five year change on age at entry to the study indicated that for some variables no more would be learned in ten years than in five (16, 23, 24, 28) although for other variables the rate of change altered as age at entry increased (11, 15, 19, 25). This work confirmed that longitudinal study may reveal changes not suggested by cross-sectional examination (11, 15, 16, 23, 24, 25, 28).

Eighteen papers have been delivered to learned societies using data from this longitudinal study. Of these ten were given to the British Geriatrics Society, three to the British Society for Research on Ageing, two to the British Society of Audiology, two to European Congresses of Gerontology and one to an Edinburgh symposium on urinary infection.

J. chron. Dis. 1970, Vol. 22, pp. 805–810. Pergamon Press. Printed in Great Britain

1

VARIABILITY IN REPLIES TO A QUESTIONNAIRE ON SYMPTOMS OF PHYSICAL ILLNESS

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AT PRESENT, a large random sample of persons aged 63 and over is being studied in the Research Unit in the Royal Victoria Hospital, Edinburgh. This is a longitudinal study being made by physician, psychiatrist, psychologist, sociologist and dietitian. During planning, efforts were made to test the reproducibility and validity of methods.

The physician's approach to each subject is by questionnaire followed by a detailed physical examination including anthropometry, spirometry, audiometry, analysis of blood and urine, electrocardiography, bone densitometry and chest X-ray.

METHODS

In the planning period, questions about physical health were chosen using such well-tried questionnaires as that of Rose on ischaemic heart disease [1] and that of the Medical Research Council on Bronchitis (1966). To these were added questions on other systems. The whole questionnaire was tried in pilot studies on subjects of appropriate age, the interviews being recorded on magnetic tape. The questions, apart from the 2 widely used questionnaires mentioned above, were modified if they failed to communicate adequately with the subjects or if they caused the observer to ask probing questions not printed on the history sheets.

The subsequent validation of the alimentary part of the questionnaire is now given as an example. After the pilot studies, the questionnaire was adminstered to patients in medical wards in a nearby hospital without the observer knowing anything beforehand of the patients' histories. In one ward with 11 people the questionnaire agreed with the ward notes in 9 and differed in 2. The procedure was repeated in a gastro-intestinal unit in the same hospital where the questionnaire agreed with the ward notes in 16 of 19 patients and differed in 3. Finally the questionnaire was asked of 30 people from a general practice without previous knowledge of their histories. Differences from the practitioner's records were present in 5 people of the 30, but in these, although the questionnaire did not make a full diagnosis, it did detect the appropriate information, for example, "excision of rectum—cause unknown" was actually

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"excision of rectum for polyposis". The questionnaire discovered one cholecystectomy (with scar) not known to the practitioner.

Finally, the questions in the form in which they are now used were asked of a group of 30 subjects aged 63 and upwards on 2 occasions at an interval of 2 months. These subjects were picked by a general practitioner from his list with no special type of patient in mind but did not form a true random sample. Of the 30, 19 were men and 11 were women. The questions were asked by the same medically qualified male interviewer (J.S.M.) on both occasions.

The replies to any question about symptoms, asked of an ordinary population on 2 separate occasions, will normally be negative in a large number on both occasions. What is interesting in the replies is the difference between the number of abnormalities admitted on at least one occasion of asking and the number in which the same abnormality is admitted on both occasions. This difference can be reported by a table, by a percentage, by a Tau correlation coefficient (where a ranking order is present) or by giving the number of abnormalities admitted on at least 1 occasion and the number admitted on both occasions.

RESULTS

The results with Rose's questionnaire on angina pectoris illustrate this. The possible results are "no angina", "angina of Grade 1" and "angina of Grade 2". Table 1 expressses the results in the 30 subjects. Eight persons had some grade of angina on at least 1 occasion. Only three of these had the same grading on both occasions. The percentage of disagreement between abnormalities admitted on at least one occasion and abnormalities admitted on both is $\frac{5}{8}\times 100=62.5$ per cent.

The Tau coefficient (τ) of correlation between the answers coded as either angina of Grade 1 or angina of Grade 2 on at least 1 occasion and answers so coded on both occasions is 0.66.

If Table 1 is collapsed into a 2×2 table by amalgamating categories so that the results simply say whether angina is present or absent, 8 persons had angina on at least one occasion of asking and 5 had angina on both occasions ($\tau=0.71$), i.e. the percentage disagreement is 37.5 per cent.

Continuing with Rose's questions on ischaemic heart disease, possible myocardial infarct was registered by 4 of 30 people on at least one occasion and by 3 on both occasions ($\tau=0.85$).

Intermittent claudication classified as none, Grade 1 or Grade 2 (as was angina pectoris) was present in 1 or other grade in 6 of 30 people on at least 1 occasion. Only 3 of the 6 had the same grading on both occasions ($\tau=0.78$). Amalgamation of categories to say simply whether intermittent claudication is present or absent

TABLE 1. HISTORY OF ANGINA PECTORIS

		Second occasion		
		None	Grade 1	Grade 2
First occasion	None	22	1	1
	Grade 1	1	3	1
	Grade 2	0	1	0

provides 6 persons who had this symptom on at least 1 occasion and 4 who had it on both occasions.

Questions additional to those of Rose framed as

1. Has any doctor ever told you of anything wrong with your heart?
2. (If yes) what did he call it?
3. (If yes) When did he tell you this?

permitted a coding of "History of Ischaemic Heart Disease in the last 10 yr". Of 30 people, 7 gave a positive history on at least 1 occasion and 5 on both occasions ($\tau=0.79$).

The Medical Research Council Questionnaire on Bronchitis gave results in which cough present on most days for at least three months of the year was graded 0, 1 or 2 in accordance with the history. These are shown in Table 2. Hence 11 persons out of 30 produced cough of Grade 1 or Grade 2 on at least 1 occasion, but the same grade was present on both occasions in only three persons, τ being 0.67. A history of the presence of phlegm on most days for at least 3 months of the year similarly graded as 0, 1 or 2 was present in 10 persons on at least one occasion and in the same grade on both occasions in 8 persons, τ being 0.89.

The syndrome of "persistent cough and phlegm" is defined as cough of Grade 1 or Grade 2, accompanied by phlegm of Grade 1 or Grade 2, both symptoms being present on most days for at least 3 months of the year. Using the above results on cough and phlegm, the syndrome of persistent cough and phlegm was present in nine persons on at least 1 occasion and in 8 persons on both occasions ($\tau=0.92$).

Dyspnoea was coded from the questionnaire as Grades 1, 2, 3, 4 or D, the last meaning that some other disability prevented the subject from making sufficient effort to become breathless. Grade 1 means that no dyspnoea is present. Results are shown in Table 3, τ here being 0.70, category D being included in the calculation of τ.

TABLE 2. GRADING OF COUGH

		Second occasion		
		None	Grade 1	Grade 2
First occasion	None	19	3	—
	Grade 1	—	1	3
	Grade 2	1	1	2

TABLE 3. GRADING OF DYSPNOEA

		Second occasion				
		D	Grade 1	Grade 2	Grade 3	Grade 4
First occasion	D	4	—	1	—	—
	Grade 1	1	8	2	—	—
	Grade 2	—	1	10	1	1
	Grade 3	—	—	—	—	—
	Grade 4	—	—	1	—	—

Consumption of cigarette tobacco graded as 0, 1, 2, 3 or 4 (corresponding to 0, 1–4, 5–14, 15–24 and more than 24 g daily) gave excellent reproducibility with 11 non-smokers and 19 smokers of whom only three changed grades on a second occasion, τ being 0.97.

Answers to the question "Are you troubled with pain in your stomach or abdomen?" produced 5 persons out of 30 with pain on at least 1 occasion, but only 1 with pain on both occasions (τ=0.26).

"How often do your bowels move?" had answers coded in 6 categories varying from a bowel movement less than once weekly in the first category to a movement more than twice daily in the sixth category. Of 30 persons, 24 produced answers giving the same category on both occasions (τ=0.58). Twenty-two of the 24 registered 1 movement daily.

"Have you ever had blood in your stools?" produced from 30 people 5 positive answers on at least 1 occasion and 2 on both occasions (τ=0.52).

If the answer to the question "Are you troubled with heartburn?" was yes, an attempt was made to grade subjects as 1, 2 or 3 representing respectively a duration of symptoms of less than 1, 1–5 or more than 5 yr. Eleven persons out of 30 had heartburn on at least 1 occasion and 5 had the symptom on both occasions (τ=0·49). Of the 5, only 3 gave the same duration on both occasions.

"Have you ever had jaundice at any time in your life?" produced 6 positive answers on at least 1 occasion and 4 on both occasions (τ=0.76).

Questions on present dysuria produced no disagreement, but only 1 person had this symptom. A question about dysuria at any time in the past was positive for 8 persons on at least 1 occasion and for 6 on both (τ=0.83). Expansion of the answers to this question to elicit whether dysuria was present on 1, 2 or more than 2 occasions widened the disagreement, τ being 0.79. A question on frequency of passing urine ("Has there been any change in how often you pass urine?") had a positive answer in 10 out of 30 on at least 1 occasion and in 5 on both occasions (τ=0.56).

Rising at night to pass urine was admitted by 20 of the 30 on at least 1 occasion and by 16 on both occasions, but classification by the number of times risen per night reduced agreement on both occasions to 14 (τ=0.73).

The presence of incontinence of urine was assumed if the answer to any of 4 questions about it was positive. These related to urgency, stress and "noticing wetness". Ten people admitted some incontinence on at least 1 occasion and 4 on both occasions (τ=0.44).

An attempt was made to grade prostatic symptoms on a 6 point scale in the 19 men in the sample. Five men scored 0 having no prostatic symptoms on either occasion of asking. The remaining 14 had a score varying from 1 to 5 on at least 1 occasion, but in only 4 was the score the same on both occasions (τ=0.52). If this scale was collapsed into yes and no, yes meaning at least 1 of the 6 points in the scale was present, 14 scored yes on at least 1 occasion and 11 on both occasions (τ=0.92).

The answers to "Have you any pain in any of your joints?" were yes in 12 out of 30 people on at least 1 occasion and in 7 on both occasions (τ=0.62). A history of stiffness in joints, important in the American Rheumatism Association's criteria for the presence of rheumatoid arthritis, was present in 7 persons on at least 1 occasion and in 3 on both occasions (τ=0.54).

Faint feelings and giddy turns are common in the elderly who often have semantic difficulties in describing them. A composite question on this ("Are you troubled with faintness, lightheadedness, unsteadiness or giddiness?") had 15 positive answers from 30 people on at least 1 occasion and 8 positive answers on both occasions ($\tau=0.51$).

A definite history of unconsciousness once or oftener was present in 5 persons on on at least 1 occasion and in 3 persons on both occasions ($\tau=0.74$).

Eighteen people admitted to some deafness on at least 1 occasion, but only 14 admitted deafness on both occasions ($\tau=0.74$). Headache was admitted by 3 persons on at least 1 occasion and by none on both occasions in response to the question "Are you troubled with headaches?".

The results described above are summarised in Table 4.

DISCUSSION

The error which must result from the use of questions to determine the prevalence and incidence of symptoms has interested epidemiologists for some years. Cochrane, Chapman and Oldham [2] in a survey of miners using several observers all asking the same questions concluded that observer bias influenced the frequency with which positive answers were recorded. Schilling, Hughes and Dingwall-Fordyce [3] with two observers grading byssinosis in the same subjects found disagreement between observers in 24 per cent. Fairbairn, Wood and Fletcher [4] reported differences

TABLE 4. DISAGREEMENT BETWEEN ANSWERS TO QUESTIONS ON 2 OCCASIONS WITH THE SAME 30 SUBJECTS

Symptom	Symptom absent	Symptom present on at least 1 occasion	Symptom present on both occasions	Percentage disagreement in last 2 columns	τ
Angina pectoris	22	8	3	62.5	0.66
Previous myocardial infarction	26	4	3	25	0.85
Intermittent claudication	24	6	3	33	0.78
Cough	19	11	3	73	0.67
Phlegm	20	10	8	20	0.89
Persistent cough and phlegm	21	9	8	11	0.92
Abdominal pain	25	5	1	80	0.26
Blood in stools	25	5	2	60	0.52
Heartburn	19	11	5	55	0.49
Jaundice	24	6	4	33	0.76
Past dysuria	22	8	6	25	0.83
Increased frequency of passing urine	20	10	5	50	0.56
Nocturia	10	20	16	20	0.73
Incontinence	20	10	4	60	0.44
Prostatic symptoms (19 men only)	5	14	4	71	0.52
Joint pain	18	12	7	42	0.62
Joint stiffness	23	7	3	57	0.54
Faintness, etc.	15	15	8	47	0.51
Blackouts	25	5	3	40	0.74
Deafness	12	18	14	22	0.74
Headache	27	3	0	100	—

between observers using an early version of the M.R.C. Questionnaire on bronchitis. Disagreements were assigned partly to the observers, partly to different replies by the same subjects and partly to difficulties of interpretation of replies made by subjects. Rose [5] found the prevalence of angina in the same population assessed by questionnaire on 4 occasions between 1961 and 1965 to be constant at around 4 per cent on each occasion. The large majority who gave positive answers for angina did so on only a single occasion since the 4 yr period prevalence was 10·4 per cent. Recognition of the poor reproducibility of symptoms is the more important in the light of a recent publication [6] describing a computer system which collects, stores, reproduces and analyses clinical case histories. The case histories include symptoms and "modifiers" which record the observer's estimate of the reliability of the symptom.

It seemed worthwhile at the start of a large longitudinal study of aging persons to emphasise the difficulty of using questionnaires by reporting the small study described above. These results obtained by 1 observer are in sharp contrast to reliability coefficients calculated for the same observer on, for example, anthropometric data. For most of these measurements the reliability coefficient is $\geqslant 0.9$.

The high percentage of disagreement in answers to questions on alimentary symptoms is disappointing since other evidence of disease in this systems is difficult to obtain apart from abdominal examination. In other system tests additional to ordinary physical examination help in assessment, for example, electrocardiography, chest X-ray and spirometry in the cardio–respiratory system. Variability in answers to questions on heartburn makes symptoms an unreliable guide to the prevalence of hiatus hernia. Some of the comparisons made are not entirely fair. For example, there could be a real change in the prevalence of abdominal pain in two months.

Some encouragement in the use of the M.R.C. Questionnaire on bronchitis comes from the fact that while disagreement about the grade of cough is 73 per cent and about grade of phlegm is 20 per cent, the syndrome of persistent cough and phlegm determined from the data as described has disagreement of only 11 per cent.

SUMMARY

The variation is reported in replies to a questionnaire on physical symptoms administered by 1 observer to 30 subjects aged 63 and upwards on 2 occasions separated by 2 months. The percentage disagreement between replies admitting some abnormality on at least 1 occasion and replies admitting the same abnormality on both occasions varies from 11 to 100 per cent.

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2

METHOD OF SAMPLING IN A STUDY OF OLDER PEOPLE WITH A COMPARISON OF RESPONDENTS AND NON-RESPONDENTS

BY

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METHOD OF SAMPLING IN A STUDY OF OLDER PEOPLE WITH A COMPARISON OF RESPONDENTS AND NON-RESPONDENTS

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A longitudinal study of ageing persons 62 years and upwards was begun in Edinburgh on 31 January 1968. An attempt was made to select a cohort representative of the elderly population. This paper describes how the sample was drawn, what success was achieved in examining it, and how an attempt was made to compare respondents and non-respondents.

Edinburgh is divided into 23 city wards in 10 of which one of us (J.W.) and colleagues provide a geriatric service. The sample was drawn from these 10 wards, contact being made with persons in the sample through their general practitioners. Ninety-five general practitioners were working in 50 practices with premises in this area. The plan was explained to the doctors, 91 of whom agreed to co-operate and allowed us access to their lists of patients held by the Edinburgh Executive Council.

A census was made from the records of the Executive Council of the name, address, date of birth, and National Health Service number of all those persons born in 1905 or earlier who lived in the defined area and who were on the list of a doctor with a surgery address in that area. There were 26,903 such persons. This population excludes those who were not on a doctor's list and those who lived in the area but attended a doctor with a surgery address outside the area. The National Health Service number helps to trace persons who have died as well as the living.

From this population of 26,903 a random sample of 936 persons was drawn. The sample was classified according to the doctor and each doctor was given a list of his patients included in the sample. The doctors visited these people, explained the study to them, and told the Research Unit of those who were willing to come for examination. These subjects were examined between 31 January 1968, and 31 January 1970.

The sample of 936 persons contained 188 who did not qualify for inclusion in the sample as defined above. The reasons for excluding these 188, who amount to 20% of the names drawn, were:

Death before 31 January 1968	64
Duplicate random numbers	17
Born after 1905 or resident outside the defined area	21
Left Edinburgh (statement by G.P.)	13
Could not be traced (statement by G.P.) —name not on electoral roll	65
Could not be traced (statement by G.P.) —name is on electoral roll	8

Some of the group that could not be traced are the 'ghosts' familiar to all general practitioners in Great Britain. Their cards have usually been in the doctors' files for many years and the patients themselves have long ago moved away or died. Many of the names date back to the partial health service which operated under the National Health Insurance Act, the records of which were absorbed into the National Health Service in 1948. Failure to locate these people is not so much a failure by the investigators as a reflection of an administrative difficulty.

Of the 748 persons who qualified for inclusion in the sample, 487 were examined (65%), 212 refused (28·5%), 45 died after the survey began without being examined (6%), and 4 moved away after the survey began without being examined (0·5%).

The next step was to try to compare respondents and non-respondents. From the Executive Council's files only age and sex are available. Marital state is not always recorded. Table I shows the sex distribu-

TABLE I

RESEARCH SAMPLE OF 748 PEOPLE AGED 62 YEARS OR MORE

	Examined	Not Examined
Male	216	69
Female	271	192
	487	261

$Z=5{\cdot}14$; $P<0{\cdot}01$.

tion for the sample of 748 persons divided into those examined and those not examined. The proportion of women in the not examined group is significantly higher than in the group who were examined.

The 1966 sample census for Edinburgh published by the Registrar General reports 2,035 men and 3,960 women of 65 years and over. The research sample of 748 people born in 1905 or earlier contains 227 men and 400 women aged 65 years and over. Testing the difference between these proportions gives $Z = 1{\cdot}00$ and $P > 0{\cdot}05$ (Table II).

TABLE II

PERSONS AGED 65 YEARS OR MORE IN 1966 EDINBURGH SAMPLE CENSUS AND IN RESEARCH SAMPLE

	Census	Sample
Male	2,035	227
Female	3,960	400
	5,995	627

$Z = 1{\cdot}00$; $P > 0{\cdot}05$.

The 487 persons aged 62 and over who were examined in the sample of 748 included 168 men and 231 women of 65 years and over. The proportion of men is significantly higher than that of the 1966 sample census ($Z = 3{\cdot}08$, $P < 0{\cdot}01$).

Hence the total sample of 748 appears to have a sex distribution similar to that of the population of Edinburgh but the examined part of the sample does not.

TABLE III

AGE RANGES OF PERSONS EXAMINED IN RESEARCH SAMPLE (487) AND IN 1966 EDINBURGH SAMPLE CENSUS

Age	Examined Group M	Examined Group F	Census M	Census F
60–64	—	—	1,297	1,570
62–64	48	40	—	—
65–69	76	98	827	1,368
70–74	39	55	579	1,120
75+	53	78	629	1,472
	216	271		

Table III gives the age distribution of the examined group (487) of the sample of 748 people, and of the 1966 sample census. It shows that it is possible to compare the age distribution of men and of women in the examined group and in the 1966 census for ages 65–69, 70–74, and 75+. Table IV shows that by testing the difference between the proportions of men and women separately in these three age ranges in the examined group and in the 1966

TABLE IV

COMPARISON OF AGE RANGES IN PERSONS EXAMINED FROM RESEARCH SAMPLE AND 1966 SAMPLE CENSUS

Age Range	Sex	Examined Group	1966 Census	Z	P
65–69	M	76	827	1·00	>0·0
70–74	M	39	579	1·25	>0·0
75+	M	53	629	0·27	>0·0
Total ⩾65	M	168	2,035		
65–69	F	98	1,368	0·91	>0·0
70–74	F	55	1,120	1·38	>0·0
75+	F	78	1,472	0·94	>0·0
Total ⩾65	F	231	3,960		

sample census, no statistically significant differenc emerges.

It would appear that the examined group has significantly different sex distribution from th Edinburgh population, i.e. a deficiency of wome in the examined group, but each sex has an ag distribution which does not differ from that in th Edinburgh population.

Further comparison of respondents and no respondents was made by sending to genera practitioners questionnaries relating to the 2 persons who refused examination and to a rando sample of 209 of those 487 persons who wer examined. The questionnaire asked whether th patient had ever had hospital care and whether h or she had had any of nine physical conditio (ischaemic heart disease, intermittent claudicatio chronic bronchitis, peptic ulcer, hiatus herni urinary tract infection, arthropathy of hip or kne without generalized arthropathy, rheumatoid art ritis, stroke) or any of three mental conditio (anxiety, depression, dementia).

Table V shows the response to the questionnai Adequate information was available for 168 re pondents (84 male, 84 female) and 174 non-respo dents (39 male, 135 female). Reasons for there bei no information available in the questionnaires of 1 respondents and 22 non-respondents were death doctor, retirement of doctor, refusal by docto

TABLE V

REPLIES TO A QUESTIONNAIRE SENT TO PRACTITIONE ABOUT RESPONDENTS AND NON-RESPONDENTS IN THE RESEARCH SAMPLE

	Respondents	Non-respondents	Z	P
Replies with adequate information	168	174	0·45	>0
Death after 31 January 1968	24	16	1·38	>0
No information	17	22	0·82	>0

TABLE VI

COMPARISON OF ASSESSMENT BY PRACTITIONERS AND RESEARCH UNIT ON MALE RESPONDENTS (N=84)
(Prevalence in percentages)

	G.P.	Research Unit	Z	P
Hospital care	90·5	96·4	1·55	>0·05
Ischaemic heart disease	27·4	22·6	0·72	>0·05
Intermittent claudication	13·1	13·1	0·00	>0·05
Chronic bronchitis	21·4	44·1	3·24	<0·01
Peptic ulcer	22·6	22·6	0·00	>0·05
Hiatus hernia	3·6	6·0	0·73	>0·05
Urinary tract infection	8·3	13·0	0·98	>0·05
Arthropathy (knee or hip)	18·0	19·0	0·17	>0·05
Rheumatoid arthritis	3·6	1·2	1·00	>0·05
Stroke	6·0	6·0	0·00	>0·05
Anxiety state	13·0	13·0	0·00	>0·05
Dementia	2·4	2·4	0·00	>0·05
Depressive illness	10·7	10·7	0·00	>0·05

TABLE VII

COMPARISON OF ASSESSMENT BY PRACTITIONERS AND RESEARCH UNIT ON FEMALE RESPONDENTS (N=84)
(Prevalence in percentages)

	G.P.	Research Unit	Z	P
Hospital care	82·2	92·9	2·10	0·01 <P<0·05
Ischaemic heart disease	14·3	13·0	0·19	>0·05
Intermittent claudication	2·4	4·8	0·86	>0·05
Chronic bronchitis	8·3	16·7	1·65	>0·05
Peptic ulcer	7·1	8·3	0·29	>0·05
Hiatus hernia	8·3	8·3	0·00	>0·05
Urinary tract infection	26·0	37·0	1·55	>0·05
Arthropathy (knee or hip)	22·6	36·9	2·04	0·01 <P<0·05
Rheumatoid arthritis	7·1	7·1	0·00	>0·05
Stroke	8·2	7·1	0·29	>0·05
Anxiety state	23·0	29·0	0·88	>0·05
Dementia	8·3	9·5	0·27	>0·05
Depressive illness	18·0	13·0	0·88	>0·05

doctor willing but could not find record, doctor answered most but did not return all questionnaires, patient moved away.

Replies by practitioners to the questionnaires about persons who had been examined were compared with the research unit's assessment separately for men and women (Tables VI and VII). In each Table the percentage prevalence of each condition is recorded as assessed by the practitioner and by the research unit. For each condition the difference between these percentages is tested. The only conditions in which a statistically significant difference exists between the assessments of the practitioner and the research unit are chronic bronchitis in men, for which the research unit's prevalence is double that of the practitioner's, and hospital care and arthropathy of hip or knee in women. These differences are explained in the discussion.

There being reasonable agreement between the practitioners and the research unit about prevalence in persons examined, the next step is to compare prevalence as described by practitioners in respondents and non-respondents separately for men and women. This comparison is shown in Tables VIII and IX where the prevalence of each condition in respondents and non-respondents is recorded as a percentage and the difference between corresponding percentages is tested. Statistically significant differences exist in men in the number who had had hospital care, ischaemic heart disease, intermittent claudication, and peptic ulcer, and in women in the number who had had hospital care, hiatus hernia, and urinary tract infection. There are, therefore, highly significant differences between respondents and non-respondents based on information from the general practitioner.

TABLE VIII

COMPARISON OF ASSESSMENT BY PRACTITIONERS IN MALE RESPONDENTS (N=84) AND MALE NON-RESPONDENTS (N=39)
(Prevalence in percentages)

	Respondents	Non-respondents	Z	P
Hospital care	90·5	79·6	1·96	<0·05
Ischaemic heart disease	27·4	7·7	3·03	<0·01
Intermittent claudication	13·1	0·0	3·61	<0·01
Chronic bronchitis	21·4	20·5	0·12	>0·05
Peptic ulcer	22·6	7·7	2·40	0·01 <P<0·05
Hiatus hernia	3·6	0·0	1·80	>0·05
Urinary tract infection	8·3	7·7	0·11	>0·05
Arthropathy (knee or hip)	18·0	13·0	0·74	>0·05
Rheumatoid arthritis	3·6	2·6	0·31	>0·05
Stroke	6·0	7·7	0·33	>0·05
Anxiety state	13·0	13·0	0·00	>0·05
Dementia	2·4	2·6	0·06	>0·05
Depressive illness	10·7	7·7	0·52	>0·05

TABLE IX

COMPARISON OF ASSESSMENT BY PRACTITIONERS IN FEMALE RESPONDENTS (N=84) AND FEMALE NON-RESPONDENTS (N=135)
(Prevalence in percentages)

	Respondents	Non-respondents	Z	P
Hospital care	82·2	61·0	3·56	<0·01
Ischaemic heart disease	14·3	10·4	0·87	>0·05
Intermittent claudication	2·4	1·5	0·45	>0·05
Chronic bronchitis	8·3	9·6	0·33	>0·05
Peptic ulcer	7·1	6·7	0·11	>0·05
Hiatus hernia	8·3	0·7	2·45	0·01 <P<0·05
Urinary tract infection	26·0	12·0	2·55	0·01 <P<0·05
Arthropathy (knee or hip)	22·6	20·0	0·46	>0·05
Rheumatoid arthritis	7·1	3·7	1·03	>0·05
Stroke	8·3	2·2	1·85	>0·05
Anxiety state	23·0	17·0	1·09	>0·05
Dementia	8·3	3·0	1·61	>0·05
Depressive illness	18·0	12·0	1·19	>0·05

Discussion

It is easy in Great Britain, where there is a National Health Service in which most people register with a doctor, to define a population from which a random sample can be drawn. The sex differences described above between respondents and non-respondents show how difficult it is to examine a sufficient number of persons in such a sample to justify making inferences about the population. The comparison of prevalence figures from general practitioners and from the research unit on persons examined shows differences for which explanation can be offered. The research unit's prevalence of chronic bronchitis (44·1%) is double that of the practitioners' (21·4%). For the purpose of this enquiry the research unit defined chronic bronchitis as the production of phlegm on most days for at least three months each year. The practitioners' criterion is unknown. The difference is in the direction which would be expected. The difference in statements about hospital care may arise because the research unit takes a history covering the subject's whole life whereas, especially in the elderly, the practitioner may not have such full information. This could account for the higher figure for the research unit's history of hospital care. The difference in prevalence of arthropathy in the knee or hip in women may be because the research unit recorded any limitation of movement in the knee or hip as arthropathy, whereas the practitioner would presumably record only those who had symptoms.

It seems, therefore, that there is reasonable agreement between the practitioners and the research unit about respondents and that the above explanations could account for the differences found. There are, however, no simple explanations of the differences described by the practitioners between respondents and non-respondents. Non-respondents, both men and women, seem to have had significantly less hospital care than respondents. Male non-respondents seem to have less vascular disease and peptic ulcer and female non-respondents less hiatus hernia and urinary tract infection. It might be concluded that the healthier subjects are less willing to be examined in a study of this kind. Speculation might suggest that the preponderance of women in the non-respondents is because elderly women are more fully occupied than elderly men and less willing to spare time for examination.

The importance of investigating non-respondents is shown in Cochrane's (1954) review of the evidence that there is an increasing percentage of abnormal chest *x*-rays as increasing pressure is brought to bear on a population to submit to *x*-ray examination. He also found in the Rhondda Fach decreasing success with increasing age, the success rate at age 65 being 70%. Five other surveys mentioned by him also showed a decrease in success as age rose. Cochrane also found in older people that fewer women than men were *x*-rayed.

In the Report on the Edinburgh *x*-ray Campaign of 1958 (Seiler, Welstead, and Williamson, 1958) it is stated that 77·9% of all males and 75·6% of all females over the age of 15 were *x*-rayed, but at ages of 60 years and over the percentage fell to 67·9 for men and 63·5 for women. Following the main Edinburgh Campaign an effort was made to *x*-ray non-respondents in one city ward (Fletcher, Mair, Sklaroff, and Williamson, 1959). This raised the response by 6·5% and showed a higher prevalence of pulmonary tuberculosis than that found in the main campaign.

Both these groups showed a health difference between respondents and non-respondents. The experience of the present survey in respect of the success rate in older people and in women agrees with that of these workers. In contrast to their findings, non-respondents seem to be healthier than respondents but the present survey was not concerned with tuberculosis.

Cartwright (1959), in an investigation of families and individuals who did not co-operate in a sample survey, found a similar distribution of numbers of consultations with the general practitioner in the previous year in respondents and non-respondents which might be interpreted as meaning no difference in health between respondents and non-respondents. She reported a declining success rate in surveying married people as age increased. In persons of 65 years and over the success rate was 74% of the sample drawn. This seems comparable with the present survey's success rate of 65% when it is remembered that Cartwright's study was by interview without clinical examination whereas the present survey included a two-hour physical and a one-hour psychiatric examination.

Akhtar (1970) in Glasgow visited personally the non-respondents in a survey of the elderly. He found them in marginally better physical health than respondents; there was no obvious difference in mental health. It seems possible that both the Glasgow and Edinburgh surveys tend to over-estimate the prevalence of some diseases in the elderly.

The W.H.O. Report on Sampling Methods in Morbidity Surveys and Public Health Investigations (1966) classified major non-sampling errors in surveys as (*a*) coverage errors, (*b*) observational errors, and (*c*) processing errors. Experience in the present survey suggests that since the latter two sources of error lie in the province of the investigator and his staff, and do not depend on subject co-operation, reduction of such error will depend mainly on the zeal with which attempts are made to eliminate it. On the other hand, the technique of approach to the subjects through the general practitioner meant that a refusal received by him prevented further approach to the subject by the investigators. The size of the coverage error depended partly on how interested the practitioner was in persuading his patients to co-operate, and this was largely beyond the control of the investigator. Direct approach to the public with a request to submit to elaborate clinical examination would quite rightly not be popular with the practitioners. That part of the coverage error due to death or removal to another district before examination could be reduced by doing the survey in the shortest possible time.

Summary

A random sample of 936 men and women aged 62 and upwards was drawn from the population records of 26,903 old people in Edinburgh; 188 (20%) did not qualify for inclusion when further investigated. Of 748 available for examination 487 (65%) were examined.

Comparison of respondents and non-respondents showed an excess of women in the non-respondents. Age distribution in respondents (for sexes separately) did not differ from the 1966 sample census.

Comparison of information about the same respondents from general practitioners and from the research unit gave reasonable agreement. Some explanation of the differences is possible.

Comparison of respondents and non-respondents using information from the general practitioners revealed significantly less hospital care, vascular disease, and peptic ulcer in male non-respondents and significantly less hospital care, hiatus hernia, and urinary tract infection in female non-respondents.

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THE DESIGN AND TESTING OF A QUESTIONNAIRE AND EXAMINATION TO ASSESS PHYSICAL AND MENTAL HEALTH IN OLDER PEOPLE USING A STAFF NURSE AS THE OBSERVER

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INTRODUCTION

THE FIRST examination in a longitudinal study of aging persons in Edinburgh was carried out in 1968 and 1969. This study is a wide one with examinations of each subject by physician, psychiatrist, psychologist, sociologist and dietician. The subjects studied were 215 men and 272 women aged from 62 to 90 yr who formed a random sample of the 27,000 older people living in a defined area of the city. The method of sampling with a comparison of respondents and nonrespondents has been described elsewhere [1]. The first examination included assessment of physical and mental health by questionnaire and by physical examination. Data gathered in this examination have been combined with information about survey questions published by other workers to derive a questionnaire and examination on physical and mental health lasting about 25 min. It was decided to find out whether a person not medically qualified could be trained to assess physical and mental health using this questionnaire and examination. The present paper shows the results with a staff nurse as observer. The first two parts of this paper describe the derivation and, as far as possible, the validation of the questionnaires on physical and mental health. The physical examination is also described. The third part details the training and testing of one staff nurse as an observer. Throughout these papers the first examination in the longitudinal study is referred to as 'the original study'.

1. PHYSICAL HEALTH

(A) *Questionnaire*

Some of the conditions whose prevalence was estimated in the original study are ischemic heart disease, obliterative arterial disease of the legs, chronic respiratory

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disease, use of tobacco, duodenal ulcer, hiatus hernia, urinary tract infection, arthropathy and stroke. The new questionnaire which was derived, as mentioned above, using data collected about these conditions in the original study, is given in Appendix A. Each section in turn of the questionnaire on physical health is now discussed.

1. *Ischemic heart disease*. Rose's questions were used in the original study [2, 3] and are included in the new one. Some 10 per cent of men and women in the original sample were angina positive while 11 per cent of men and 3.4 per cent of women had had a possible myocardial infarct. Electrocardiograms were made on each subject in the original study and coded using the Minnesota Code. Definite ischemic heart disease was said to be present with coding of 1.1.1–1.2.8 and possible ischemic heart disease with coding 1.3.1–1.3.6 and/or 4.1–4.3 and/or 5.1–5.3 and/or 7.1. Using these criteria, in the original study the E.C.G. detected 0.7 per cent of definite and 10 per cent of possible ischemic heart disease where no positive history was present. This would suggest that in a large survey carried out in the subjects' homes Rose's questions, which are already validated, would suffice without electrocardiography. An extra yield of 0.7 per cent does not justify carrying an electrocardiograph into several thousand homes.

2. *Intermittent claudication*. In the original study Rose's questions detected 10 per cent of men and 2.5 per cent of women with this condition and are used unchanged in the new questionnaire.

3. *Chronic respiratory disease*. The full M.R.C. Questionnaire on Respiratory Symptoms [4] was used in the original study. Common symptoms in men were persistent cough and phlegm (32 per cent) and chest illness in the last 3 yr (17 per cent). The same symptoms occurred in smaller percentages of women. The severer grades of dyspnea (3 and 4) were commoner in women (18 per cent) than in men (14 per cent). The proportion of men and women with other respiratory symptoms increased as the grade of dyspnea increased. It was thought that the short version of the M.R.C. questionnaire as given in Appendix A.3 would be adequate for a larger survey. This would allow the assessment of chronic bronchitis according to the various criteria described in the literature. Chronic bronchitis was by far the commonest respiratory disorder in the original study.

4. *Smoking habits*. Questions in the original study revealed 79 per cent of men and 26 per cent of women as smoking or having smoked cigarettes. As expected, cigarette smoking was associated with an increase in symptom prevalence when compared with non-smoking. Pipe smoking did not have this association since only 7 per cent of 26 pipe smokers in the original study had persistent cough and phlegm compared with 38 per cent of 170 male cigarette smokers and 7 per cent of 17 male non-smokers. The new questionnaire therefore asks about duration and amount of cigarette smoking only (Appendix A.4).

5. *Duodenal ulcer*. The original study of 487 persons used questions about abdominal pain, vomiting, melena, hematemesis, heartburn, whether any doctor had

diagnosed duodenal ulcer and whether the subject had had an operation for ulcer. Of 64 persons who gave a history of duodenal ulcer diagnosed in hospital, 28 recalled operation, 23 bleeding, 8 epigastric pain relieved by food and 15 epigastric pain not relieved by food. Of 26 persons without a history of hospital investigation, 12 recalled pain and 15 bleeding as symptoms which could have been due to ulcer. These symptom categories are not mutually exclusive. The question in the original study which produced most classifications of subjects as having or having had duodenal ulcer was the general one about hospital admission or investigation.

A history of bleeding from the alimentary tract is usually paralleled in persons investigated in hospital by information about X-ray. In persons not investigated in hospital a history of possible bleeding is of uncertain diagnostic value. Questions about bleeding have therefore been omitted from the new questionnaire (Appendix A.5).

Epstein [5] concluded that the best criteria in diagnosing duodenal ulcer in a survey were (1) the patient's doctor said an ulcer was present and that X-ray confirmed this, (2) 'stomach' pain 2 hr after food relieved by food, (3) 'stomach' pain awakening the patient by night.

Combining experience in the original study with the views of Epstein a minimum prevalence of duodenal ulcer would be estimated by asking if any doctor had made this diagnosis and confirmed it by X-ray, and by reporting numbers with epigastric pain 2 hr after food relieved by food and/or pain causing awakening by night. These questions are given in Appendix A.5. Subjects who have had an operation and are now symptom free should be detected by the question about any doctor diagnosing duodenal ulcer.

The prevalence detectable with these questions is described as minimum because Dunn and Etter [6] found in 206 male executives that a medical history failed to reveal 49 per cent (17 of 35) of radiologically demonstrated ulcers and 6 per cent (11 of 171) of X-ray negative cases were judged positive on the history.

6. *Hiatus hernia.* It has been said that 'heartburn aggravated by posture (lying, bending, stooping) is the typical symptom of uncomplicated sliding hernia' [7]. Questions in the original study showed 15 per cent of men and 23 per cent of women to have heartburn. In half of these people it was worse on lying or stooping. Sliding hernia is therefore a common cause of distressing symptoms in older people. Surgical repair is regarded as safe in the elderly with good results in 90 per cent of uncomplicated cases [7]. Questions on heartburn and the effect of posture on it have therefore been included in the new questionnaire (Appendix A.6).

The minimum nature of prevalence determined in this way is shown by the report of Dyer and Pridie [8] that 33 per cent of 95 volunteers without major gastrointestinal symptoms had a sliding hernia on X-ray and by the report of Pridie [9] that there was X-ray evidence of hiatus hernia in 30 per cent of 500 volunteers with gastrointestinal symptoms. The questionnaire would, however, detect those with disability.

7. *Urinary tract infection.* A question asked in the original study 'Have you ever had cystitis or a chill or infection in your bladder?' was answered affirmatively by 66 (24 per cent) of the 272 women. Other questions about urinary infection concerned dysuria and frequency of passing urine in the past. Of the 66 women 21 recalled no

dysuria or frequency but remembered having had cystitis, 17 recalled past dysuria alone, 2 past frequency alone and 26 recalled both dysuria and frequency in the past. Of the 202 women who did not remember past cystitis, 15 recalled dysuria, one frequency and 6 dysuria and frequency combined. These bring the total of women in the original study with a history suggesting past urinary infection to 88 (33 per cent) of 268, no data being available in 4 women.

Agreement with this figure is shown by data collected from a general practice in East Lothian [10]. During the previous 16 yr one or more acute urinary infections, diagnosed from symptoms and signs at the time of infection had been recorded in 46 (28 per cent) of 166 women aged 63 or more in 1962. The difference between the Edinburgh and East Lothian figures is not significant (χ^2 1.14, $p > 0.05$).

These facts suggest that the best selectors of persons with previous acute urinary tract infection are a history of cystitis or dysuria. Two such questions are included in the new questionnaire (Appendix A.7). Frequency although present in more than 80 per cent of acute infections in general practice seems to be poorly remembered and this has therefore been omitted. Six of seven men who remembered past frequency and denied having had cystitis had had a prostatectomy.

8. *Arthropathy*. Questions were asked in the original study about joint pain, swelling and stiffness. During subsequent examination joint movements were recorded as normal or restricted. As an example of the results in the original study details are given about pain and movement in the knees in men. In 213 men, 12 of 37 with painful knees and 15 of 176 with no pain in the knees, were found to have restricted knee movement. In two men no history was obtainable. Similar results are found in other limb joints in both sexes. Restricted hip joint movement was present in 20 per cent of those without pain but the nature of the pain, often referred to the knee, makes answers about it difficult to assess. The figures suggest that in a survey including arthropathy some joint examination would be needed as well as questioning.

Morning stiffness was recorded in the original study in 6 men of 213 and 15 women of 267. Of these 21 people, 1 man and 8 women had rheumatoid arthritis. Four women with rheumatoid arthritis did not admit to morning stiffness.

Cobb *et al* [11] described three screening questions which they found had 66 per cent sensitivity and 95 per cent specificity in the detection of rheumatoid arthritis. The second and third of these are included in the questionnaire. (Appendix A.8 (ii) and (iii)) but the first question of Cobb *et al* 'Have you ever had any arthritis or rheumatism?' is replaced by 'Have you ever had pain in any of your joints?' (Appendix A.8 (i)). The latter question was answered positively by all persons in the original study who were diagnosed as having rheumatoid arthritis. In Eastern Scotland the words arthritis and rheumatism are used colloquially to cover many different painful conditions. In the original study and in the new questionnaire, joint pain seemed a more appropriate enquiry.

In an older population a survey of arthropathy should include degenerative joint disease. The accurate diagnosis of this needs X-ray since clinical criteria are unreliable [12]. This is not possible in a large survey using nurses as observers but the nurses having collected information on symptoms as described above and on joint movement (*vide infra*), samples of persons with and without symptoms and restricted movement could be further examined by a doctor and by X-rays.

9. *Stroke.* In the original study 5 per cent of men and 6 per cent of women had a history of stroke. Answers to the question 'Has any doctor ever said you had had a stroke?' are highly reproducible and the question is used in the short questionnaire. Only two persons in the original study had clinical signs which could have been interpreted as pyramidal lesions without a history of stroke. These were a woman with a hemiparesis present since birth and a man with unexplained bilateral extensor plantar responses.

10. *Hospital history.* In the original study, 86 per cent of the men and 78 per cent of the women admitted being in hospital at some time in their lives. About half of these percentages claimed to have been admitted in the previous 5 yr. About two-thirds of men and women had had an operation at some time and about one-fifth of men and women had had an operation in the previous 5 yr.

Approximately half the subjects had been out-patients at some time and about one-fifth had been out-patients in the previous 5 yr. Replies were validated by combining admission and out-patient attendance as 'hospital episodes' and examining hospital letters in the general practice records of a subsample of 50 of all the persons examined. Letters examined were those written from hospital in the previous 20 yr. The subjects were found to under-report 30 per cent of hospital episodes but the general practice records under-recorded 19 per cent of such episodes. The questions about hospital care (Appendix A.10 (i)–(iii)) sometimes confirm replies given in the rest of the questionnaire and sometimes are the only source of information about the conditions being investigated.

(B) *Physical examination*

1. *Blood pressure* is measured with a random zero sphygmomanometer [13]. This is used here in preference to the London School of Hygiene instrument because subjects are to be examined at home and the L.S.H. instrument is heavy.

2. *Height* is measured without shoes against a wall, standing on a piece of plywood to which a tape measure is attached. A spirit level is used to ensure the tape is held vertical. The level is then used as a headboard to read off the height on the tape measure.

3. *Weight* is measured without jacket and shoes on a spring balance checked daily against standard weights.

4. *Triceps skinfold thickness* measured with a Harpenden Caliper is used to estimate obesity. This has the advantage of needing no further undressing. In the original study obesity was estimated by summing triceps, subscapular and suprailiac folds. The correlation coefficient between this sum and the triceps fold was 0.79 for men and 0.81 for women. Seltzer and Mayer [14] have shown that the triceps fold is a good index of obesity in women.

5. *Peak expiratory flow rate.* This is measured with a Wright Peak Flow Meter. In the original study a Vitalograph was used. The Peak Flow Meter is easier to carry into houses, needs no electricity and will detect those with airways obstruction who

are the majority of persons with respiratory disease. In the original study 25 per cent of the men and 5 per cent of the women had F.E.V.$_{1\cdot 0}$/F.V.C. per cent of 60 or less and the groups with symptoms contained significantly higher proportions of persons with this ratio <60. P.E.F.R. is therefore a useful adjunct to the M.R.C. Short Questionnaire on Bronchitis. Persons with dyspnea and normal P.E.F.R. need separate investigation.

6. *Handgrip* was measured in the original study using the Arthritis and Rheumatism Council's modified sphygmomanometer cuff attached to a mercury-manometer 600 mm. long. The mean value for all men was 365.5 mm Hg (S.D. 98.4) and for all women 219.6 mm Hg (S.D. 65.0). In 27 persons both handgrips were equal to or less than 120 mm Hg: Twelve of the 13 persons with severe rheumatoid arthritis were in this group. The remaining 15 persons had dementia (9), hysteria (1), arthropathy not rheumatoid (5). Bilateral grip $\leqslant 120$ mm Hg seems to be associated with either severe arthropathy or mental disturbance. Evidence from the original study to be published elsewhere shows a low bilateral figure for handgrip to be associated with a high figure in the American Rheumatism Association's criteria for Rheumatoid Arthritis. Overlap of values made handgrip an unsatisfactory detector of past strokes. Of 27 persons with a history of stroke only four had a unilateral grip $\leqslant 120$ mm Hg. The results of measuring handgrip in a large study of the elderly should be of interest in respect of arthropathy and possibly in the assessment of mental health. Since the interest is in lower values, an ordinary sphygmomanometer can be used as the manometer.

7. *Joint examination*. The observer records normal or restricted movement in hands, shoulders, knees and hips. Persons admitting joint pain or stiffness or found to have restricted joint movement or bilateral weak grip need further investigation along with a sample of persons not having these things.

2. MENTAL HEALTH QUESTIONNAIRE

The prevalence in the original study of chronic brain syndrome was 9.1 per cent and of affective illness or neurosis 14.7 per cent. The prevalence of other mental illness amounted to only 0.9 per cent [15]. These findings correspond closely to those in elderly persons in Newcastle [16]. The new questionnaire was designed to estimate the prevalence of chronic brain syndrome and affective illness or neurosis only. No estimate was made for paranoid illness because this is relatively rare and questions needed to discover paranoid illness seem strange to normal older people. The aims of the new questionnaire were accurate diagnosis, acceptability to the subjects and brevity. The questionnaire is described under the headings of (1) chronic brain syndrome and (2) depressive illness or anxiety state. The questions are given in full in Appendix C.

2(a) *Chronic brain syndrome*

Prevalence was assessed in the original study by full clinical examination and by the use of the following four established tests.

1. The mental status questionnaire [17] M.S.Q.
2. The mental impairment measurement [18] M.I.M.

3. The intellectual rating scale [19] I.R.S.
4. The psychological test proforma [20] P.T.P.

In the last two tests scoring was translated into 'Error Scores' to make all four tests comparable. The matrix in Table 1 shows high correlation among the results of the four tests in the original study. All correlation coefficients are highly significant ($p<0.001$). The relationship between results in each of the four tests and clinical assessment in the original study is (Table 2) highly significant.

TABLE 1. CORRELATION MATRIX FOR THE FOUR TESTS FOR MENTAL IMPAIRMENT

	MSQ	MIM	IRS	PTP
Mental status questionnaire (MSQ)	1	0.92	0.81	0.88
Mental impairment measurement (MIM)	—	1	0.82	0.78
Intellectual rating scale (IRS)	—	—	1	0.75
Psychological test proforma (PTP)	—	—	—	1

TABLE 2. COMPARISON OF SCORING ON TESTS FOR MENTAL IMPAIRMENT AND THE CLINICAL DIAGNOSIS OF CHRONIC BRAIN SYNDROME IN 487 OLDER PEOPLE (PERCENTAGES)

		Clinical diagnosis		
Test	Test score	C.B.S. absent	C.B.S. present	χ^2
Mental status questionnaire (MSQ)	Less than 3	98.6	36.4	219.6*
	3 or over	1.4	63.6	
Mental impairment measurement (MIM)	Less than 2	98.8	34.1	238.4*
	2 or over	1.2	65.9	
Intellectual rating score (IRS)	Less than 2	92.6	6.8	217.7*
	2 or over	7.4	93.2	
Psychological test proforma (PTP)	Less than 10	99.8	40.9	247.2*
	10 or over	0.2	59.1	

*Significant at 0.001 per cent level.

The four tests and the clinical assessment were made by the same observer (M.M.M.) who first carried out the tests, then made the clinical assessment and finally counted the error scores in the four tests. It is possible that the observer's clinical judgement was affected by the subject's performance in the four tests. A separate study was therefore carried out on 75 new out-patients. One psychiatrist assessed these patients for the presence or absence of chronic brain syndrome while another (M.M.M.) separately administered and scored the Mental Status Questionnaire (No. 1 of the four tests). The relationship between chronic brain syndrome assessed in this way by clinical examination and by Mental Status Questionnaire was highly significant (χ^2 38.15, D.f. 1, $p<0.01$).

Figure 1 compares the estimate of mental impairment by the four tests in the 44 subjects in the original study who were assessed clinically as suffering from chronic brain syndrome. The severity of mental impairment was estimated for each test in accordance with the equivalent error score recommended by the author of each test. All cases clinically described as moderate to severe are in a similar category in three of the four tests, the exception being the Intellectual Rating Scale. The clinical diagnosis of mild chronic brain syndrome has a variable placing among the different tests. This finding is not unexpected because there is wide variation amongst psychiatrists in the assessment of mild mental impairment.

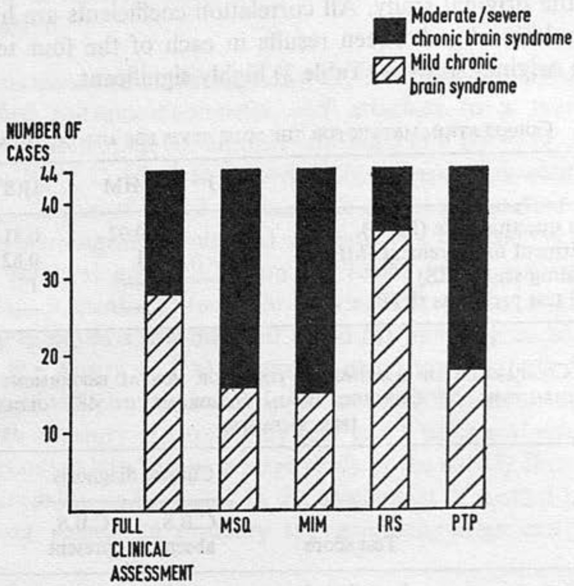

FIG. 1. Comparison of four tests of intellectual impairment in 44 persons diagnosed by clinical assessment as mild or moderate/severe chronic brain syndrome.

Sensitivity and specificity [21] of each of these four tests were calculated from data in the original study assuming that clinical assessment of chronic brain syndrome was 100 per cent accurate (Table 3). This assumption is necessary when assessing tests of mental impairment, in spite of the variation among psychiatrists, because psychiatric examination is still the only clinical method available.

TABLE 3. SENSITIVITY AND SPECIFICITY OF THE FOUR TESTS OF MENTAL IMPAIRMENT

Test	Sensitivity	Specificity
Mental status questionnaire	0.64	0.99
Mental impairment measurement	0.66	0.99
Intellectual rating scale	0.93	0.93
Psychological test proforma	0.59	0.99

It was decided to use the Mental Impairment Measurement of Isaacs and Walkey to diagnose Chronic Brain Syndrome in the new questionnaire because of

1. high specificity (0.99);
2. sensitivity higher than that of Mental Status Questionnaire or Psychological Proforma;
3. the questions being the most acceptable to the subjects;
4. the test being the shortest of the four.

The interpretation of the error scores in this test is 0–1=no mental impairment, 2=possible chronic brain syndrome, 3= definite chronic brain syndrome.

2 (b) *Depressive illness or anxiety state*

Data collected in the original study were examined to see which questions discriminated best between those who were emotionally well and those who were suffering from depression or anxiety. Table 4 (Q1–Q6, Q8–Q12, Q14) lists the replies to 12 of these questions, 5 of which are from the Signs Symptoms Inventory [22]. Those, in the original study, answering yes or no to the individual questions are compared in the table with the final assessments made in that study as to the presence or absence of depressive illness or anxiety. The table shows that for every question a significantly higher proportion ($p<0.01$) of those answering yes or its equivalent were clinically assessed as depressed or anxious compared with those who answered no. Two questions based on the Beck Inventory [23] were assessed in the same way in a separate study on out-patients (Table 4, Q7, Q13). Answers to those two questions had the same significance as those to the 12 questions described above. These 14 questions were included in the new questionnaire to identify depressive illness or anxiety. When using the questionnaire, replies given to each question are recorded as nearly verbatim as possible and used to determine whether emotional distress is absent, possible or certain. The presence or absence of depressive illness or anxiety state was decided in the present study by a psychiatrist (M.M.M.) after consideration of the replies to all fourteen questions and their interpretation in respect of emotional distress.

TABLE 4. COMPARISON OF 14 QUESTIONS RELATING TO EMOTIONAL ILLNESS WITH CLINICAL ASSESSMENT OF EMOTIONAL ILLNESS IN ORIGINAL STUDY

		Clinical assessment: Emotionally well		Clinical assessment: Anxious or depressed				
Question (numbered as in Appendix C)	N*	Reply suggests emotional distress c	Reply suggests emotional distress absent d	Reply suggests emotional distress a	Reply suggests emotional distress absent b	χ^2	Sensitivity $\frac{a}{a+b}$	Specificity $\frac{d}{c+d}$
1	375	54	267	27	27	29.8	0.5	0.83
2	437	32	331	31	43	54.2	0.42	0.91
3	431	93	268	38	32	23.4	0.54	0.74
4	444	5	365	16	58	57.9	0.22	0.99
5	444	46	324	28	46	28.8	0.38	0.88
6	444	2	368	18	56	81	0.24	0.99
7	82	5	51	16	10	12.59	0.62	0.91
8(i)	442	13	357	32	40	111	0.44	0.96
8(iii)	439	15	351	29	44	85.9	0.40	0.96
9	446	68	304	35	39	29.2	0.47	0.82
10	445	40	331	27	47	32.1	0.36	0.89
11	438	16	353	27	42	80.5	0.39	0.96
12	417	12	337	36	32	137	0.53	0.97
13	125	4	63	28	30	29.4	0.48	0.94
14	432	39	327	39	27	87.7	0.59	0.89

*N varies because not all subjects in interview in original study were asked all questions.

All χ^2 significant at 0.001 per cent level.

2 (c) *Validation of the psychiatric screening questionnaire*

A comparison was made in 75 consecutive out-patients attending a geriatric consultative clinic, of the diagnosis made by one of us (M.M.M.) using only the screening questionnaire with the diagnosis made by another psychiatrist after full clinical assessment. The disagreement between the two methods was 4 per cent for emotional illness (Table 5) and 29 per cent for chronic brain syndrome (Table 6).

Table 5. Comparison of diagnosis of affective illness or anxiety state made by using the questionnaire and by full clinical assessment

Source of subjects	Illness absent	Illness found by at least one method	Illness found by both methods	Percentage disagreement in last 2 columns	Totals
Geriatric outpatients	25	50	48	4	75
General practice	34	16	11	31	50

Table 6. Comparison of diagnosis of chronic brain syndrome (C.B.S.) made by using the questionnaire and by full clinical assessment

Source of subjects	C.B.S. absent	C.B.S. found by at least one method	C.B.S. found by both methods	Percentage disagreement in last 2 columns	Totals
Geriatric outpatients	61	14	10	29	75
General practice	47	3	3	0	50

One of us (S.C.) who is a trained nurse but not otherwise qualified in psychiatry, was taught to use the questionnaire and then administered it to 50 patients in their own homes. These patients of 65 yr and upwards were selected at random from their lists by two friendly general practitioners but did not form a statistically random sample. The diagnostic category in the 50 patients was decided by the psychiatrist (M.M.M.) after coding the replies collected by the nurse and assessing their significance. Two weeks later the same doctor visited these patients and made a full clinical assessment. Comparing this full assessment with the assessment made from data collected by the nurse resulted in no disagreement between the two methods for chronic brain syndrome (Table 6) and 31 per cent disagreement for emotional illness (Table 5).

Other relevant points in these studies on validation are:

1. Out-patient examinations comparing psychiatrist with psychiatrist were done on the same day, so that diagnostic categories would not be expected to change between examinations.
2. Home examinations comparing nurse and psychiatrist were two weeks apart. Emotional illnesses could change sufficiently to affect diagnosis in this time.
3. Emotional illnesses were more severe in out-patients than in people at home, making agreement more likely in out-patient diagnoses.
4. Chronic brain syndrome found at home was severe compared with the milder, and therefore harder to assess, cases found in out-patients.
5. All coding of the replies to the questionnaires was done by one person (M.M.M.)

It has therefore been shown that:

1. Diagnoses made from this simple screening questionnaire administered by one psychiatrist agree reasonably well with independent clinical assessment by another psychiatrist.
2. The psychiatrist (M.M.M.), without having interviewed the subjects, was able, using replies to the screening questionnaire administered by an observer not medically qualified, to make an assessment of mental health which was in reasonable agreement with that made by her two weeks later after full psychiatric examination.

The screening questionnaire described is not intended to replace psychiatric examination but to identify older people likely to have chronic brain syndrome or emotional illness. Because older people may accept subnormal health without complaint, the general practitioner may remain unaware of unreported needs [24]. The screening questionnaire could be used in general practice to detect previously unknown mental illness and could be used by a nurse as well as by a doctor.

3. TRAINING A NURSE AS AN OBSERVER AND TESTING HER PERFORMANCE

Having decided on the questions to be asked and the examination to be performed in a large survey of the elderly population, the next step was to train a nurse as an observer and subsequently to test her performance. The nurse who trained (S.C.) was experienced in working with older people, and having spent 2 yr helping in the longitudinal study was already orientated towards survey work.

3.1 *Questionnaire on physical health*

Work began with an explanation of the reasons for the questions and the way in which they should be asked. Clear instructions have been provided for the use of the questionnaires on ischemic heart disease and intermittent claudication [3]. Gramophone records of the M.R.C. questionnaire on Respiratory Symptoms are available from the London School of Hygiene. These records of 20 actual interviews, 10 for training and 10 for testing, were transferred to magnetic tape and edited into the shortened version described above. The observer found this material useful, especially the interviews on bronchitis which seemed to cover all situations. After she had listened repeatedly to the 10 training interviews and then used the 10 testing ones, it was obvious that the observer had a good grasp of how to use the M.R.C. Questionnaire on Respiratory Symptoms and how to ask probing questions. The remaining questions were fairly simple but definite instructions were written down about their use so that the observer would always know how to proceed. For example, in the duodenal ulcer section (Appendix A.V(a) and (b)) questions about abdominal pain ask 'Are you ever troubled with pain in your stomach or abdomen?' If yes, 'Where do you feel it?' (Mark pain site as X on drawing of abdomen). If yes, 'How soon after eating?' The instructions for this section read 'The purpose of this section is to discover people with epigastric pain 2 hr after food. The reason for asking about "pain in the stomach or abdomen" is that many people do not count epigastric pain as abdominal pain. "Where do you feel it?" makes people point to the site. Make sure you know where the site is before you record it. If still uncertain after "Where do you feel it?" ask "Is the pain above or below your navel?" and if above "Is it in the top part of your stomach?" '

After the questionnaire and instructions had been studied, the observer practiced asking the questions of patients in the day hospital and in the wards. All interviews were recorded on magnetic tape. From the tape recordings notes were made of mistakes in the use of the questionnaire and of questions found to be awkward in form or content. Frequent discussions about these and any other difficulties were held with the nurse observer. As a result she not only became expert in using the questionnaire but by constructive criticism helped to modify it. All decisions about changes were written into the instructions for the use of the questionnaire.

Eventually the questionnaire reached its present form and the observer had learned to use it. She then asked the questions of 33 patients in the practice of a nearby practitioner. Two weeks later one of us (J.S.M.) visited the same patients and asked the same questions. All 66 interviews were recorded on magnetic tape and criticized by both nurse and doctor.

An interobserver study is shown in Table 7 in which diagnoses based on each section of the questionnaire are given together with some symptoms. The columns of the table report the numbers in whom both observers found the condition absent, the numbers in whom the condition was found by at least one observer and the numbers in whom the condition was found by both observers. The worst disagreement was in respect of a history of recurrent chest illness. The last column reports percentage disagreement.

TABLE 7. DISAGREEMENT BETWEEN ANSWERS TO QUESTIONS ON PHYSICAL HEALTH BY THE SAME 33 SUBJECTS TO TWO OBSERVERS

Symptom or diagnosis	Condition found by neither observer	Condition found by at least one observer	Condition found by both observers	Percentage disagreement in last 2 columns
Angina pectoris	29	4	2	50
Myocardial infarct	32	1	1	0
Intermittent claudication	31	2	2	0
Persistent cough	24	9	5	44.4
Persistent phlegm	24	9	4	55.5
Recurrent chest illness	28	5	1	80
Peptic ulcer	31	2	2	0
Past urinary infection	25	8	6	25
Past dysuria	25	8	4	50
Arthropathy (derived)	25	8	3	62.5
Stroke	28	5	5	0

The nurse-observer then asked the questions of 28 patients of another practitioner. After 2 weeks she asked the same patients the same questions again. Results of this intra-observer study are shown in Table 8 where the last column gives percentage disagreement. Important differences were present for angina pectoris and for arthropathy (derived). The latter as described above is based on the three questions about joint pain, morning stiffness and joint swelling and is a yes-no variable which is 'yes' if the answers to the three questions are yes but 'no' otherwise. It seems probable that the nurse observer compares as well with herself as most observers do [25] and on the whole, as expected, compares better with herself than with another observer.

TABLE 8. DISAGREEMENT BETWEEN ANSWERS TO QUESTIONS ON PHYSICAL HEALTH BY THE SAME 28 SUBJECTS TO ONE OBSERVER ON TWO OCCASIONS

Symptom or diagnosis	Condition absent on both occasions	Condition found on at least one occasion	Condition found on both occasions	Percentage disagreement in last 2 columns
Angina pectoris	20	8	3	62.5
Myocardial infarct	24	4	2	50
Intermittent claudication	24	4	3	25
Persistent cough	23	5	3	40
Persistent phlegm	19	9	6	33.3
Recurrent chest illness	22	6	4	33.3
Peptic ulcer	24	4	3	25
Past urinary infection	15	13	9	31
Past dysuria	16	12	9	25
Arthropathy (derived)	23	5	1	80
Stroke	25	3	3	0

3.2 *Methods of examination*

(a) *Blood pressure.* The technique of sphygmomanometry was explained in detail after which the observer practiced this until she felt proficient. Several sessions were then held in which the observer and a doctor (J.S.M.) simultaneously recorded the indirect blood pressure in the same subject using a multi-access electronic stethoscope. Finally observer and doctor simultaneously recorded blood pressure in this way in 10 subjects. Table 9 shows that there was satisfactory agreement between the observers.

TABLE 9. COMPARISON OF NURSE-OBSERVER WITH ANOTHER OBSERVER (OR METHOD) IN PERFORMANCE OF MEASUREMENTS

Variable measured	Observer 1	Observer 2	Mean of all readings: Observer 1	Mean of all readings: Observer 2	Mean difference	S.D. of mean difference	N	t to test difference of mean difference from zero
Systolic B.P. (mm/Hg)	Nurse	Doctor	168.2	167.6	0.6	1.35	10	1.4
Diastolic 4 B.P.	Nurse	Doctor	78.8	78.4	0.4	1.26	10	1.0
Diastolic 5 B.P.	Nurse	Doctor	77.4	77.0	0.4	1.58	10	0.8
Tape recording (sec.)								
Systolic end point	Nurse	L.S.H. standard times	23.88	23.52	0.36	0.65	12	1.89
Diastolic 4 end point	Nurse	L.S.H. standard times	61.22	62.69	1.47	2.17	12	2.26*
Diastolic 5 end point	Nurse	L.S.H. standard times	64.82	64.77	0.05	0.88	12	0.19
Triceps skinfold (log transformation)	Nurse	Doctor	214.7	213.5	1.2	4.64	14	0.98
Height (mm)	Nurse (tape measure)	Nurse (Stadio-meter)	1589.9	1585.1	4.8	3.46	10	4.17†

*Significant at 5 per cent level.
†Significant at 1 per cent level.

The observer also practiced listening to the Korotkov sounds in 12 subjects in a training series on magnetic tape supplied by the London School of Hygiene [26]. Since the L.S.H. sphygmomanometer has a constant rate of fall of mercury of 2 mm per sec, an observer can be trained by listening to recorded Korotkov sounds and noting the time for systolic, diastolic phase 4 and diastolic phase 5 sounds to appear after a preliminary time marker. The times of the trainee can then be compared with standard times supplied by the L.S.H. Table 9 shows the times of the nurse-observer compared with L.S.H. standard times for the test series. The difference between the observer's times and standard times is significantly different from zero only for diastolic phase 4 sounds.

(b) *Triceps skinfold thickness.* Explanation and demonstration of the technique was followed by practice with the Harpenden Caliper. Comparisons were then made between nurse-observer and doctor measuring 14 subjects on one occasion (Table 9). The nurse-observer then compared repeatability of her own technique by measuring 10 subjects on two occasions (Table 10). The mean difference is not significantly different from zero in either group of tests.

TABLE 10. COMPARISON OF MEASUREMENTS MADE BY NURSE-OBSERVER ON THE SAME SUBJECTS ON TWO OCCASIONS

Variable measured	Mean of readings on 1st occasion	Mean of readings on 2nd occasion	Mean difference	S.D. of mean difference	N	t (testing difference of mean difference from zero)
Triceps skinfold (log transformation)	218.4	218.4	0	2.26	10	—
P.E.F.R. (ml.)	398.1	387.6	10.5	20.1	10	1.57
Height by tape measure (mm)	1630.4	1630.0	0.4	11.2	27	0.19
Hand grip R. (mm Hg)	197.2	198.8	1.6	17.9	12	0.30
Hand grip L. (mm Hg)	200.0	198.8	1.2	8.3	12	0.48

(c) *Peak expiratory flow rate.* The same technique of explanation and practice was followed by the observer measuring P.E.F.R. in the same ten subjects on two occasions (Table 10). The mean difference is not significantly different from zero.

(d) *Height.* The nurse-observer was already familiar with the use of the Harpenden stadiometer. She therefore practiced the method described above using a tape measure and then measured the same group of 27 people on two occasions. Results in Table 10 show satisfactory agreement. It was assumed that height measured on the stadiometer was accurate. Height measured by tape measure was compared with that measured by stadiometer in ten people. Table 9 shows that the mean difference of 4.8 mm differs significantly from zero.

(e) *Measurement of handgrip*, using the Arthritis and Rheumatism Council's modified sphygmomanometer cuff as a dynamometer, was already familiar to the nurse-observer since it was used in the longitudinal study. She therefore measured handgrip on both sides in 12 people on two occasions. Satisfactory reproducibility is shown in Table 10.

(f) *Joint movement* was recorded as normal or abnormal, the latter being any degree of passive movement less than full. After demonstration and practice, the nurse-observer and doctor independently assessed the same movements in hands, shoulders and knees in 10 people. There was no disagreement on hand movement but there was disagreement for one subject for each of shoulder and knee movements.

3.3 *Questionnaire on mental health*

The same staff nurse (S.C.) learned to use the questionnaire on mental health. Training in the use of both questionnaires was concurrent. As before the observer received explanation and instruction after which she practiced using the psychiatric questionnaire in hospital patients and outpatients. A difficulty for the observer is that whereas with the physical health questions the observer aims at obtaining clear yes-no answers and uses probing questions designed with such answers in mind, replies to the mental health questions must be written down as nearly verbatim as possible to prevent value judgements by the observer and to give maximum information to the psychiatrist who assesses the records. Interviews were recorded on magnetic tape which allowed checking of the accuracy of the observer's written record. The psychiatrist and nurse observer used the record on tape to discuss technique and mistakes. As before suggestions by staff nurse helped to improve the acceptability of the questions. With some outpatients the nurse observer used the questionnaire with the psychiatrist present, so that each case could be reviewed immediately after asking the questions.

Once the nurse observer was trained in the technique she asked the questions of 22 patients in the practice of a nearby practitioner. Two weeks later the same 22 patients were asked the same questions by the psychiatrist. This interobserver study is summarized in respect of emotional illness in Table 11 which compares the numbers of questions found positive by at least one observer with the number found positive by both observers. The last column gives percentage disagreement between these groups. Disagreement in respect of chronic brain syndrome was 50 per cent, 6 cases being found by at least one observer, but only 3 by both observers. However, three of the cases had borderline mental impairment.

The nurse observer then administered the psychiatric questionnaire to a further 28 patients in a different general practice. After two weeks she asked the same patients the same questions again. This intra-observer study is summarized in Table 12 for emotional illness. No persons with chronic brain syndrome were found in the 28 patients.

4. DISCUSSION

The reasons for including particular questions about any disorder in the questionnaire and for excluding others have been detailed in the text. The disorders selected for investigation are those which the original study showed to be common in older people. Some of the variables to be measured in the examination are designed to detect present disability but others, e.g. height, skinfold thickness, blood pressure, could be examined for prognostic value if the subjects in the survey were later followed up using hospital or general practice records and, eventually, registration of death.

A small portable tape recorder proved very valuable in training the nurse-observer in the use of the questionnaire. This revealed when questions were omitted, when replies were wrongly interpreted and when incorrect or unnecessary probing questions were asked, e.g. (from the Physicial Health Questionnaire):

Q: Are you ever troubled with heartburn?
A: Yes.
Q: What is the effect, if any, of standing, stooping, lying or sitting?
A: It comes on at night when I get to bed.

This should be interpreted as 'worse on lying' but the observer went on to ask:

Q: You couldn't tell me whether it is worse in any of these four positions?
A: No, I couldn't tell you.

The tape recorder also revealed questions which were embarrassing or not understood. Questions about urinary incontinence were omitted because although acceptable in the original study when asked by a middle-aged male doctor in a white coat, they appeared to be resented when asked by a young woman in nurse's uniform. 'Are you ever troubled with abdominal pain?' was changed to 'Are you ever troubled with pain in your stomach or abdomen?' because the former question often led to 'no' if the pain was epigastric.

Tape recording of interviews by the doctors of subjects already questioned by the nurse allowed her to examine these critically and discuss with the doctors their reasons for probing questions. Mistakes by the doctors perhaps helped the nurse by showing her that even practised observers sometimes depart from exact instructions which they themselves have laid down.

It has been possible to show that a staff nurse can quickly learn to make measurements in which she compares satisfactorily with another observer or with herself on a second occasion. Two measurements were recorded in which the mean difference between paired measurements was significantly different from zero. The first was the nurse-observer's time compared with L.S.H. standard time for the appearance of diastolic phase 4 sounds. The mean difference of 1.5 sec is equivalent to 3 mm of mercury and while this may be a statistically significant difference the error is acceptable

TABLE 11. DISAGREEMENT BETWEEN ANSWERS TO QUESTIONS TO INDICATE EMOTIONAL ILLNESS BY THE SAME 22 SUBJECTS TO TWO OBSERVERS

Question (numbered as in Appendix C)	No indication of emotional distress found by either observer	Indication of emotional distress found by at least one observer	Indication of emotional distress found by both observers	Percentage disagreement in last 2 columns
1	15	7	6	14
2	15	7	2	71
3	15	7	0	100
4	—	—	—	—*
5	—	—	—	—*
6	19	3	2	33
7	19	3	2	33
8	13	9	5	44
9	16	6	4	33
10	21	1	1	0
11	11	11	7	36
12	18	4	4	0
13	16	6	3	50
14	13	9	5	44

*Not tested.

TABLE 12. DISAGREEMENT BETWEEN ANSWERS TO QUESTIONS TO INDICATE EMOTIONAL ILLNESS BY THE SAME 28 SUBJECTS TO ONE OBSERVER ON TWO OCCASIONS

Questions (numbered as in Appendix C)	Indication of emotional distress absent on both occasions	Indication of emotional distress present on at least one occasion	Indication of emotional distress present on both occasions	Percentage disagreement in last 2 columns
1	17	11	7	36
2	25	3	1	67
3	23	5	1	80
4	26	2	1	50
5	17	11	8	27
6	22	6	1	83
7	21	7	3	57
8	19	9	2	78
9	16	12	3	75
10	19	9	6	33
11	18	10	7	30
12	24	4	3	25
13	27	1	0	100
14	17	11	6	45

for survey purposes. Similarly the mean difference between height by tape measure and height by stadiometer is significantly different from zero with a value of 4.8 mm. If 2 standard deviations are added to this mean difference the figure becomes 12 mm which is acceptable in the survey.

The interobserver and intraobserver studies of the mental health questionnaire (Tables 11 and 12) show some replies for which reproducibility is poor. Sometimes a change in the reply on a second occasion is due to a real change in mood, since the questions were repeated two weeks after being first asked. Reproducibility is less important in individual questions in the mental health questionnaire since the assessment of mental health by the psychiatrist is based on the replies to all the questions. Similarly the low sensitivity of some of the mental health questions (Table 4) does not necessarily mean they are unsuitable because final assessment uses the replies to all 14 questions and specificity is high.

5. SUMMARY

A questionnaire has been devised based on another study by the authors and on the publications of other workers to estimate physical and mental illness in older people. A simple physical examination follows the questionnaire. A staff nurse was trained to use the questionnaire and do the examination. Her performance was found to be satisfactory in respect of accuracy and reproducibility.

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APPENDIX A

Questionnaire on physical health for use by staff nurse in a survey of older people

1. Rose's questions on angina pectoris and possible myocardial infarction (Rose 1962).
2. Rose's questions on intermittent claudication (Rose 1962).
3. A shortened version of the M.R.C. Questionnaire on Respiratory Symptoms (1966) including questions 1, 3, 5 on cough, questions 6, 8, 10 on phlegm, questions 12a, 12b on past chest illness and questions 14a, 14b, 14c, 14d on breathlessness.
4. *Smoking*

(a) (i) Do you smoke cigarettes now?
(ii) If yes to Q. (a) (i), How many manufactured cigarettes do you usually smoke per day?
(iii) How old were you when you began to smoke cigarettes?

(b) (i) If no to Q. (a) (i), If you do not smoke cigarettes now did you ever smoke them?
(ii) If you used to smoke regularly how many cigarettes per day were you smoking before you gave up?
(iii) How old were you when you began to smoke cigarettes?
(iv) When did you give up smoking?

5. *Duodenal ulcer*
   - (a) (i) Has any doctor ever said you had a duodenal ulcer?
     - (ii) If yes, was it confirmed by X-ray?
   - (b) (i) Are you ever troubled with pain in your stomach or abdomen?
     - (ii) If yes to Q. (b) (i), Where do you feel it? (Mark X on pain site).
     - (iii) If yes to Q. (b) (i), How soon after eating?
     - (iv) If yes to Q. (b) (i), Does milk or food relieve the pain?
     - (v) If yes to Q. (b) (i), Does the pain ever wake you at night?

6. *Hiatus hernia*
   - (i) Are you troubled with heartburn?
   - (ii) If yes, what is the effect, if any, on the heartburn of standing, stooping, lying or sitting?

7. *Urinary tract infection*
   - (i) Have you ever at any time had cystitis or a chill or infection in your bladder? If yes, how many times?
   - (ii) Have you at any time in the past had pain on passing urine?

8. *Arthritis and rheumatism*
   - (i) Have you ever had pain in any of your joints?
   - (ii) Do you wake up with stiffness or aching in your joints or muscles?
   - (iii) Have you ever had swelling in any of your joints?

9. *Stroke*
   Has any doctor ever said you have had a stroke?

10. *Hospital history*
    - (i) Have you ever been in hospital? If yes, what was wrong? When?
    - (ii) Have you ever attended hospital as an outpatient? If yes, what was wrong? When?
    - (iii) Have you ever had an operation? If yes, what was wrong? When?

APPENDIX B

Examination by staff nurse in a survey of older people

		Syst.	D4.	D5.
Blood Pressure	1.			
	2.			
Dynamometer	R grip	1.		2.
	L grip	1.		2.
Peak Flow Rate	1.		2.	
Weight	kg.			
Height	mm.			
Triceps skinfold (L)	1	2		

Open your hands		Full
	Hand movement	
Clench your fists		Restricted
Put your arms above your head		Full
	Shoulder movement	
		Restricted
Extension of knees		Full
	Knee extension	
		Restricted
Squat		Full
	Hip movement	
		Restricted
Get up and walk across the room		Normal
		With difficulty
		With help
		Cannot

Appliances None
Stick
Tripod stick
Walking aid
Chair
Caliper Yes No

Do you go out alone?
If no, do you go out accompanied?
Are you able to go anywhere you like?

Mobility rating
No restriction
Goes out – restricted
Housebound
Bedfast

In persons who have
a dyspnea grading of 5
and/or restricted movement in a large joint
and/or difficulty in walking across a room, ask
Are you able to dress?
Are you able to go up and down stairs?
Can you get in and out of bed?
Are you able to wash yourself?

Urine Glucose
Protein

APPENDIX C

Questionnaire on mental health for use by staff nurse in a survey of older people

"Some of the questions I am going to ask are about things like memory and concentration and may seem a little different from the things a doctor usually asks. Please give me your full name."

Questions to assess Chronic Brain Syndrome.

1. What is your full postal address?
2. How long have you been living at this address?
3. What day of the week is it today?
4. What month are we in?
5. What year is it?
6. How old are you?
7. When is your birthday?
8. What year were you born?
9. Just making a guess, about what time is it just now?

(Each wrong answer scores 1. Sum error score.)

Questions to assess Depression or Anxiety.

"These questions are about how you are feeling in yourself".

1. Have you any anxieties or problems that worry you at present?
   If yes (i) Are you feeling very upset by this?
   (ii) Is there any other particular worry bothering you at present?
2. (i) Are there times when you feel anxious without really knowing why?
   (ii) Are you distressed by silly pointless thoughts that keep coming into your mind against your will? (S.S.I.)
3. Have you any fears that tend to haunt or worry you?
4. What interests have you? (sewing, knitting, T.V. etc.)
   (If none) Have you lost interest in almost everything? (S.S.I.)
5. Do you look forward to things?
   (If not, or doubtful) Does the future seem pointless? (S.S.I.)
6. Do you find it a bother to do the things you are able for?
   If yes (i) Does even the thought of having to do anything feel an effort to you?
   (ii) Do you sometimes have to push yourself to start even the simplest task? (S.S.I.)

7. (Ask women)
   Do you tend to cry any more often than you used to?
   (Ask men)
   Have you ever felt like crying?
   (If yes) Have you felt more like crying recently than you used to in the past? (Beck)
8. (i) How are you in your spirits today? Are you quite happy or do you feel down in your spirits?
   (ii) Have your spirits been good or poor lately?
   (iii) Have your spirits ever been so low that you have just sat for hours on end? (S.S.I.)
9. (i) How are you sleeping just now?
   (ii) Do you feel rested when you rise in the morning?
   (iii) Has your sleep been good or poor during the past 12 months?
10. Do you sleep with or without sleeping tablets?
11. Have you felt nervous or depressed at any time during the past 12 months?
    (if yes) (i) Do you feel better or worse now compared to then?
    (ii) Were you able to cope adequately with your everyday life when you were like this?
12. Are you being given any medicines, tablets or capsules to soothe your nerves or make you less depressed?
    If yes, do you know what you have been given?
13. (i) Do you enjoy your food?
    (ii) Has your appetite been good or poor lately? (Beck)
14. Would you say that you are content with your present way of life?
    Do you have doubts about this?
    Are you dissatisfied?

S.S.I. means question is based on Signs Symptoms Inventory (Foulds 1965).
Beck means question is based on Beck Depression Inventory.

4

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REVIEWS AFTER ONE AND FIVE YEARS IN A LONGITUDINAL STUDY OF AGEING PERSONS

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Summary

A simple random sample of older people composed of 215 men and 272 women aged 62 years and over was examined in Edinburgh in 1968–9. After one year, 86 per cent of the men and 79 per cent of the women were re-examined; 7 per cent of the men and 4 per cent of the women had died and the remainder were not re-examined for various reasons, mainly refusal. After five years, 53 per cent of the men and 54 per cent of the women were re-examined; 36 per cent of the men and 22 per cent of the women had died and the remainder were not re-examined mainly because of various types of refusal. Causes of death resembled in frequency and sex differences those reported by the Registrar General. Methods used in tracing and improving cooperation of subjects are described.

Introduction

A longitudinal study of ageing persons was begun in Edinburgh in January 1968. It consisted of examination by a physician, a psychiatrist and others. The physician used a semistructured questionnaire about physical health, a full clinical examination and a number of special examinations including anthropometry, audiometry, visual acuity, respiratory function tests, electrocardiography, haematology, biochemistry and radiographic measurements of heart size and bone mass. The psychiatrist used a semistructured questionnaire to perform a full psychiatric examination and carried out several standard tests of intellectual function. The reproducibility of questionnaires and measurements was tested before the study began. Reproducibility of measurements was tested after the original examination and before the reviews. The other investigators were a psychologist, a sociologist and a dietician. The present paper describes success, failure and death rates in examinations made one year and five years after the original examination and discusses these results and related factors. Differences between proportions were examined with the binomial theorem.

Original Examination

This was made during 1968 and 1969. The sample was drawn from the population of persons born in 1905 or earlier who in January 1968 lived in an area composed of ten city wards in Edinburgh and who were on the list of a doctor with a surgery address in the defined area. A census made from Executive Council records listed 26 903 persons who qualified for inclusion in the population as defined. These people were on the lists of 91 doctors working in 50 general practices. Persons composing a simple random sample of 748 people drawn from the above population were approached through their general practitioners to ask them to take part in the study. Those who accepted were examined. If the general practitioners reported refusal by any person, no further approach was made to that person.

Of the 748 persons in the simple random sample, 487 were examined (65 per cent), 212 refused (28.5 per cent), 45 died after the survey began without being examined (6 per cent) and four (0.5 per cent) moved away after the survey began without being examined. The age and sex distributions of the 487 people who were examined are given in Table I. The method of sampling with a comparison of respondents and non-respondents has been described in detail elsewhere (Milne *et al.*, 1971).

Table I. Age and sex distribution of persons in the original sample

Age	Men	Women
62–69	122	137
70–79	73	101
⩾80	20	34
Totals	215	272

These authors showed that age and sex distribution in the sample as drawn (748 people) did not differ significantly from the distributions in the 1966 Edinburgh sample census but the examined group (487 people) showed a significantly smaller proportion of women compared with that in the census. The age distributions within each sex in the examined group did not differ significantly from those in the 1966 census.

The distribution of percentage acceptance rates at the original examination is given in Table II in respect of practices singlehanded or otherwise. The table shows that the mode for acceptance rate is in the 60–69 per cent group and that 30 of the 50 practices have acceptance rates between 50 per cent and 80 per cent. No difference emerges when acceptance rates in singlehanded practices are compared with those in practices with two or more doctors.

Table II. Acceptance rates in general practices in the original examination of a longitudinal study of ageing persons

Percentage acceptance	Number available	Number examined	Number of practices	Doctors in practice	
				1	>1
<30	7	1	2	2	–
30–	23	8	2	1	1
40–	54	24	3	1	2
50–	134	76	9	4	5
60–	267	170	13	5	8
70–	153	111	8	3	5
80–	82	70	4	1	3
90–	11	10	1	1	–
100	17	17	6	5	1
Totals	748	487	48*	23	25

* Two practices had no patients.

Review After One Year

One year after the first examination, the first review was arranged. No person in the study was contacted without first asking the general practitioner concerned whether a further approach was acceptable to the doctor or to the patient. Table III shows success and failure in the first review. The greater proportion of men (85.6 per cent) compared with women (78.7 per cent) who returned for examination is significant ($P < 0.05$), as is the greater rate of refusal to return in women (17.3 per cent compared with men 7 per cent, $P < 0.01$).

The difference in death rate between men (6.5 per cent) and women (3.7 per cent) is not significant. The death rate in each sex does not differ significantly from the loss by death given after one year in Scottish Life Tables for 1961 (men 8.2 per cent, women 6.6 per cent) for a random sample of persons in the age range of the study. Only one person left Edinburgh before and only two were not traceable at the one-year review.

Review After Five Years

Five years after the original examination, practitioners were again asked for permission to approach the surviving members of the sample. No person was approached who refused to come to the one-year review. Table IV shows the results of the five-year review. The proportions of men (52.6 per cent) and women (54.4 per cent) who returned no longer differed significantly. The refusal rate in women (21.3 per cent) was significantly greater than that in men (9.3 per cent, $P < 0.01$). Conversely a significantly greater proportion of men (36.3 per cent) compared with women (22.1 per cent) had died since the study began ($P < 0.01$).

Further comparison of deaths in the sample, during five years, with the loss over five years in the Scottish Life Tables (men 38 per cent, women 30.6 per cent) showed that the proportion of men who died did not differ from that expected but a significantly smaller proportion of women died compared with that expected from the life tables ($P < 0.01$).

Table III. Results of review of the sample after one year (percentages in brackets)

Age and sex	Reviewed	Dead	Refusal —Plain	Refusal —G.P.	Refusal —Ill	Left Edinburgh	Not traceable	Total
Men								
62–69	109	3	4	1	3	1	1	122
70–79	58	10	4	0	1	0	0	73
⩾80	17	1	2	0	0	0	0	20
Totals	184	14	10	1	4	1	1	215
	(85.6)	(6.5)	(4.7)	(0.4)	(1.9)	(0.4)	(0.4)	
Women								
62–69	110	4	21	1	1	0	0	137
70–79	80	2	12	1	5	0	1	101
⩾80	24	4	2	2	2	0	0	34
Totals	214	10	35	4	8	0	1	272
	(78.7)	(3.7)	(12.9)	(1.5)	(2.9)		(0.3)	

Table IV. Results of review of the sample after five years (percentages in brackets)

Original age and sex	Re-viewed	Dead	Refused at 1st review not asked at 2nd review	Refused —plain	Refused —G.P.	Refused —ill	Left Edin-burgh	Not trace-able	Total
Men									
62–69	71	34	8	2	3	1	3	0	122
70–79	38	29	3	2	0	0	0	1	73
⩾80	4	15	1	0	0	0	0	0	20
Totals	113	78	12	4	3	1	3	1	215
	(52.6)	(36.3)	(5.6)	(1.9)	(1.4)	(0.5)	(1.4)	(0.5)	
Women									
62–69	91	16	19	5	3	2	1	0	137
70–79	43	28	12	6	5	2	2	3	101
⩾80	14	16	3	0	1	0	0	0	34
Totals	148	60	34	11	9	4	3	3	272
	(54.4)	(22.1)	(12.5)	(4.0)	(3.3)	(1.5)	(1.1)	(1.1)	

The five-year refusal rates were reduced to 21.3 per cent in women and 9.3 per cent in men by the deaths before the five-year review of 11 women and two men who had refused to return to the one-year review. Tables III and IV show that refusal due to illness was greater at one year than at five years. Illness causing refusal was confirmed by the general practitioners of the subjects concerned. Of those men in the column in Table IV headed 'refusal plain' one refused without known reason, one had been recently bereaved and two were receiving treatment elsewhere. Of the eleven women under the same heading, seven wrote letters to decline the third review, one was too busy and three were 'not able now'. The last three when visited offered firm refusal to attending hospital or being examined at home. Refusal by the general practitioner increased from five persons to 12 over the four years between reviews. These were all patients of one doctor who thought the survey harmful to patients and who increased the prohibition of return from five patients from that practice at one year to all 12 survivors at five years. This increased the over-all refusal rate by 2.5 per cent.

In the four years between reviews, the number who left Edinburgh increased from one to six and the number who could not be traced from two to four. Loss from these causes in five years was small, being 2.1 per cent of the examined group. Of the four persons 'not traced', three were thought to be dead at the anniversary when the review was made. They were found to be alive when deaths in the sample were being checked by the Registrar General. By this time it was much too late to call them for a five-year review. Three persons who had left Edinburgh were not included under that heading because they returned from Inverness, Fife and Northumberland respectively in order to take part.

Deaths in the Sample

The causes of death in the sample and the relative frequency of these are given for the five-year period in Table V. The figures are small for statistical comparison but are

Table V. Deaths in the sample

Cause of death	Men: Number of deaths	Men: Percentage of total deaths	Women: Number of deaths	Women: Percentage of total deaths	Both sexes: Number of deaths	Both sexes: Percentage of total deaths
Malignant disease	26	33.33	9	15.00	35	25.36
Ischaemic heart disease	24	30.77	13	21.67	37	26.81
Other heart disease	2	2.56	7	11.67	9	6.52
Chronic bronchitis	8	10.26	2	3.33	10	7.25
Pneumonia	5	6.41	7	11.67	12	8.70
Cerebrovascular accident	9	11.54	15	25.00	24	17.39
Genito-urinary	1	1.28	1	1.67	2	1.45
Alimentary	—	—	1	1.67	1	0.74
Other infection	1	1.28	1	1.67	2	1.45
Accident, poison, violence	1	1.28	3	5.00	4	2.90
Dead but not traced by Registrar General	1	1.28	1	1.67	2	1.45
Totals	78		60		138	

similar to those in the Annual Report of the Registrar General for Scotland (1971) in that the commonest cause of death with the sexes combined is heart disease followed by, in descending order of frequency, malignant disease, cerebrovascular accident and bronchitis. Sex differences in the sample are similar to those reported by the Registrar General. Heart disease, malignant disease and bronchitis are more frequent causes in men and cerebrovascular accident in women. Relative frequencies of principal cause of death in Scotland in 1971 and in the sample are compared in Table VI. It is interesting

Table VI. Relative frequency of some causes of death in Scotland 1971 and in the Sample

Cause of death	Percentage frequency: Scotland 1971	Percentage frequency: Sample
Heart disease	34.5	33.33
Malignant disease	20.7	25.36
Cerebrovascular accident	16.2	17.39
Accident, poison, violence	4.8	2.90
Bronchitis	4.2	7.25
Pneumonia	3.7	8.70

that in 26 men who died from malignant disease the sites were bronchus 14, alimentary tract eight and genito-urinary tract four. In nine women, sites were breast four, alimentary tract four and genito-urinary tract one. Bronchogenic carcinoma was an important cause of mortality in the sample.

Methods Used in Tracing Subjects

1. Practitioners were asked to allow a review examination. If the subject had moved or gone to another doctor, the practitioner could sometimes give details. After obtaining permission, the subject was offered an appointment by letter and a reply-paid card was enclosed.
2. Subjects who kept postponing an appointment or whose answers on the card were equivocal or who failed to reply were visited by one of us (J.C.). This visit often resulted in acceptance.
3. The Executive Council and, later, the General Practitioner Service of the Lothian Health Board were often able to tell the Research Unit the name of the subject's new doctor. The practitioner was then asked to allow an examination and could supply the subject's new address.
4. Sometimes, a new address not available from the above steps was obtained from the National Health Service Central Register.
5. In a few cases other methods were successful. If a street had been demolished, Edinburgh Corporation House Department could supply a new address. One subject thought to be dead was found in a mental hospital by one of us (J.S.M.) with a service commitment there. Information about patients was sometimes supplied spontaneously by general practitioners. Some subjects notified us, of their own accord, of change of address. On two occasions, former neighbours could give information. The electoral register was used only at the time of the original examination in tracing some subjects who were difficult to contact.
6. If none of these actions revealed the subject's address, the Registrar General for Scotland was kind enough to search his records to find out if the subject had died. This search was much easier if the National Health Service Number was available. These numbers were recorded when the sample was drawn in 1968 but at that date were not always known to the Executive Council. Some deaths were found by scanning the death columns of *The Scotsman*.

Methods Used to Improve Cooperation

Attempts were made in the study to minimize difficulties for those who took part. Transport by motor car was offered to all and usually accepted. Meals were provided if the examinations clashed with mealtimes. Most people had at least a cup of tea during their visit to the hospital. Subjects were only brought to the hospital once per review. An investigator who did not see the subject then made a home visit rather than recall the subject to the hospital. Subjects were examined in the evening or at week-ends if such times were most convenient to them.

Originally it was intended to examine the sample once a year. The one-year review suggested this was too frequent and the next review was made four years later. During this interval it was necessary to keep in touch with the people in the sample. This was done by sending each a Christmas card each year and by sending a simple postal questionnaire one year after the one year review. The questionnaire asked four questions about health and was accompanied by a letter announcing the delay in further review. Sixty-six per cent of subjects originally examined returned the questionnaire, which is a smaller proportion than those examined at the one-year review (82 per cent) but a greater one than the five-year figure of 54 per cent. Twenty-two persons (4.5 per cent) answered the questionnaire having refused the one-year review and 13 persons (2.7 per cent) did not reply but attended the five-year review. The people in the sample appreciated the Christmas cards. Many took to sending cards to the staff of the research unit and others expressed their pleasure when next examined. Immediately before the five-year review a slip was enclosed with the Christmas card saying the review was imminent.

The same investigators (physician and psychiatrist) have examined the sample throughout the study. This has helped since many of the subjects now regard them as old friends. The other investigators took part in the original examination only.

Discussion

The value of longitudinal study is now accepted. Parnes (1972) pointed out that some types of variables cannot be measured retrospectively, particularly those which are subject to change over time and can be ascertained only by objective measurement by someone other than the respondent. Sussman (1964) regarded longitudinal design as providing the most sensitive method of confirmation of hypothesis concerning change.

In the present study, the approach to the persons studied has been through the general practitioner. Although there is wide variation in success by this method (Table II) it is more satisfactory than an approach by an unheralded investigator. Where the observers in this study made first contact with the subjects themselves, in those few cases where the general practitioner was unwilling to help, their success rate was around 50 per cent. Ethical difficulties would arise if the practitioners were not involved since longitudinal studies discover persons with diseases previously unknown. If the investigator has a service commitment such cases can be investigated in the hospital, provided the practitioner agrees. This avoids the feeling that the study is causing extra work for the practitioner. The present observers found their general-practitioner colleagues helpful in approaching subjects initially, in tracing them for review and in notifying deaths. Cooperation was enhanced by holding meetings at the hospital to which all participating practitioners were invited. In addition to being kept informed of progress and results of the survey their comments were sought. The importance of the practitioners' support was clear in the present study where unwittingly antagonizing one practice out of 50 was responsible for 14 per cent of all failures at the five-year review.

The response rate in the original examination in the present study was 65 per cent. Gordon *et al.* (1959) recorded a response rate of 68.8 per cent in the Framingham study and noted a poorer response in older people. At a six-year follow-up, these workers examined 86 per cent of the original respondents with 2.7 per cent of deaths. The remainder were known to be alive. In the present study at a five-year follow-up 82 per cent were examined again or had died, the residue being alive. Allowing for the greater age of subjects in the present study, the results seem comparable. A difference is that in Framingham the refusal rate was similar in the sexes. Riegel *et al.* (1967) in a study of socio-psychological factors of ageing included in their sample 304 persons, with equal numbers of each sex, aged 60 years upwards. After five years, 50 per cent were re-examined, 20 per cent were dead, 21 per cent refused and 9 per cent were too ill for testing. The present study had proportionately more deaths and fewer refusals from illness, but figures for the other groups are similar. The Framingham study found repeated postponement more common than outright refusal. The present authors confirm this and have sometimes converted repeated postponement to frank refusal by visiting the subjects concerned.

The refusal rate was higher in women than in men in each of the three examinations. Although in the five-year review the proportions of men and women examined were equal, this anomaly is the resultant of the greater death-rate in men and the greater refusal rate in women. The reason for refusal was often not known. Refusals by relatives (seven in all) on behalf of the subjects occurred at the one-year review only. Illness of a relative was offered as a reason once at each review. Carrington (1970) regarded failure to respond to the second contact as the largest single cause of loss from his study.

One cause of refusal in the one-year review was that the initial examination had been too long. This was mentioned by five women but almost certainly affected more. Looking back it does seem that four-hours' examination in hospital by three observers and a further two hours at home on separate days with two others was excessive. Investigators should be ruthless in pruning studies to a size acceptable to their subjects. 'While we are at it we may as well do . . .' is a dangerous maxim. Analysis of data from initial examination enabled information collected in the reviews to be restricted to that most likely to be fruitful. It would have been better to do this with larger pilot studies before the longitudinal study began.

Migration was a minor cause of loss of respondents in the present study although some investigators found it a serious cause of attrition (Carrington, 1970; Dallas, 1971). Carrington found only 8 per cent of his migrants to be of 65 years or over. Douglas & Blomfield (1956) showed how a study on a national scale offsets the effect of migration.

Methods of follow-up have to be appropriate to the area of the study. Chung (1971) in the U.S.A. found the telephone the most useful instrument for follow-up while in Edinburgh only a minority of older people have a telephone. Sims (1973) tracing younger persons used methods similar to those in the present study in respect of National Health Service sources and records of death but also employed letters to the present occupier of a subject's previous address, the telephone directory, the electoral register and a visit to the former address.

In the present study, transport by motor car was essential to success. Many subjects would otherwise have needed two buses to reach the hospital. Dallas (1971) also found transport essential in a study of children in the U.S.A. Douglas & Blomfield (1956) kept interest alive in their study of children by sending accounts of findings to the health visitors and letters of appreciation to mothers. The present authors believe their Christmas cards to have been welcomed. Dunn & Paul (1966) commented on the advantage to the subjects in their study in the Hawthorne works of discovery of a new disease. In the elderly the converse may well be true that the participants are glad to know no new disorder has emerged. Reports on examinations were sent promptly to subjects' practitioners and in many cases information regarding hearing aids etc. was acceptable.

A frustrating aspect of longitudinal study is the later realization of errors of design. The subjects in this study were too few. Life tables show that in ten years the sample is likely to be reduced to 73 men and 116 women. These figures for survivors do not allow for refusal. After ten years there may be too few persons to obtain statistically significant results. since standard errors will be large. It would also have been wise to use a random sample stratified for age rather than a simple random one to obtain sufficient persons in the oldest age-groups. This would have improved, for example, regressions on age.

The present sample is too small for studies of prevalence and incidence of any but the commonest diseases, e.g. ischaemic heart disease. It has, however, proved adequate for the study of many measurements. It might have been better to study two samples. A large one of several thousand people with minimum examination would have provided prevalence and incidence figures about disease. Detailed measurements could have been made on a smaller group such as the present sample, although measurements such as height need large samples to fill the cells in the extremes of the table.

The present authors hope that this account of their successes and failures may be of help to others planning longitudinal studies of older people.

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5

AGE AND AGEING

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FACTORS ASSOCIATED WITH MORTALITY IN OLDER PEOPLE

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Summary

A random sample of older people from Edinburgh (215 men and 272 women aged 62–90 years) was examined clinically and by a questionnaire. Various measurements were made. Five years later, mean values of measurements were compared in those who had died and in survivors. Where significant differences occurred, regression techniques were used to separate age and mortality effects. Variables in which death was the predominant independent variable in the regressions were body weight, bi-iliac diameter, $FEV_{1.0}$, transverse chest diameter, index of kyphosis, leucocyte ascorbic acid and some nutrient intakes in men plus transverse cardiac diameter and leucocyte ascorbic acid in women. Apart from index of kyphosis in men and cardiac diameter in women, mean values were significantly larger in survivors. Dichotomous variables from questionnaire and examination significantly related to mortality were 'possible' ischaemic heart disease in women, diastolic hypertension in men, persistent cough in men and dyspnoea worse than grade 2 in men and women. Cigarette smoking had no mortality effects in this study.

INTRODUCTION

The project from which the present paper is derived is a longitudinal study of older people which has been carried on in Edinburgh since 1968. Although the subjects in the study have now been examined on three occasions, the material used here is based on the initial and hence cross-sectional examination.

The aims of the study were to assess physical and mental health in a random sample of the older population and to determine the range of certain measurements in older people. At the first examination made in 1968–9, each subject was interviewed using a semi-structured questionnaire to record past medical history and past and present symptoms of physical health. After the interview a full clinical examination was made. This included measurements detailed below.

Five years after the initial examination, a follow-up of all subjects, described in detail elsewhere (Milne & Chopin 1975), allowed each to be classified as alive or as having died during the five years. The present paper reports the relationship between death during the five years and data recorded at the initial examination.

Materials and Methods

The random sample examined was obtained as follows. In 1968 there were 91 doctors in 50 general practices with surgery addresses in a defined area of Edinburgh, composed of ten city wards. The National Health Service lists of these doctors contained a total of 27000 persons born in

1905 or earlier. From this total a simple random sample was examined of 487 persons divided into 215 men and 272 women aged 62–90 years. Details of sampling with a comparison of respondents and non-respondents have been given elsewhere (Milne, Maule & Williamson 1971).

Measurements made and used in the present analysis included systolic and diastolic (phase 4) blood pressures measured with a London School of Hygiene sphygmomanometer, and one-second forced expiratory volume and forced vital capacity measured with a Vitalograph spirometer. The ratio $FEV_{1.0}/FVC\%$ was calculated for each subject. Transverse cardiac diameter was measured from a chest radiograph. Body weight was recorded using a lever balance accurate to the nearest 100 g. Standing height and sitting height were measured with a Harpenden stadiometer. Arm span was measured with a wall-mounted caliper. Other anthropometric data recorded were bi-acromial and bi-iliac diameters with a Harpenden anthropometer, circumferences of upper arm and calf with a steel tape and skinfold thickness with a Harpenden caliper, the sites being biceps, triceps, subscapular and supra-iliac. Antero-posterior and transverse chest diameters and intercondylar diameters of humerus and femur were measured with the anthropometer. Handgrip was measured with the Arthritis and Rheumatism Council modified sphygmomanometer cuff and a mercury manometer. Variables related to the skeleton which were recorded included X-ray density of the radius compared with a metal wedge, metacarpal cortical thickness (Milne & Lonergan 1977), an estimate of wedging in vertebral bodies (Milne & Lauder 1976), and an index of kyphosis (Milne & Lauder 1974). Indices calculated were span : height ratio, thoracic index, androgyny score (Tanner 1951) and weight : height ratios—the appropriate ones in Edinburgh being W/H^2 in men and W/H in women, where W is body weight and H standing height.

Biochemical and haematological variables recorded were haemoglobin, packed cell volume, mean corpuscular haemoglobin, white cell count, plasma urea, serum uric acid, serum alkaline phosphatase acid and (log) leucocyte ascorbic acid (Milne et al. 1971). Information about diet and physical activity was collected by historical methods in respect of energy expenditure, energy intake, and intakes of protein, fat, carbohydrate, calcium, iron, vitamin A, thiamine, riboflavin, nicotinic acid, vitamin C, vitamin D and pyridoxin.

The prevalences of angina pectoris, previous myocardial infarction and intermittent claudication were obtained with Rose's questionnaire (Rose 1962). The presence of probable and possible ischaemic heart disease was determined by the method of Reid et al. (1966). The presence or absence of hypertension was recorded by dividing subjects into two groups in respect of systolic and diastolic blood pressure. The systolic groups were those with pressures less than 160 mmHg and those with pressures of 160 mmHg or more. The diastolic groups were those with pressures less than 100 mmHg and those with pressures of 100 mmHg or more. Also recorded were the prevalences of systolic and diastolic murmurs.

The MRC Questionnaire on Respiratory Symptoms (1965) was used to estimate the prevalences of persistent cough, persistent phlegm and dyspnoea worse than grade 2. Present cigarette smoking or its absence was recorded. Cataract was noted if any lenticular opacity was present.

The data collected were stored on magnetic tape in the Edinburgh Regional Computing Centre. After five years a further variable was added to record each subject as being either dead (coded as 0) or surviving (coded as 1). Death had occurred during the five years in 78 of the 215 men and 60 of the 272 women. Age effects were apparent in death since 34 (27.9%) of 122 men aged less than 70 years at entry to the study had died compared with 44 (47.3%) of 93 men aged 70 years and over ($P<0.005$). In women, 16 (11.7%) of 137 younger women had died compared with 44 (32.6%) of 135 older women ($P<0.001$). There is also a sex difference since significantly greater proportions of men compared with women died in both younger ($P<0.001$) and older ($P<0.05$) groups.

Results

1. Data from measurements

Mean values of the measurements listed above were calculated in men and in women for the dead and for survivors. The mean values were compared in each sex in dead and survivors using the two-tailed t test. Significant differences were found in 33 measurements in men and in 16 in women. These differences were likely to be affected by age and possibly to have a prognostic value in relation to death. In an attempt to separate these two possible effects, regression techniques were used.

The computer programme, used to calculate the regressions was the Statistical Package for the Social Sciences (SPSS: Nie et al. 1975). This programme can calculate stepwise regressions and will include a dichotomous variable such as that for death (0) and surivial (1) described above. For each of the 49 variables mentioned above where the *t* test showed a significant difference in mean values betwen dead and survivors, the variable was regressed first on age and then on 'death'. The calculation was repeated first on 'death' and then on age.

These multiple regressions showed that in 17 of the 33 dependent variables in men the coefficient of regression of the dependent variable on death was greater than the coefficient of regression on age. In two of the variables the levels were equal.

Eight of the 19 variables (upper arm and calf circumferences, four skinfold thicknesses, intercondylar diameter of humerus and the bulk index W/H^2 where W is body weight and H is standing height) had a high correlation with body weight and have been omitted from Table I which gives details of the regressions.

Table I. Significance levels of coefficients of regression on age and on death, and multiple correlation coefficients in respect of 13 dependent variables (11 in men and 2 in women)

Dependent variable	*Significance levels of coefficients of regression on*		*Coefficients of correlation with*		
	Age %	*Death* %	*Age*	*Death*	*Age and death*
Men					
Body weight	N.S.	0.1	0.04	0.29	0.29
Bi-iliac diameter	N.S.	0.1	0.11	0.19	0.25
$FEV_{1.0}$	N.S.	0.1	0.13	0.35	0.36
$FEV_{1.0}/FVC\%$	N.S.	1	0.01	0.22	0.22
Trans. chest diam.	N.S.	5	0.06	0.16	0.16
Index of kyphosis	5	1	0.17	0.18	0.23
(Log) leucocyte ascorbic acid	N.S.	0.1	0.01	0.24	0.25
Protein intake	0.1	0.1	0.23	0.20	0.28
Iron intake	0.1	0.1	0.23	0.26	0.32
Thiamine intake	N.S.	5	0.13	0.15	0.18
Vitamin C intake	N.S.	5	0.09	0.17	0.18
Women					
Transverse cardiac diam.	5	0.1	0.14	0.23	0.25
(Log) leucocyte ascorbic acid	1	0.1	0.20	0.24	0.28

N.S. = not significant.

A further examination of mean values of body weight in men is given in Table II. Similar mean weights were found in survivors with and without known ischaemic heart disease. Mean values of body weight in men who had died were smaller, although not always significantly so, than those of survivors and varied little whether the certified cause of death was malignant disease, ischaemic heart disease or all causes other than

Table II. Mean values with standard errors (S.E.) of body weight in various groups of dead and surviving men

	Surviving (S) or dead (D)	Mean	S.E.	N
Ischaemic heart disease				
present	S	71.04	1.79	47
absent	S	70.61	1.20	90
Death certified as due to:				
ischaemic heart disease	D	65.06	2.49	25
cause other than ischaemic heart disease	D	62.52	1.62	49
malignant disease	D	63.95	2.30	25

ischaemic heart disease combined. No estimate is available of the prevalence of malignant disease in survivors.

The relationship between forced expiratory volume and the index of kyphosis was examined in men with the correlation coefficient. In the whole group of men, the coefficient was -0.20 ($N=213$, $P<0.01$), the interpretation being that the greater the degree of kyphosis the smaller is $FEV_{1.0}$.

Table I also gives details of two out of the 16 variables, examined by regression in women, where death was the predominant independent variable in the regression (i.e. in respect of significance and correlation coefficient).

All mean values of significant variables in both sexes were greater in survivors compared with the dead with two exceptions. These were transverse cardiac diameter in women and the index of kyphosis in men. The latter index is larger when kyphosis is greater. Details of these mean values with standard deviations are given in Table III for dead and surviving men and women.

Table III. Mean values, with standard deviations (S.D.) of variables significantly related to mortality in dead and surviving men and women

Variable	Dead			Survivors		
	Mean	S.D.	N	Mean	S.D.	N
Men						
Body weight (kg)	63.4	11.69	74	70.8	11.65	137
Bi-iliac diameter (mm)	296.9	15.62	76	303.5	16.41	137
$FEV_{1.0}$ (ml)	1727	749.6	72	2260	682.6	136
FEV/FVC%	63.6	16.57	72	70.4	13.20	135
Trans. chest diameter (mm)	275.9	16.95	76	282.3	20.11	137
Index of kyphosis	12.10	3.62	76	10.94	2.67	137
(Log) leucocyte ascorbic acid	1.156	0.314	74	1.316	0.304	130
Protein intake (g)	68.6	16.90	75	75.8	16.27	137
Iron intake (mg)	10.4	3.03	75	12.0	2.73	137
Thiamine intake (mg)	0.87	0.22	75	0.94	0.21	137
Vitamin C intake (mg)	28.8	15.67	75	34.4	15.87	137
Women						
Trans. cardiac diameter (mm)	136.6	17.46	53	128.5	12.68	204
(Log) leucocyte ascorbic acid	1.240	0.295	51	1.414	0.288	196

2. Data from the questionnaire and clinical examination

These data were examined with the χ^2 test for 2×2 contingency tables. No significant difference emerged between dead and surviving men or women in prevalences of angina pectoris, previous myocardial infarction, intermittent claudication and systolic or diastolic murmurs. The presence of probable or possible ischaemic heart disease showed no mortality difference in men, although in women the prevalence of possible ischaemic heart disease was greater in those who had died. There was no difference between the dead and the survivors in the prevalence of systolic hypertension in either sex or of diastolic hypertension in women. In men, 14 (58%) had died out of 24 with diastolic hypertension, compared with 63 (33%) of 190 without ($P < 0.05$).

Persistent cough showed a significantly greater prevalence in men who had died, but not in women, while the prevalence of persistent phlegm showed no difference between the groups in either sex. Dyspnoea worse than grade 2 was present in a significantly larger proportion of the dead in both sexes. Cigarette smoking showed no effects on mortality in men or in women.

Cataract was present in a greater proportion of dead compared with surviving women but no such effect was found in men.

The possible effect of age was examined by dividing men and women into those less than 70 years and those of 70 years and over at entry to the study. The χ^2 tests were repeated in these groups.

In men persistent cough was significantly more prevalent in dead compared with survivors in the younger group only. Dyspnoea greater than grade 2 was significantly more prevalent in the older group of dead men only. In women, the significantly greater prevalence of severe dyspnoea in the dead in the whole group of women, disappeared when the women were divided into two age groups but the prevalence remained larger in dead compared with survivors.

The greater prevalence of possible ischaemic heart disease in the whole group of dead women persisted after separation into two age groups. This was also true of cataract in women but this diagnosis showed no mortality effect in men in any group.

Discussion

There have been relatively few studies in the elderly of examination findings later related to survival. Those already published were reviewed by Hodkinson & Exton-Smith (1976). These authors themselves followed up 852 persons aged 65 years or more who were examined in the nation-wide Nutrition Survey of the Elderly (1972) in 1967–8. They selected variables related to survival, as did the present authors, using the t test on continuous variables and χ^2 on binomial variables. Further treatment of their data differed from that in the present study. They used survival as the dependent variable in multiple regressions in men and in women where the independent variables were those found to be related to survival by the t test or χ^2. Variables not contributing significantly to the regressions were deleted. This study corresponds more closely with the present study than any other published work. Similarities and differences in the findings will emerge in this discussion.

The present study has shown that the mean weight of dead men was significantly less than the mean weight of surviving men. No such effect was found in women. Sourander, Ruikka & Kasanen (1970), in a five-year follow-up of the aged in Finland, concluded that weight had no prognostic value. So did Hodkinson & Exton-Smith (1976) in the United Kingdom. On the other hand, Libow (1971) reported findings similar to those of the present study in an eleven-year follow-up of elderly men. The latter study was of healthy elderly men and Libow suggested that the weight effect might result from the exclusion of men with obesity or hypertension. The present study of a random population sample, with no deliberate exclusions, reported a similar weight effect.

The mean body weight of men certified as dying of ischaemic heart disease in the present study was less than in surviving men with this disease (Table II). The difference may reflect the known tendency of patients to lose weight in the late stages of chronic heart failure. The mean value of body weight in men certified as dying of ischaemic heart disease was similar to that of men who died of malignant disease. These two causes accounted for 50 of 78 deaths. The remaining 28 deaths contained too few ascribed to any one cause for comparisons to be made.

Anderson & Cowan (1976), when calculating regressions to predict survival time after attendance at a consultative clinic, found weight made no contribution to the regression. On the other hand the mean weight of their men (62.7 kg) was similar to that of dead men in the present study and people attending a consultative clinic are selected in a manner other than random.

Bi-iliac diameter is technically a difficult measurement to make since in a fat person the anthropometer cannot easily reach through subcutaneous tissue to the iliac crests. The greater value of the bi-iliac diameter in male survivors in the present study may reflect their greater body weight compared with the dead.

The lower values of $FEV_{1.0}$ and FEV/FVC% found in men who died in the present study are presumably related to the greater prevalence in men of chronic respiratory symptoms. Probably this is also the reason for the lesser transverse chest diameter found in dead men. The negative correlation between $FEV_{1\cdot0}$ and the index of kyphosis in men probably also reflects the changes in shape of the thorax in chronic respiratory disorders. Anderson and Cowan found the kyphotic angle, which is a similar measurement to the index of kyphosis in the present study, increased (i.e. kyphosis was greater) as survival time in their study decreased in both men and women.

Gilmore (1975), examining the dead and survivors in a three-year longitudinal study of elderly people living at home, found no difference in the two groups in the proportions taking less than the recommended amounts of protein, potassium, calcium, iron, thiamine, riboflavin, or vitamins C or D. In the present study significantly lower mean intakes were found, in dead compared with surviving men, of protein, iron, thiamine and vitamin C. In both sexes the mean (log) leucocyte ascorbic acid was significantly lower in the dead. It is possible that mortality is associated with subclinical malnutrition, which does not otherwise seem to have overt effects in the United Kingdom (Nutrition Survey of the Elderly 1962, Lonergan et al. 1975). Comparison of mean intakes in the present study, in dead and survivors, with recommended daily intakes showed values less than the recommended intake of vitamins C and D in dead men of 70 years and over and of riboflavin in dead and surviving men of 70 years and over. In women less than the recommended intakes were found, in dead and surviving women of all ages, for iron, riboflavin, vitamin C and vitamin D. There is therefore some evidence in the present study of an association between lower dietary intakes and mortality.

Hodkinson and Exton-Smith found only reduced intakes of pyridoxin and vitamin C and lower serum pyridoxin and leucocyte ascorbic acid levels as nutritional factors adverse to survival. Of these, only vitamin C intake in men and serum pyridoxin in women contributed significantly to the regressions. In the present study lower vitamin C intake was an adverse factor in men as were lower leucocyte ascorbic acid levels in both sexes. The present study was done in Edinburgh and reported lower vitamin C intakes than any area in the Nutrition Survey of the Elderly except the northern ones (Sunderland, Rutherglen, Angus). The agreement about low vitamin C intake in men between the present study and that of Hodkinson and Exton-Smith suggests this finding may be of real significance. The findings in Edinburgh in respect of leucocyte ascorbic acid strengthen this view.

The only measurement in women, apart from (log) leucocyte ascorbic acid mentioned above, which was associated with mortality was transverse cardiac diameter. This had a larger mean value in dead women compared with survivors. It has already been shown elsewhere that this observation is associated with heart disease in older women (Lauder & Milne 1976). Sourander et al. (1970) reported a higher mortality in persons of both sexes with an 'enlarged heart' as measured from a chest radiograph.

Mean values of systolic and diastolic blood pressures in the present study did not differ in those who died and those who survived. If subjects were arbitrarily divided in respect of systolic ($\geqslant 160$ mmHg) and diastolic ($\geqslant 100$ mmHg) hypertension, only diastolic hypertension in men was significantly associated with mortality. Sourander et al. (1970) and Hodkinson and Exton-Smith found no correlation between blood pressure or hypertension and mortality. Anderson and Cowan found blood pressure of no value in predicting survival time. By contrast Libow found mean systolic blood pressure significantly lower in surviving men. Kitchin & Milne (1977) using data from the present study found systolic hypertension in a significantly greater proportion of deaths due to ischaemic heart disease.

Variables indicative of ischaemic heart disease in the present study showed no difference in prevalence between dead and survivors except for the category of 'possible' ischaemic heart disease in women. For this variable the prevalence was greater in those who died. Ischaemic heart disease is common in the elderly. Data from the present study revealed a prevalence in the whole sample of 18% probable and 28% possible ischaemic heart disease (Kitchin, Lowther & Milne 1973). The possibility that the androgyny score might prove to be higher in men with ischaemic heart disease was suggested by the present study (Milne 1972). Five-year follow-up has not shown any relationship between this score and death. Although ischaemic heart disease was an adverse factor revealed by χ^2 in the study by Hodkinson and Exton-Smith, it did not contribute to the regressions. The association of persistent cough with mortality in younger men is probably due to chronic bronchitis. There was no prognostic association between cough and bronchogenic carcinoma in men in the present study. Deaths from bronchogenic carcinoma in men numbered 14 and from other malignant disease 12 (Milne & Chopin 1975) but the prevalence of cough did not differ significantly in these groups. It seems reasonable that the more severe grades of dyspnoea should have been more prevalent in the groups who died.

Cataract was more prevalent in women who died in the present study and this finding was not related to age. There is no obvious explanation of this but the information has been recorded for future comparison with other studies.

For obvious reasons increasing age would be expected to be associated with an increasing proportion of deaths in a study of the elderly. Such a relationship is found in the present study. Anderson and Cowan found age to be one of the two important variables isolated by them in equations to predict survival time. Age was the most powerful factor reported by Hodkinson and Exton-Smith. By contrast, Gilmore found no such association in her longitudinal study of the elderly.

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6

COMPARISON OF TEACHING MACHINE WITH AN OBSERVER IN DETECTION OF ANGINA PECTORIS BY QUESTIONNAIRE

BY

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COMPARISON OF TEACHING MACHINE WITH AN OBSERVER IN DETECTION OF ANGINA PECTORIS BY QUESTIONNAIRE

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History-taking machines are now in use in health surveys (Mayne, Weksel, and Sholtz, 1968; Slack, Hicks, Reed, and Van Cura, 1966) or their use is suggested (Edwards, 1970). It seems, therefore, worth while to compare history taking by machine with a standard questionnaire administered in the ordinary way.

METHOD

The Geriatric Research Unit in Edinburgh uses a teaching machine (tm 1024 Educational Systems Ltd.) with an attached general purpose data-collecting system (ts 512) for psychological testing. A comparison has been made, using Rose's (1962) questionnaire on angina pectoris, of questions asked by this machine with questions asked in the ordinary way.

The questionnaire was put on coloured film. The first frame displayed 'the pictures you are going to see will ask you questions. You answer each question by pressing RED or BLUE. Each picture will explain which colour you press in your reply. Now press RED'. The capitals represent large red and blue buttons on the teaching machine by means of which dichotomous responses are made. The second frame said 'After this picture the questions begin. Now press BLUE'. These two frames served to familiarize the subject with the machine and to show whether the procedure had been understood.

Succeeding frames carried Rose's questions 1 to 5 exactly as published. Questions 6 and 7 were altered as described below. Question 8, concerning pain other than precordial, and question 9, concerning consultation with a doctor about the pain, were not asked. Each frame offered alternative replies in the form of 'If yes press RED, if no press BLUE'. The machine was programmed to pass steadily through the questionnaire unless the subject pressed a button for an answer which in the published questionnaire would cause the observer to ask no more questions and reject the diagnosis of angina; the machine then displayed a frame saying 'End of Questions'. Question 6 was altered to 'How soon is it relieved?' and was, of course, not asked unless question 5 was answered 'Relieved'. To obtain answers to question 7 concerning the site of the pain, 'Will you show me where it was?', three frames were needed, each of which on a diagram showed a possible pain site and asked 'Do you feel it here?' The film, therefore, as far as possible asks Rose's questions as published but explains on each frame what the alternative answers are.

All persons to whom the questionnaire was administered in the ordinary way were questioned by one observer (J.S.M.) who used the training material supplied by Rose and tested reproducibility before beginning the study (Milne, Hope, and Williamson, 1970).

The subjects examined were men and women aged 63 years and upwards forming a random sample of older people living in a defined area of Edinburgh and taking part in a longitudinal study. This sample has been fully described elsewhere (Milne, Maule, and Williamson, 1971). The investigation described was performed in the second (annual) examination of the longitudinal study. Two hundred and nine men and 244 women took part.

During the first examination all subjects were asked the questions in the ordinary way. One year later subjects were assigned at random to two groups. The first was asked Rose's questions in the ordinary way. The other was questioned by the teaching machine. From the replies can be given the prevalence of angina at the first examination, and the incidence between first and second examinations can be calculated.

Replies fall into three groups: (1) to the ordinary questions, (2) to the machine, and (3) to the ordinary questions when the machine was not in working order or could not be used. This machine was an early model, now obsolete, which easily went out of order and as there was no service engineer in Scotland repairs were inevitably delayed. The machine could not be used on home visits, necessitated by illness, or in blind people. These reasons for not using the machine cannot certainly be said to be random, so although bias from this reason

TABLE I

PREVALENCE OF ANGINA PECTORIS AT FIRST EXAMINATION (BY ORDINARY QUESTIONNAIRE) DISPLAYED IN GROUPS USED AT SECOND EXAMINATION

Group Used on Second Occasion	Angina at First Examination			Z	P
	Present	Absent	% Present		
Males					
Questionnaire	14	91	13·3	0·90	> 0·05
Machine	6	62	8·8		
Machine not usable	5	29	14·7	0·84	> 0·05
Females					
Questionnaire	15	118	11·4	0·53	> 0·05
Machine	6	61	9·0		
Machine not usable	4	35	10·3	0·22	> 0·05

seems unlikely the results are reported under the three headings.

RESULTS

The prevalence of angina at the first examination was 25 of 207 (12·1%) men and 25 of 239 (10·5%) women. Two men and five women were demented and could not answer the questions. Table I shows the prevalence of angina at the first examination in these men and women classified in the groups in which they were examined on the second occasion.

This shows that the prevalence of angina at the first examination is distributed in similar proportions for each sex in the three groups used at the second examination. All men and women found to have angina at the first examination were removed from the study and Table II shows the incidence of angina between the first and second examinations in those free of angina at the first examination.

The percentages in column 3 show a higher incidence of angina in men and women using the teaching machine. This incidence is significantly different from that found by questions asked in the ordinary way and from questions asked in the ordinary way because the machine was not usable. The exception is in comparing 'machine' and 'machine not usable' in men where Z is 1·70 and P > 0·05. However, the group of 'machine not usable' consisted of only 29 men, so that confidence limits are larger.

TABLE II

INCIDENCE OF ANGINA PECTORIS BETWEEN FIRST AND SECOND EXAMINATIONS

	Angina			Z	P
	Present	Absent	% Present		
Males					
Questionnaire	5	86	5·5	2·87	< 0·01
Machine	13	49	21·0		
Machine not usable	2	27	6·9	1·70	> 0·05
Females					
Questionnaire	2	116	1·7	3·17	< 0·01
Machine	8	53	13·1		
Machine not usable	0	35	0	2·22	0·01 < P < 0·05

DISCUSSION

The prevalence of angina at the first examination in this study is 12·1% in men and 10·5% in women. Brown, Davidson, McKeown, and Whitfield (1957) reported a prevalence of 6% in men of the seventh decade. Droller and Pemberton (1953), in a random sample of 476 elderly people, reported disabling angina in 6·5% of men and women, with a larger percentage of milder symptoms. Reid, Holland, Humerfelt, and Rose (1966), in postal workers aged 40 to 59 years, reported a prevalence of 4%. Rose (1968) found a prevalence at the initial examination of 3·8% in men aged 35 to 59. Taking account of the increasing prevalence of angina with age, it seems that the prevalence at the first examination in the present study is consistent with other reported studies.

The present study reports an annual incidence of angina in men of 5·5% detected by questionnaire, of 6·9% by questionnaire (machine not usable), and of 21% by teaching machine. The annual incidence reported by Rose (1968) in men aged 35 to 59 varied from 1·0 to 3·6%, and that reported by Paul *et al.* (1963) in men aged 40 to 45 was 0·5%. Stamler *et al.* (1960) reported a 1·5% incidence of all coronary heart disease in men aged 50 to 59. Chapman *et al.* (1957) found an incidence of all coronary heart disease of 2·9% in men aged 55 to 70. The present study has a one-year incidence of angina in women of 1·7% detected by questionnaire and 13·1% by teaching machine. These figures suggest that in both men and women use of the teaching machine led to a falsely high incidence of angina between the first and second examinations. We consider that the fault is in the machine estimate rather than in that of the oral questionnaire because the questionnaire has been carefully validated (Rose, 1962; Rose and Blackburn, 1968) and in the present study care was taken to use the oral questionnaire in the way advised by Rose.

All through the questionnaire on film each frame offers alternative answers, with 'yes' or other positive equivalent always the upper alternative. A subject who becomes 'set' on this button will go through the whole questionnaire and emerge labelled angina positive. The high false positive results from the teaching machine may therefore be an example of a phenomenon known to psychologists as response set. Eysenck (1970), discussing scales of authoritarianism, says 'many subjects respond in a stereotyped manner regardless of the content of the question asked. Thus an acquiescent person might tend to reply with "yes" to all questions in a questionnaire regardless of their content. As all the items in the authoritarian scale are worded in such a way that "yes" answers are in the authoritarian direction, it is not impossible that the test might measure acquiescence rather than authoritarianism'. The principle here described in the particular case of authoritarianism applies in general to all similarly constructed questionnaires. Vernon (1964), discussing validity, says 'the common element running through a set of intercorrelated tests may be a response set rather than the presumed trait'.

A fundamental difference between Rose's questions asked in the ordinary way and by the teaching machine is that while all 'yes' (or equivalent to 'yes') answers on the machine are in the angina direction, only the first three of Rose's questions asked in the ordinary way have 'yes' in the angina direction. The other questions asked in the ordinary way invite a reply which cannot be literally 'yes' or 'no' and the possible replies are not indicated by the questions. As an example, 'If you stand still what happens to it?' The machine says 'If RELIEVED press RED. If NOT RELIEVED press BLUE', and a person set on the red button still replies in the angina direction. The question asked in the ordinary way does not indicate any answer as being in the angina direction and the subject has to think of his reply. Response set seems less likely with questions asked in the ordinary way. It is easy to see why Rose insists that the questions should be asked exactly as published without changing a word.

The importance of response set at a time when investigators are turning to visual display to ask questions can be shown from the literature. Slack *et al.* (1966), in the Multiphasic Checkup of the Permanente Medical Group, displayed a series of questions on a screen beneath which the possible responses 'yes', 'no', 'don't know', and 'don't understand' were listed one above the other numbered 1 to 4, and the subject answered by pressing one of four numbered keys. Answers were fed into a computer. The authors reported that in 50 subjects investigated for a history of allergy by this method and separately investigated by a physician in the ordinary way, computer and physician agreed in respect of 13 people. The computer obtained a positive history in 22 people not found positive by the physician. In this system the history taking is flexible in that 'yes' leads to a qualifying question and 'no' stops the particular line of questions and leads to a further general question. These results resemble those reported in the present study.

Also, in the Permanente Medical Group, Collen *et al.* (1964) described self-administered questioning by sorting prepunched I.B.M. cards into a divided letter box with middle section 'yes' and bottom section 'no'. Mayne *et al.* (1968), in the Mayo Clinic, collected data before interview by a physician using a display terminal on which the patient recorded his responses by means of an electronic light pen, but although the system was flexible with 'branching' techniques of questioning, all 'first-level' questions were of a fixed-choice type. Difficulty may arise even with self-administered questionnaires. Brodman and van Woerkom (1966), using a Medical Data Index based on the Cornell Medical Index (before examination by a physician), asked patients to circle 'yes' or 'no' after each question. Physicians diagnosed 2·9 diseases per patient and the Index 3·8 diseases per patient. Physicians, commenting on the 0·9 disease excess of the Index, said that in 0·4 no information was available as to whether the disease was present and that in 0·5 the disease was known not to be present. All these symptoms offer alternative answers apparently with the order of presentation fixed. Edwards (1970), in a paper describing a carefully worked out flow diagram to investigate dysphagia, with 'yes'–'no' responses, mentioned a teaching machine on-line to a computer as a means of using the system but was careful to warn that an experienced doctor is needed to interpret the results. Concerning the teaching machine he noted the 'significant proportion of patients who will not answer the question asked even if they can read it', a comment which confirms the authors' experience among older people.

When the questionnaire for the present study was put on film, the authors were unaware of the dangers of using a technique where 'yes' was in a constant position. From the literature it appears that however well known response set may be to psychologists, it is less well recognized by physicians, in which case the present study offers a warning. It would be possible to programme the machine so that the blue button was used as 'yes' rather than 'no' in some of the frames. Further study would be needed to determine whether this improved the results or, in old people, caused confusion.

Conclusion

While histories collected by machines and processed by computers may eventually help the doctor to save time, the present authors' experience among older people and a brief survey of the literature suggest that care is needed in validating these methods before using them.

Summary

Results are presented comparing the incidence of angina pectoris determined by Rose's questionnaire used by one observer with that determined by a teaching machine using the same questions on film. The machine produces a falsely high incidence, due probably to a cause well recognized by psychologists. Evidence is presented from the literature to show that this may affect results in surveys using history-taking machines.

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The Use of Medical Services by Older People

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Introduction

The information given in this paper about the use of Medical Services by Older People was collected in the first examination in a longitudinal study of ageing persons being carried out in Edinburgh. The subjects studied formed a random sample, of persons aged 62-92 years, from a defined area of Edinburgh. There were 215 men and 272 women drawn from a population of 27,000 older people on the lists of 91 doctors working in 50 general practices. The method of sampling has been fully described elsewhere with a comparison of respondents and nonrespondents (Milne, Maule and Williamson, 1971).

Method

Information was collected by one of us (J.S.M.) from all subjects, at an interview using a semi-structured questionnaire followed by detailed clinical examination. A full history was taken regarding admission to hospital, out-patient care, operative surgery and use of general practitioner services.

Validation of Method

Of 487 persons from 50 practices who took part in the whole survey, 55 were drawn from three practices. The practice records were inspected in 49 of the 55 persons. Of the remaining six, two were dead, one had left the country and the records could not be found in three.

Using letters from hospitals in the practice records all hospital contacts were listed, both inpatient and outpatient, which had occurred between 1948 and the date of the examination in the Research Unit (1968 or 1969). These contacts were classified under the diagnostic headings used in this paper and are listed in Table I. The totals sum the experience of the 49 subjects. It can be seen that subject and doctors' record agrees in 76 episodes and that in 40 episodes the doctors' record is not matched by a statement from the subject. In a further 18 episodes, a convincing history by the subject reported a hospital episode not found in the letters in the doctors' record. Hence the total number of episodes of hospital contact reported by 49 subjects is 94 and by their doctors 116. Although this part of the study shows under-reporting of hospital care by older people, the remainder of this paper reports the findings about the use of medical services without correction for such under-reporting.

Table I

Hospital contacts reported by 49 older men and women compared with general practice records

Diagnosis	Subject's statement and doctors record agree	Diagnosis in doctor's record only	Diagnosis in patient's statement only
Cardiovascular	6	3	1
Urinary	4	3	0
C.N.S.	0	3	0
Stroke	0	0	1
Mental Illness	1	2	0
Alimentary (except neoplasm)	18	6	6
Respiratory (except tuberculosis or neoplasm)	4	1	1
Malignancy	3	0	0
Tuberculosis	1	0	0
Infective	1	0	0
Prostatic	2	0	0
Gynaecological	12	2	2
"Rheumatic"	11	7	2
Diabetes	0	0	0
Injury	6	1	3
E.N.T.	1	2	1
Eye	4	7	1
Dermatological	0	3	0
Endocrine	2	0	0
Other	0	0	0
	76	40	18

Table II

Use of hospital throughout life in men and women aged 62 years and upwards. (Percentages).

Number of episodes	Total use =outpatient and admission combined		Admissions		Outpatient attendance	
	Men	Women	Men	Women*	Men	Women
0	3.3	8.5	14.4	21.7	43.3	38.6
1	18.1	19.9	27.9	25.7	27.4	35.7
2	21.4	22.0	20.5	26.5	18.1	15.1
3	18.6	16.2	13.0	8.8	5.6	5.5
4	12.6	12.1	10.2	5.5	2.8	0.7
5	9.8	7.4	4.2	5.1	0.5	1.8
>5	14.9	11.8	8.4	4.4	0.9	0.4
No information	1.4	2.2	1.4	2.2	1.4	2.2
N	215	272	215	272	215	272

*Excludes obstetric admissions.

Table III

Use of hospital during the previous 5 years in men and women aged 62 years and upwards. (Percentages).

Number of episodes	Admissions		Outpatient attendance	
	Men	Women	Men	Women
0	58.6	61.4	65.1	62.1
1	25.6	26.5	23.3	27.2
2	12.1	6.6	7.9	5.5
>2	2.3	3.3	2.3	2.9
No information	1.4	2.2	1.4	2.2
N	215	272	215	272

Standardisation for Age

The mean age of all men in the sample was 70.01 years and of all women 71.35 years. The population used for standardisation was the random sample as it was drawn from the population before any changes due to refusal, death or change of address, had occurred. This sample contained 370 persons aged 62-69, 276 persons aged 70-79 and 102 persons aged 80 years and over. It has been shown to have no significant difference from the Edinburgh Sample Census of 1966 (Milne, Maule & Williamson, 1971). Standardisation did not affect the crude rates for use of medical services. For example the standardised rates for outpatient attendance in the previous 5 years were 33.6% for men and 36.1% for women, the crude rates being 34.9% and 37.9% respectively.

Analysis of Data

Data are reported as percentages, the totals of men and women from whom the percentages are derived being given in the tables. Differences in prevalence were tested using the binomial theorem.

Total Hospital Contact

Numbers of admissions and of outpatient attendances recorded in the interview were summed to give a figure of total hospital episodes which is shown as percentages in columns 1 and 2 of Table II. Outpatient attendance which subsequently led to admission was counted as admission only. Attendance as an outpatient over a period was counted as one episode provided that period was unbroken by any discharge from further attendance. 3.3% of men and 8.5% women have no hospital history. Significantly fewer women than men have a history of contact with hospital in this sample.

Admission to Hospital

In Table II columns 3 and 4 give the percentages of men and women admitted to hospital at some time during life, related to the number of admissions. 14.4% of men and 21.7% of women have not been in hospital. Significantly more men than women have been admitted to hospital at some time during life. This excludes obstetric admissions.

Table III, columns 1 and 2, shows for both sexes in the sample the number of hospital admissions in the last 5 years. There is no apparent sex difference in these admissions, 41.4% of men and 38.6% of women having been admitted to hospital.

Outpatient Attendances

Columns 5 and 6 in Table II give percentages of men and women attending hospital as outpatients at any time during life. 43.3% of men and 38.6% of women have not attended as outpatients. The sex difference is not significant. The greater overall contact with hospital by men seems therefore to be related to admission rather than outpatient attendance.

The numbers of men and women attending hospital as outpatients in the last 5 years are shown in Table ~~II~~, columns 3 and 4. 65.1% of men and 62.1% III of women have not been outpatients in the last 5 years and again there is no significant difference between the sexes.

Table IV

Reason for use of hospital at any time during life in men and women aged 62 years and upwards. (Percentages give proportion of all men or all women with each diagnosis).

Diagnosis	Admission		Outpatient attendance	
	Men	Women	Men	Women
Cardiovascular	14.9	10.3	6.0	6.3
Urinary	7.9	1.8	3.3	0.7
C.N.S.	2.8	1.8	1.9	0.7
Stroke	1.9	2.2	0.5	0
Mental Illness	2.8	3.3	0.9	0.4
Alimentary (except neoplasm)	43.7**	29.4**	10.7	11.8
Respiratory (except T.B. or neoplasm)	18.1**	7.7**	7.4	1.8
Malignancy	3.7	2.6	2.3	1.5
Tuberculosis	4.2	2.9	1.4	0
Infective	11.6*	5.5*	2.8	1.1
Prostatic	6.5	—	0	—
Gynaecological	—	31.6	—	2.2
"Rheumatic"	6.5	9.2	11.6	16.5
Diabetes	0.9	0.7	0.9	1.8
Injury	20.5**	11.8**	18.6	16.5
E.N.T.	8.8	6.6	7.0	5.1
Eye	0.9	5.1	5.6	9.9
Dermatological	5.1	2.6	4.7	4.8
Endocrine	0	2.6	0	1.1
Other	3.3	3.7	1.9	2.2
No information	1.4	2.2	1.4	2.2
N	215	272	215	272

Sex difference significant at 1% level **
5% level *

Table V

Surgical operations throughout life and in the last 5 years in men and women aged 62 years and upwards. (Percentages).

Number of operations	Throughout life		In the last 5 years	
	Men	Women	Men	Women
0	34.8	36.8	79.4	79.0
1	33.4	29.8	15.7	16.9
2	16.2	17.3	3.6	0.7
3	6.0	7.0	0	1.5
4	3.2	4.4	—	—
>4	5.0	2.9	—	—
No information	1.4	1.8	1.4	1.8
N	215	272	215	272

Table VI

Reasons for operation at any time during life in men and women 62 years and upwards. (Percentages give proportion of all men or all women with each operation).

Operation	Males	Females
Abdominal (excl. gastrectomy)	38.5	23.5
Gastrectomy	3.7	0.4
Genitourinary	12.1	33.1
Orthopaedic	11.6	10.3
E.N.T.	10.2	6.3
Eye	0.9	3.7
Thoracic	0.9	0.4
Neurosurgical	0	0.4
Other	10.7	14.0
No information	1.4	1.8
N	215	272

Table VII

Diagnostic reasons for various consultations with practitioners in older people. (Percentages).

Diagnosis	Last consultation with doctor		Reason for regular consultation with doctor		Reason for illness in bed last year	
	Men	Women	Men	Women	Men	Women
Cardiovascular	14.2*	23*	11.2*	18.8*	1.9	1.8
Urinary	0.9	2.3	0	0.7	0	1.1
C.N.S. (not stroke)	4.2	4.5	2.8	2.6	2.3	0.7
Stroke	1.9	1.5	1.9	0.7	1.9	0.7
Mental	1.4	5.3	0.9	2.9	0	0.4
Alimentary (except neoplasm)	10.8	8.7	2.3	2.9	1.9	2.9
Respiratory (except T.B. and neoplasm)	25.9**	11.7**	7.0	1.1	17.2*	10.3*
Malignancy	1.4	0.8	0.5	0.7	0.9	0.4
Tuberculosis	0.5	0.4	0.5	0	0	0
Infective	1.9	1.9	0	0	0.9	0
Prostatic	1.4	—	0	—	0.5	—
Gynaecological	—	1.9	—	0.4	—	0.4
"Rheumatic"	16.9	16.6	1.9	8.5	1.4	4.4
Diabetes	0.9	1.1	0.9	1.1	0.5	0
Injury	5.2	6.0	0.5	1.5	0	2.6
E.N.T.	3.8	3.4	0	0	0.5	0.4
Eye	2.8	3.4	0	0	0	0.4
Dermatological	4.7	2.3	0.9	1.5	0	0.4
Endocrine	0	1.5	0	1.5	0	0.7
Other	0.9	3.8	0	0.4	0	0
No information	1.4	2.6	1.4	2.6	1.4	2.6
N	215	272	215	272	215	272

Sex difference significant at 1% level **
5% level *

Reasons for Use of Hospital

The diagnostic categories leading to the use of hospital are given in Table IV. The percentages of men and women in the sample admitted to hospital for these reasons are given in columns 1 and 2. The commonest reasons for admission were alimentary, respiratory, cardiovascular, gynaecological and injury.

The percentages of men and women who had attended as outpatients in the various categories are given in columns 3 and 4 of Table 4. The commonest reasons for outpatient attendance were alimentary, "rheumatic" and injury.

Surgical Operations

Table V details the percentages of men and women in the sample who have had surgical operations throughout life and in the last 5 years. The part played by operative surgery in modern society is shown by the facts that two thirds of men and women in the sample have had an operation at some time in life and one fifth have had an operation in the last 5 years. Just over 30% of men and women in the sample have had more than one operation at some time and just under 3% have had more than one operation in the last 5 years. The reasons for operation given in Table VI. The commonest operations are abdominal, genitourinary, orthopaedic and ear, nose and throat. Although numbers are small, gastrectomy is much commoner in men than women while the trend is reversed in eye surgery. The greater proportion of men compared with women having had abdominal surgery is significant.

Use of General Practitioner Service

The interviewing doctor collected information from the subjects about this with details of interval since the subject's practitioner was last consulted, reason for that consultation, whether the practitioner was consulted regularly and if so why, whether the subject had been confined to bed by illness in the previous year and if so for how long and with what condition.

Seventy five per cent of men and 85% of women had been attended by their doctors within the previous year. Regular consultation with the doctor for some chronic complaint was admitted by 46% of women and 31% of men in the sample. In both cases, the higher figure in women was significant. Confinement to bed by illness during the previous year had occurred in 30% of men and 28% of women. In most of these the illness had lasted less than 28 days. Table VII gives percentages of men and women in the various diagnostic categories who made use of the general practitioner service. The commonest reasons for the last consultation with the doctor were cardiovascular, respiratory, alimentary and "rheumatic". The commonest reason for regular consultation was cardiovascular disease although six times as many men as women needed regular attention for respiratory disease and four times as many women as men for "rheumatic" troubles. Respiratory disease was the most important cause of illness causing confinement to bed in the previous year in both sexes.

Discussion

It is difficult to estimate the value of information, about the use of medical services, gathered in a survey. The material gathered in this report was obtained from persons using the comprehensive health service in Scotland. In the age groups examined the service is free, so that no financial barrier makes access difficult for the observer. Since almost all persons are on the lists of doctors practising in the Health Service, it is possible to obtain a random sample of the population for study.

The difficulty in assessment is therefore in respect of reliability of replies rather than of extrapolation from sample to population. In the present study doctors' records show that subjects under-report 34% of hospital episodes (inpatient and outpatient) occurring in 20 years. On the other hand, the filed hospital letters in general practitioners' records under-record 19% of hospital episodes described by the subjects. Palmer, Kasap, Bennett and Holland (1969) in a study of hospital usage in Lambeth recorded a tendency for subjects to over-report hospital usage. Their figures for persons of 55 years and over placed 91% of men and 80% of women as replying correctly about hospital usage in the previous six months. Saunders (1959) in a study of hospital admission in the previous 12 months by survey and by hospital records found 8.4% of recorded hospital episodes not reported in the survey and 6.5% of episodes reported in the survey not recorded by the hospital. Previously Belloc (1954) in San Jose, California, in a survey seeking information about hospital admission in the preceding 12 months compared with hospital records found 13.5% of recorded admissions not reported by the survey and 10.8% of reported admissions not recorded by the hospital. Solon, Sheps, Lee and Barbano (1962) in Beth Israel Hospital, Boston, found both under- and over-reporting of usage of outpatient clinics. The U.S. National Health Survey (1965a) found in persons of 65 years and over, with diagnostic categories of episodes which were "most threatening", "somewhat threatening" and "non-threatening" under-reporting of 33%, 16% and 17% respectively. Hospital episodes, excluding deliveries, were under-reported by 18% of persons aged 65-74 and 14% of persons 75 years and over. The U.S. National Survey (1965b) also found that 87% of the episodes of hospitalisation under the care of H.I.P. Physicians during the study year were reported by the respondents on household interview. The same survey recorded "of the persons for whom physician services were noted on the med 10's in the year preceding household interview, 81% were reported to have had their last doctor contact within this period." The present study has not validated the replies to "When did you last consult your doctor?" but the above information suggests answers should be fairly reliable.

Ferguson and MacPhail (1954) found increasing hospital usage by men with increasing age while in women the figure remained relatively constant. The present study shows greater overall hospital usage by men.

The U.S. National Health Survey (1965a) gave as percentages under-reporting in particular diagnostic categories. Examples are mental disorder 32%, C.N.S. and sense organs 17%, heart disease 13%, peptic ulcer 19% and dermatological 19%. These figures are not comparable statistically with but show the same trend as the present study. Belloc (1954) confirms the under-reporting of mental disorder and eye trouble.

Summary

Percentages are used to assess the use of medical services in a random sample of 215 men and 272 women aged 62 and upwards and living in Edinburgh. Almost all persons of this age in Edinburgh make use of the comprehensive, and to them, free health service. Only 3.3% of men and 8.5% of women have had no hospital contact during life.

14.4% of men and 21.7% of women have not been admitted to hospital during life. 58.6% of men and 61.4% of women have not been admitted in the last five years. 43.3% of men and 38.6% of women have not attended as outpatients during life. 65.1% of men and 62.1% of women have not attended as outpatients in the previous five years. Men have significantly greater hospital contact during life than women. The commonest reasons for admission are alimentary, respiratory, cardiovascular, injury and gynaecological. Common reasons for outpatient attendance are alimentary, "rheumatic" and injury. Two thirds of men and women have had an operation at some time in life. One fifth of men and women have had an operation in the last five years. The commonest types of surgery are abdominal, genito-urinary, orthopaedic and ear, nose and throat.

75% of males and 85% of females in the sample had had contact with general practitioners in the previous year. 46% of women and 31.4% of men consult the doctor regularly. Almost 30% of men and women had had an illness in bed in the previous year. Common reasons for asking advice are cardiovascular, respiratory, alimentary and rheumatic disease. Women make significantly more use of the general practitioner service than men.

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RESPIRATORY FUNCTION TESTS IN OLDER PEOPLE

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SUMMARY

1. Forced expiratory volume in ml ($FEV_{1\cdot 0}$) and forced vital capacity (FVC) were measured in a random sample of older people (215 men, 272 women) aged 62 years and upwards.

2. Multiple regression equations were calculated to predict these variables by using age and height. In contrast with younger groups most of the variance was not explained by these equations.

3. The equations developed predict lower values for $FEV_{1\cdot 0}$ and FVC than other published series most of which contain relatively few older people.

Key words: respiratory function, aged.

A recent review of the literature on normal lung function (Cotes, 1968) reveals the shortage of information available on this subject in older people. Data for young and middle-aged subjects are freely available but for the elderly the information tends to form a small part of series covering large age ranges (Needham, Rogan & McDonald, 1954; Berglund, Birath, Bjure, Grimby, Kjellmer, Sandgrist & Söderholm, 1963). One widely used nomogram for normal values in males extrapolates to age 90 years from a series containing nineteen subjects over 60 years and none over age 66 years (Kory, Callahan, Boren & Syner, 1961). It seemed therefore that respiratory function tests would form a useful part of a longitudinal study of older people being carried on in Edinburgh. The present paper reports the results of such tests performed at the first examination of 215 men and 272 women aged 62–90 years who formed a random sample of 27 000 older people living in a defined area of the city. The method of sampling has been described elsewhere (Milne, Maule & Williamson, 1971) with a comparison of respondents and non-respondents.

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METHODS

The tests were the one second forced expiratory volume ($FEV_{1\cdot0}$) and the forced vital capacity (FVC) performed on a Vitalograph spirometer. This instrument was reported suitable by Drew & Hughes (1969) for measuring $FEV_{1\cdot0}$ and FVC in population studies covering normal subjects and those with obstructive airways disease. Tests were performed with subjects sitting. Five determinations were made, the first two being rejected (Cotes, 1968). Height was measured with a Harpenden stadiometer. Subjects were questioned by using the M.R.C. Questionnaire on Respiratory Symptoms (1965). All testing and questioning was done by one observer (J.S.M.).

Reproducibility of the tests was examined by the observer before the survey began. Tests were performed in ten subjects on two separate occasions. The mean differences between paired readings of $FEV_{1\cdot0}$, FVC and height and the standard deviations of these differences are reported in Table 1. Reproducibility of answers to the questionnaire were also studied (Milne, Hope & Williamson, 1970).

TABLE 1. Reproductibility of tests used

Test	Mean of first readings	Mean of second readings	Mean difference	SD of mean difference
$FEV_{1\cdot0}$ (ml)	3576	3617	41	128
FVC (ml)	4532	4574	42	105
Height (mm)	1723·0	1721·5	1·5	5·5

The Vitalograph was calibrated against a piston and cylinder which had itself been calibrated by water displacement. Volumes registered by the Vitalograph were 6% too large for volumes between 1000 ml and 3000 ml and 12% too large for a volume of 500 ml. The results in this paper have not been corrected for these differences.

RESULTS

The results were examined by standard statistical methods (Snedecor & Cochran, 1967). $FEV_{1\cdot0}$ and FVC are reported as the mean of three readings in each subject. For each subject the $FEV_{1\cdot0}$ was calculated as a percentage of the FVC ($FEV_{1\cdot0}\%$).

Mean values

Mean values with standard deviations and numbers of subjects from whom these statistics are derived are given in Table 2 for $FEV_{1\cdot0}$, FVC and $FEV_{1\cdot0}\%$. The mean values for the three variables decrease with age in women, but such a decrease in men is less obvious. The regression of each of the three variables on age in men and in women is given in Table 3. The age difference in $FEV_{1\cdot0}$ in men is not significant, but the decrease with age in women is significant at the 1% level. The decrease in FVC with age is significant at the 5% level in men and at the 1% level in women. No significant age change in $FEV_{1\cdot0}\%$ was found in men but the decrease with age in women is significant ($P<0{\cdot}05$).

Multiple regression equations

These were calculated in the manner usually employed in younger people, namely $FEV_{1\cdot0}$ and FVC on age and height, and $FEV_{1\cdot0}\%$ on age alone. The results are given in Table 4. Equations have been calculated for three groups in each sex, the groups being those without persistent cough and phlegm, those with persistent cough and phlegm and the two combined.

TABLE 2. $FEV_{1\cdot0}$, FVC and $FEV_{1\cdot0}\%$ in older men and women (volumes at B.T.P.S.)

Age	Mean	$FEV_{1\cdot0}$ (ml)			FVC (ml)			$FEV_{1\cdot0}$/FVC(%)		
	age	Mean	SD	*n*	Mean	SD	*n*	Mean	SD	*n*
Men										
62–69	65·4	2179	774	121	3166	875	120	68·6	14·1	120
70–79	73·9	1922	719	70	2848	837	70	66·9	16·5	70
80+	83·9	1971	507	17	2889	696	18	68·9	10·8	17
All men	70·0	2075	747	208	3035	862	208	68·0	14·7	207
Women										
62–69	66·0	1632	486	134	2028	555	135	80·5	10·1	134
70–79	74·3	1432	458	91	1804	531	90	80·5	13·1	89
80+	84·1	1017	399	21	1446	418	20	73·5	16·8	20
All women	71·3	1505	501	246	1898	563	245	79·9	12·1	243

TABLE 3. Regression of respiratory function tests on age in older men and women

Test and sex	Mean of respiratory function test	a (constant)	b (age)	SE b	Mean age	d.f.	*t*	*P*	SE around regression
Men									
$FEV_{1\cdot0}$	2087·9	+3076·80	−14·170	8·263	69·79	203	1·71	N.S.	741·5
FVC	3047·2	+4464·83	−20·314	9·468	69·79	203	2·15	<0·05	849·6
$FEV_{1\cdot0}\%$	68·04	+64·27	+ 0·054	0·165	69·79	203	0·33	N.S.	14·77
Women									
$FEV_{1\cdot0}$	1519·8	+3793·56	−32·445	5·198	70·14	235	6·24	<0·01	460·0
FVC	1901·2	+4271·10	−33·832	5·939	70·14	235	5·70	<0·01	525·5
$FEV_{1\cdot0}\%$	79·99	+99·73	− 0·282	0·136	70·14	235	2·07	<0·05	12·06

No attempt was made to subdivide the sample in respect of smoking habits, since only 7·9% of the men were non-smokers, the value in women being 73·2%. Predicted values for men and women without symptoms and without considering smoking habits are given in Fig. 1 for $FEV_{1\cdot0}$, in Fig. 2 for FVC and in Fig. 3 for $FEV_{1\cdot0}\%$. Figs. 1 and 2 show the respiratory function variable on the ordinate, height (mm) on the abscissa with lines to allow prediction of

TABLE 4. Multiple regression of respiratory function tests on age and height in older men and women with and without respiratory symptoms

	Mean of respiratory function test	b_1 (age in years)	Mean age	b_2 (height in mm)	Mean height	Constant a	SEE b_1	SEE b_2	SE around regression	r	n	Age range	Intercept difference ± SE*
$FEV_{1\cdot0}$													
Men: no cough and phlegm	2224·5	−13·695	70·52	+3·615	1675·4	−2866·7	8·398	0·762	642·9	0·41	137	62–90	69±5·9
Men: cough and phlegm	1812·7	−8·518	68·31	+4·278	1664·9	−4727·7	17·933	1·625	723·0	0.36	68	62–85	50±4·8
All men	2087·9	−7·415	69·79	+4·022	1671·9	−4118·3	7·795	0·715	691·1	0·38	205	62–90	63±3·9
Women: no cough and phlegm	1559·7	−24·279	69·87	+2·244	1544·4	−209·66	5·347	0·458	427·4	0·46	215	62–89	64±3·8
Women: cough and phlegm	1129·1	−18·909	72·73	+2·548	1543·6	−1429·4	14·885	1·566	441·2	0·48	22	64–89	75±8·4
All women	1519·8	−26·399	70·14	+2·219	1544·3	−55·477	5·086	0·450	438·6	0·47	237	62–89	65±3·6
FVC													
Men: no cough and phlegm	3126·6	−16·097	70·52	+5·486	1675·4	−4929·9	9·093	0·825	696·2	0·52	137	62–90	114±8·8
Men: cough and phlegm	2887·3	+2·192	68·31	+7·514	1664·9	−9772·0	20·568	1·872	832·9	0·47	68	62–85	95±9·0
All men	3047·2	−10·211	69·79	+6·015	1671·9	−6296·2	8·425	0·773	747·0	0·50	205	62–90	108±6·6
Women: no cough and phlegm	1925·9	−24·096	69·87	+2·905	1544·4	−876·68	6·070	0·520	485·3	0·47	215	62–89	80±5·5
Women: cough and phlegm	1660·0	−21·024	72·73	+5·056	1543·6	−4615·6	17·727	1·864	525·4	0·61	22	64–89	103±17·0
All women	1901·2	−25·423	70·14	+3·057	1544·3	−1036·6	5·686	0·503	490·3	0·49	237	62–89	89±5·2
$FEV_{1\cdot0}\%$													
Men: no cough and phlegm	70·92	−0·007	70·52	—	—	+71·38	0·182	—	14·02	0·003	137	62–90	—
Men: cough and phlegm	62·24	−0·208	68·31	—	—	+76·44	0·336	—	14·70	0·08	68	62–85	—
All men	68·04	+0·054	69·79	—	—	+64·27	0·165	—	14·77	0·02	205	62–90	—
Women: no cough and phlegm	81·03	−0·247	69·87	—	—	+98·28	0·131	—	10·79	0·13	215	62–89	—
Women: cough and phlegm	69·74	+0·100	72·73	—	—	+62·47	0·609	—	18·78	0·04	22	64–89	—
All women	79·99	−0·282	70·14	—	—	+99·73	0·136	—	12·06	0·13	237	62–89	—

* Add to predict from best of three readings.

normal values at four different ages. Fig. 3 includes age, but not height, against $FEV_{1\cdot0}\%$. In Fig. 3 the line for men is included for completeness only since no age effect is present.

The alterations in the regressions resulting from the presence of symptoms are shown graphically in Figs. 4, 5 and 6 in respect of $FEV_{1\cdot0}$, FVC and $FEV_{1\cdot0}\%$. To simplify the diagram, lines for two ages (62 and 80) are included rather than four as in previous figures.

For $FEV_{1\cdot0}$ the effect of symptoms in both men and women appears to be a decrease in the predicted value. The slope of the regression line is similar to that for persons without symptoms.

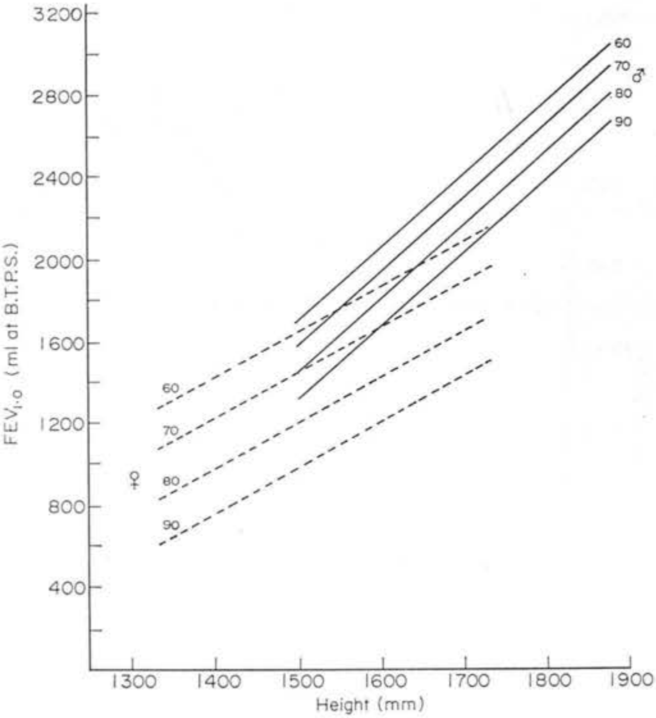

FIG. 1. Regressions of $FEV_{1\cdot0}$ on age and height in older men and women without respiratory symptoms.

The lines for age are closer together in both sexes in persons with symptoms. For FVC in both sexes the slope of the regression line is steeper in persons with symptoms. The lines for different ages are slightly closer together in women with symptoms than in persons without symptoms but in men with symptoms the lines are very close together. The regression coefficient for age in men with symptoms is positive and the coefficient for height and the constant are such that older men have slightly larger values of FVC than younger men. The standard deviation around the regression is, however, so large that little significance can be attached to this in the present sample. The predicted values for $FEV_{1\cdot0}\%$ are lower with symptoms than without symptoms in both sexes (Fig. 6). None of the regression coefficients for $FEV_{1\cdot0}\%$ on age in either sex in persons with and without symptoms differs significantly from zero.

Comparison of multiple regression equations based on the mean of three and the best of three readings

The difference between the best of three and the mean of three readings was computed in each subject in respect of $FEV_{1\cdot 0}$ and FVC. This difference was then regressed on age and height in men and women separately for those without symptoms, for those with symptoms and for the two groups combined. None of the regression coefficients differed significantly from zero. In

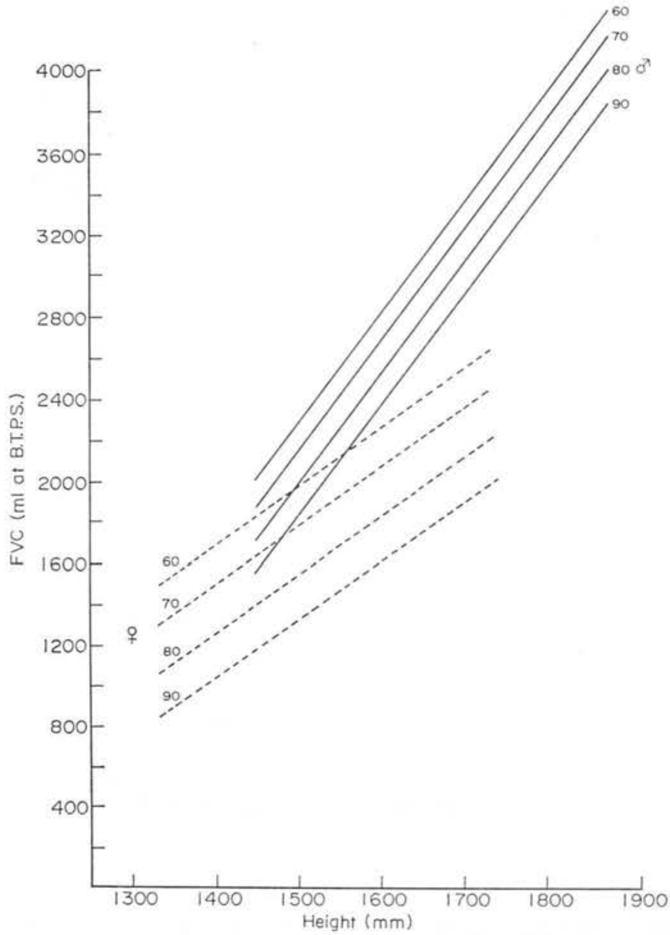

FIG. 2. Regressions of FVC on age and height in older men and women without respiratory symptoms.

effect this means the regression lines for the best of three readings can be regarded asparallel to the regression lines for the mean of three readings already computed. The predicted value for the best of three readings can be computed from the predicted value for the mean of three readings by adding the difference between the intercepts of the regression lines. This difference together with its standard error is given in the last column of Table 4.

The demonstration that the regression lines for mean of three and best of three readings are

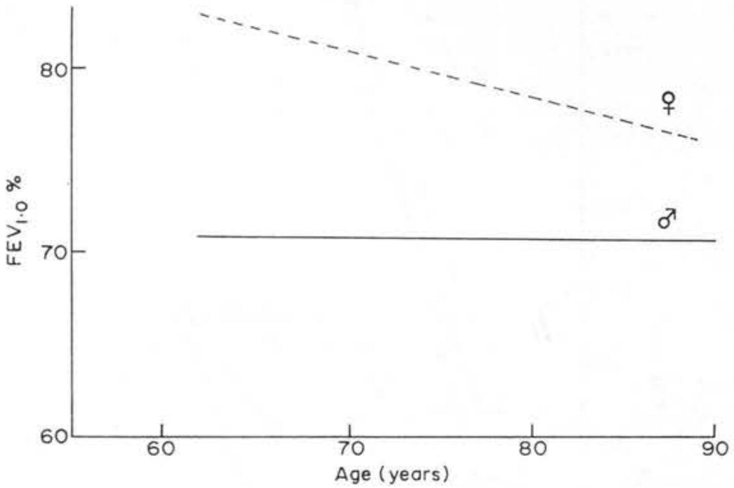

FIG. 3. Regressions of $FEV_{1\cdot0}\%$ on age in older men and women without respiratory symptoms.

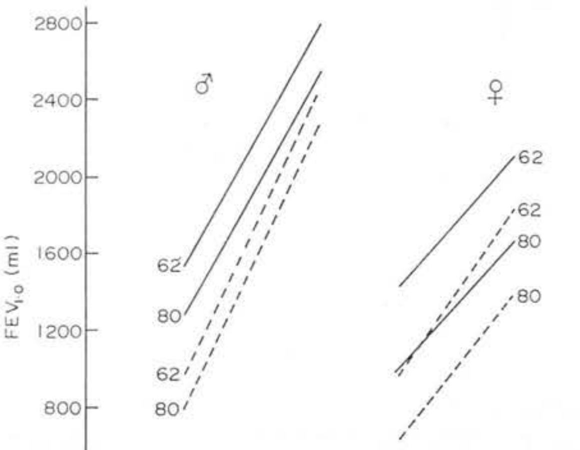

FIG. 4. Regressions of $FEV_{1\cdot0}$ on age and height in older men and women with (----) and without (——) persistent cough and phlegm.

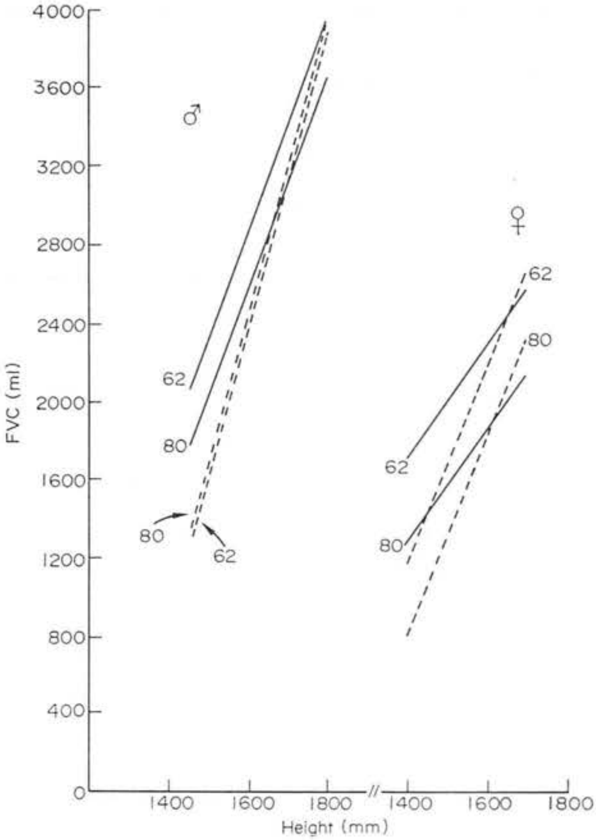

FIG. 5. Regressions of FVC on age and height in older men and women with (– – – –) and without (——) persistent cough and phlegm.

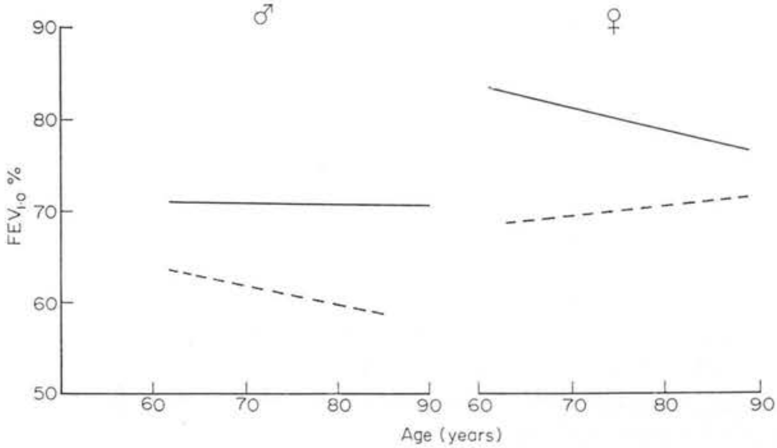

FIG. 6. Regressions of $FEV_{1\cdot0}\%$ on age in older men and women with and without persistent cough and phlegm.

parallel suggests that it is immaterial whether the regression coefficients are calculated from best performance or mean performance results. In fact the variation in best performance in the present study is greater than that in mean performance. This is borne out by the consistently higher standard errors round the regression lines in best performance compared with mean performance results. Since the differences in the intercept values are of the order of 100 ml or less, the difference between mean of three and best of three readings is not of clinical importance.

Stored tables

The following tables have been lodged with the Librarian of the Royal Society of Medicine from whom they are available on request.

(a) Tables 1a, 1b and 1c give frequency distributions of $FEV_{1.0}$ in three age ranges of men and women without symptoms, with persistent cough and phlegm and in these two groups combined (deposited as *Clinical Science* Tables 42/15, 42/16 and 42/17).

(b) Tables 2a, 2b and 2c give the same information for FVC (deposited as *Clinical Science* Tables 42/18, 42/19 and 42/20).

(c) Tables 3a, 3b and 3c give the same information for $FEV_{1.0}\%$ (deposited as *Clinical Science* Tables 42/21, 42/22 and 42/23).

(d) Table 4a, gives mean values and SD of $FEV_{1.0}$, FVC and $FEV_{1.0}\%$ in three age ranges of men and women without symptoms and with persistent cough and phlegm (deposited as *Clinical Science* Table 42/24).

(e) Tables 5a, 5b and 5c give correlation matrices amongst respiratory function tests, age and height in three age ranges of men and women without symptoms, with persistent cough and phlegm and in these two groups combined (deposited as *Clinical Science* Tables 42/25, 42/26 and 42/27).

DISCUSSION

The paucity of data about ventilatory capacity in older people, particularly those over 70 years of age, leaves a gap in the range of normal values. The present study examines results from a large random sample of older people in Edinburgh and may help to fill this gap. The material shows that it is difficult to describe a group of 'normal' older men since 33% of the present sample of men have persistent cough and phlegm and 92% of these men smoke or have smoked. With current smoking habits it is difficult to obtain the large group of elderly male non-smokers without symptoms who would be needed to determine 'normal' values. The sample of older women makes determination of normal values more likely since only 9% have persistent cough and phlegm and only 27% smoke or have smoked. Subdivision was therefore only into groups with and without symptoms but not into smokers and non-smokers.

Although the correlation between age, height and ventilatory capacity has been clearly shown in younger people, the relationship is less clear in older people. If the '*t*' test is used with the present results to examine the regression coefficient for age, the coefficient is found not to be significantly different from zero in any group of men in Table 4 for $FEV_{1.0}$, FVC or $FEV_{1.0}\%$. For women the coefficient for age differs significantly from zero for $FEV_{1.0}$ and FVC except for women with cough and phlegm whose number is only twenty-two. For $FEV_{1.0}\%$ in women the coefficient for age is significant only in the whole group. For height the coefficient is significantly different from zero in all groups of men and women in respect of $FEV_{1\cdot0}$ and FVC except for $FEV_{1\cdot0}$ in women with persistent cough and phlegm.

In older people in the present study when $FEV_{1\cdot0}$ and FVC are regressed on age and height the values of the multiple correlation coefficient (r) are smaller than those reported in younger people. Age and height in older people therefore explain a smaller proportion of the variance than in younger people.

Table 5 gives values for $FEV_{1\cdot0}$, vital capacity (VC) and $FEV_{1\cdot0}\%$ calculated from some of the equations given in the literature and from those derived in the present study for a man

TABLE 5. Values calculated from multiple regression equations for a man of 70 years 1·6 m tall and a women of 70 years 1·5 m tall

	Sex	Reference	Age range	Predicted value	Predicted value (present study)*
$FEV_{1\cdot0}$	M	Cotes *et al.* (1966)	20–64	2·21	1·96
(ml at	M	Kory *et al.* (1961)	18–66	2·37	
B.T.P.S.)	M	Berglund *et al.* (1963)	7–70	2·41	
	M	Ferris *et al.* (1964)	25–74	2·22	
	F	Ferris *et al.* (1964)	25–74	1·59	1·46
	F	Berglund *et al.* (1963)	7–70	1·74	
VC	M	Kory *et al.* (1961)	18–66	3·18	2·72
(ml at	M	Berglund *et al.* (1963)	7–70	3·84	
B.T.P.S.)	M	Needham *et al.* (1954)	20–70	2·73	
	M	Ferris *et al.* (1964)	25–74	2·86	
	F	Berglund *et al.* (1963)	7–70	2·39	1·79
	F	Needham *et al.* (1954)	20–70	1·92	
	F	Ferris *et al.* (1964)	25–74	1·94	
$FEV_{1\cdot0}\%$	M	Berglund *et al.* (1963)	7–70	65·7	70·9
	F	Berglund *et al.* (1963)	7–70	73·8	81·0

* Based on data from subjects without persistent cough and phlegm.

70 years of age 1·6 m tall without symptoms and a woman 70 years of age 1·5 m tall without symptoms. Values for $FEV_{1\cdot0}$ and FVC calculated from the equations in the literature are larger than those predicted from the present study. The Scottish figures of Needham *et al.* (1954) are close to those of the present study.

Seven of the 215 men in the sample and twenty-six of 272 women (three in the age range 62–69, ten in the range 70–79 and thirteen of 80 years or more) were unable to perform the test at all or were unable to provide three readings. The progressive increase in the percentage of women unable to perform the test as age increases is associated with an increasing proportion of older women with dementia. Of a total of twenty-six women who did not perform the tests, ten were diagnosed on psychiatric examination as having dementia.

ACKNOWLEDGMENTS

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Enlarged copies of the nomograms in Figs. 1 and 2 can be obtained on application to the authors.

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9

Respiratory Symptoms and Smoking Habits in Older People with Age and Sex Differences[1]

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Abstract. Using the M.R.C. Questionnaire on Bronchitis and a questionnaire on smoking on a random sample of persons aged 62 and upwards, information was gathered about respiratory symptoms and smoking habits. Cough, phlegm, repeated chest illness and wheeze were commoner in men than in women. Significantly more younger than older men had these symptoms. This age trend was not found in women. Dyspnoea was commoner in women than in men and significantly more older than younger women had the severer grades of dyspnoea.

73% of women and 8% of men have never smoked. A greater proportion of men than women smoke cigarettes and their daily consumption is larger. A lesser proportion of older than younger men and women smoke cigarettes, but a greater proportion of older than younger men smoke pipes. A greater proportion of cigarette smokers than non-smokers in both men and women admit to cough, phlegm, chest illness, admission to hospital with respiratory illness and wheeze. The proportion of men with persistent cough and phlegm increases as cigarette consumption rises.

Key Words
Ageing
Bronchitis
M.R.C. questionnaire

The prevalence of respiratory symptoms and smoking habits has been estimated during the first examination in a longitudinal study of aging persons being carried out in Edinburgh. The subjects were 215 men and 272 women aged 62–90 years who formed a random sample of a population of 27,000 older people living in a defined area of the city. The sampling method has been fully described elsewhere [MILNE *et al.*, 1971], with a comparison of respondents and non-respondents.

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Table I. Respiratory symptoms in older men and

	N	Question No. in M.R.C. Questionnaire						
		5	10	5 and 10	12a	12b/c	21b	
		cough	phlegm	persistent cough and phlegm	chest illness in past 3 years[1]		chest illness in past 3 years[2]	
					1	>1	1	>1
Men								
62–69	122	55 (45)	57 (47)	47 (39)	12 (10)	17 (14)	15 (12)	16 (13)
70+	93	25 (27)	33 (35)	21 (24)	3 (3)	5 (6)	6 (6)	5 (5)
All men	215	80 (37)	90 (42)	68 (32)	15 (7)	22 (10)	21 (10)	21 (10)
Women								
62–69	137	22 (16)	18 (13)	9 (7)	18 (13)	7 (5)	9 (7)	7 (5)
70+	135	22 (16)	24 (18)	16 (12)	17 (13)	5 (4)	13 (10)	8 (6)
All women	272	44 (16.2)	42 (15)	25 (4)	35 (13)	12 (4)	22 (8)	15 (6)
χ^2 Difference between all men and all women		***27.75	***41.98	***38.80	1 and > 1 combined 0.002		1 and > 1 combined 2.92	
Difference between men <70 and $\geqslant 70$		**7.52	2.74	*6.22	**8.53		*6.10	
Difference between women <70 and $\geqslant 70$		0.01	1.23	2.41	0.12		0.91	

1 Chest illness with more phlegm than usual lasting 3 weeks.
2 Chest illness preventing usual activity for one week.

Methods

One observer (J. S. M.) determined symptom prevalence in all subjects using the Medical Research Council Questionnaire on Respiratory Symptoms (1966). Before beginning the survey, this observer used training material supplied by the London School of Hygiene. Smoking habits were recorded by the same observer using a questionnaire which sought details about past and present smoking of cigarettes, pipes and cigars and about tobacco consumption, duration of smoking and years, if any, since smoking ceased. Reproducibility of the questionnaires was tested before the survey began [MILNE *et al.*, 1970].

women (percentage of row total = number in brackets)

Question No. in M.R.C. Questionnaire									
5, 10 and 12 persistent cough and phlegm and chest illness	5, 10 and 21 persistent cough and phlegm and chest illness	15a wheeze, not most days	15b wheeze, most days	16b wheezy attacks with shortness of breath	14a I no dyspnoea	14a II dyspnoea hurrying on level	14b III dyspnoea walking with others	14c IV dyspnoea at own pace	14a other disability prevents dyspnoea grading
15 (12)	18 (15)	40 (33)	29 (24)	15 (12)	40 (33)	64 (52)	5 (4)	10 (8)	–
3 (3)	3 (3)	22 (24)	14 (15)	10 (11)	28 (30)	38 (41)	3 (3)	13 (14)	–
18 (8)	21 (10)	62 (29)	43 (20)	25 (12)	68 (32)	102 (47)	8 (4)	23 (11)	14 (7)
1 –	2 (1)	36 (26)	9 (7)	12 (9)	47 (34)	63 (46)	9 (7)	8 (6)	–
1 –	6 (4)	40 (30)	8 (6)	7 (5)	34 (25)	43 (32)	18 (13)	13 (10)	–
2 (1)	8 (3)	76 (28)	17 (6)	19 (7)	81 (30)	106 (39)	27 (10)	21 (8)	37 (14)
***15.62	**10.01	combined **10.41		3.06	I+II compared with III+IV 1.81				–
*4.57	**8.01	**6.77		0.12	1.83				–
–	–	0.32		1.31	**8.34				–

* Significant at 5-percent level; ** significant at 1-percent level; *** significant at 0.1-percent level.

Results

Respiratory Symptoms

Information from replies to the M.R.C. Questionnaire is summarised in table I. In respect of cough (Q.5), phlegm (Q.10), persistent cough and phlegm (Q.5 and Q.10), persistent cough and phlegm with chest illness in the previous three years (Q.5, Q.10 and Q.12 or Q.21), and wheeze (Q.15), a significantly greater proportion of men have symptoms compared with women. For the same symptoms (except phlegm) and for a history of chest illness in

Table II. Relationship between persistent cough and phlegm and admission to hospital for respiratory disease in older people

Persistent cough and phlegm		Admissions			No data	χ^2
		no	yes	% yes		
Men	no	126	18	12.5	2	
	yes	47	21	30.9		** 10.40
Women	no	226	15	6.2	6	
	yes	19	6	24.0		** 7.63

** Significant at 1-percent level.

the previous three years, not necessarily associated with persistent cough and phlegm, the table shows a significantly greater proportion of men under 70 years of age to have the symptoms compared with men of 70 years and over. This age difference is absent in women. Table II shows that in both men and women, persistent cough and phlegm is associated with a significantly larger number of hospital admissions for a respiratory reason.

Although a history of chest illness in the previous three years is admitted by 17% of men and women (table I), breakdown into those with one and more than one chest illness reveals a trend for a greater proportion of men to have more than one chest illness (10%), compared with one chest illness (7%). In women the trend is reversed, the figures being 13% for one and 4% for more than one chest illness. Occasional wheeze is of equal prevalence in men and women, but regular wheeze is admitted by more men (20%) than women (6%).

Dyspnoea grading (table I) places 79% of the men and 69% of the women in grade I or grade II, i.e. either not breathless on exertion or breathless hurrying on the level or walking up a slight hill. These could be regarded as within the limits of normal in older people. This leaves 14% of men and 18% of women in grade III or grade IV, i.e. breathless with someone of the subject's own age or having to stop when walking at the subject's own pace. 7% of men and 13% of women were unclassified either because of dementia (2 men, 4 women) or because some other disability prevented exertion to cause dyspnoea (12 men, 33 women). If grades I and II combined are compared with grades III and IV combined (table I) there is no sex difference and no age difference in men, but significantly more women of 70 years and over are in grades III plus IV than women under 70 years ($p<0.01$). This age effect is

Table III. Relationship between dyspnoea and other symptoms in older people

Symptom		Men dyspnoea grades I+II	Men dyspnoea grades III+IV	χ^2	Women dyspnoea grades I+II	Women dyspnoea grades III+IV	χ^2
Wheeze	present	75	24		53	31	
	absent	95	7	***11.55	134	17	***21.68
Persistent cough	present	46	19		9	10	
and phlegm	absent	124	12	***14.13	178	38	***11.01

Data are not available in 14 men and 37 women.
*** Significant at 0.1-percent level.

Table IV. Smoking history in older people. Percentages

Sex	Never smoked	Ex-smoker	Present smoker, does not inhale	Present smoker, inhales	% who smoke now	No data	Total (=N)
Men	7.9	28.4	18.1	44.7	62.8	0.9	215
Women	73.2	7.4	9.2	9.2	18.4	1.0	272

in contrast to that reported for other symptoms. Table III shows that for men and women with wheeze and with persistent cough and phlegm, a significantly greater proportion of those with these symptoms are in the group with dyspnoea of grades III and IV.

Smoking Habits

Smoking history is summarised in table IV and type of smoking in table V. 63 % of the men and 18 % of the women smoke at the present time (table IV), the difference being highly significant ($p<0.001$). Women smoke or have smoked cigarettes only and 26 % have done so (table V) at some time. 79 % of men smoke or have smoked cigarettes and only 26 % of men smoke or have smoked pipes (table V). 73 % of the women and 8 % of the men have never smoked.

Table V. Type of smoking in older people. Percentages

Sex	Non-smoker	Cigarettes	Pipe	Cigarettes and pipe/cigars	No data	Total (=N)
Men	7.9	64.7	12.1	14.4	0.9	215
Women	73.2	25.8	0	0	1.0	272

Table VI. Age differences in smoking habits in older men and women. Percentages in brackets

Type of smoker	<70 years		>70 years		χ^2
	smoker	non-smoker	smoker	non-smoker	
Men					
Cigarettes now	76 (63)	45	38 (41)	54	** 9.65
Cigarettes now or formerly	109 (90)	12	61 (66)	31	*** 18.25
Pipe now	16 (13)	105	23 (25)	69	* 4.30
Pipe now or formerly	22 (18)	99	35 (38)	57	** 10.56
Women					
Cigarettes now	37 (27)	99	13 (10)	120	*** 13.45
Cigarettes now or formerly	49 (36)	87	21 (16)	112	*** 14.29

* Significant at 5-percent level; ** significant at 1-percent level; *** significant at 0.1-percent level.

Age differences in smoking habits are given in table VI. A significantly greater proportion of present or former cigarette smokers of both sexes are under 70 years of age rather than of 70 years and over. In men who are present or former pipe smokers, a significantly greater proportion are 70 years or over rather than under 70 years.

Cigarette consumption divided into less than 15g and 15g or more daily is given in table VII. A significantly greater proportion of men compared with women consume 15g or more of tobacco daily at the present time (χ^2 10.08, $p<0.01$). A similar result is found in ex-smokers (χ^2 11.14, $p<0.001$). The proportion of present smokers consuming 15g or more daily is greater in

Table VII. Consumption of cigarettes in older men and women

Type of smoker	Tobacco consumption				No data	Totals
	cigarettes, g/day		pipe only	none		
	<15	≥15				
Men						
Ex-smoker	16	40	5	–		
Present smoker	54	60	21	–		
Never smoked	–	–	–	17	2	
Total	70	100	26	17	2	215
Women						
Ex-smoker	15	5	0	–		
Present smoker	37	13	0	–		
Never smoked	–	–	–	199	3	
Total	52	18	0	199	3	272

Table VIII. Frequency distribution of cigarette consumption in present and past smokers in older men and women. Percentages in brackets

Sex	Cigarette tobacco, g/day					No data	Totals
	nil	1–4	5–14	15–24	24+		
Men	43[1]	6	64	67	33	2	215
	(20.0)	(2.8)	(29.8)	(31.2)	(15.3)	(0.9)	
Women	199	19	33	13	5	3	272
	(73.2)	(7.0)	(12.1)	(4.8)	(1.8)	(1.1)	

[1] 26 are pipe smokers.

men aged less than 70 years (50 of 76), compared with men of 70 years and over (10 of 38, χ^2 15.84, $p<0.001$). Numbers in women are too small for statistical treatment. Table VIII gives the range of daily consumption of cigarette tobacco in grammes and confirms that a greater proportion of men consume 15g or more daily compared with women. Pipe smokers seem to consume less tobacco than cigarette smokers in that of 39 present pipe smokers only 3 smoke 15g or more daily, and of 17 ex-pipe smokers only 6 did so.

Table IX. Total years of smoking in older men and women. Percentages

Sex	Total years smoked				No data	N
	nil	1–19	20–39	40+		
Men	7.9	2.8	13.5	74.9	0.9	215
Women	73.2	6.3	9.9	8.8	1.8	272

Table X. Interval since stopping smoking in older people. Percentages

Sex	Years since stopped				No data	Still smoke or never smoked	N
	<5	5–14	15–24	≥25			
Men	7.0	9.8	7.4	3.7	0.9	71.2	215
Women	1.5	1.8	2.2	1.5	1.1	91.9	272

Table IX which gives the total years for which subjects have smoked, shows that 75% of the men have smoked for 40 years or more while only 9% of the women have done so, the difference being highly significant. 190 of 196 male smokers of all types (97%) have smoked for 20 years or more, compared with 51 of 68 (75%) female smokers (χ^2 30.76, $p<0.001$). The mean number of years as a smoker for men is 44.0, SD 17.2, and for women 8.0, SD 15.7. Table X gives the number of years since subjects stopped smoking and shows that 28% of the men and 7% of the women have stopped smoking.

The Relationship of Symptoms to Smoking Habits

Persistent cough and phlegm is present in 38% of 170 men in the sample who smoke or have smoked cigarettes, but in only 7% of 43 men who have not done so (χ^2 15.37, $p<0.001$). The symptoms are present in 18.6% of 70 women in the sample who smoke or have smoked cigarettes and in only 6.1% of 198 who do not (χ^2 9.69, $p<0.01$). Twice the proportion of male compared with female smokers have persistent cough and phlegm although the proportion of non-smokers with the symptom is similar in the two sexes. The men classed as non-cigarette smokers include pipe smokers, but pipe smoking does not seem to affect the prevalence of symptoms in these men, compared with that in women who do not smoke. Of 21 men presently smoking pipes only, added to 17 men who never smoked, 2 men admit to persistent cough and phlegm. In men, the prevalence of persistent cough and phlegm is associated with the amount of cigarette tobacco consumed daily since 15 of 54 present cigarette smokers smoking less than 15g daily have the symptoms, compared with 34 of 60 who smoke 15g or more daily (χ^2 9.66, $p<0.01$). This indicates that increasing cigarette consumption is associated with increasing prevalence of persistent cough and phlegm in present male cigarette smokers. The numbers in women are small, but the trend in present cigarette smokers is the same since 13.5% of 37 who smoke less than 15g daily have persistent cough and phlegm, compared with 30.8% of 13 who smoke more than 15g daily.

The syndrome of persistent cough and phlegm plus chest illness in the last three years (with extra phlegm and lasting three weeks or more) is found in 12.4% of 170 men who smoke or have smoked cigarettes, but in no men who have never smoked cigarettes. The numbers in women are again small being 4.3% of 70 smokers and 2.5% of 198 non-smokers.

A history of admission to hospital for a respiratory reason is given by 21.8% of 170 men who smoke or have smoked cigarettes, but by only 4.7% of 43 men who have not. A similar trend in women is shown by a history of admission for respiratory disease in 14.3% of 70 women who smoke or have smoked cigarettes, but in only 5.6% of 196 women who have not. No relationship was found between a history of admission to hospital and cigarette consumption above and below 15g daily, the history being positive in 10 of 54 men at present smoking less than 15g, and in 13 of 60 men at present smoking more than 15g daily (χ^2 n.s.).

An association is present between cigarette smoking and wheeze since 55% of 170 men who smoke or have smoked cigarettes have wheeze, compared with 25.6% of 43 who have never smoked cigarettes (χ^2 12.13, $p<0.001$). The results for women show that 46% of 70 women who smoke or have smoked cigarettes have wheeze, compared with 31% of 198 who have never smoked cigarettes (χ^2 5.06, $p<0.05$). In present cigarette smokers both men and women, no association could be shown between the proportion with wheeze and the proportion smoking more or less than 15g daily. 48% of 54 men smoking less than 15g had wheeze, compared with 65% of 60 smoking more than 15g (χ^2 3.30 n.s.). 49% of 37 women smoking less than 15g had wheeze, compared with 62% of 13 smoking more than 15g (χ^2 0.60 n.s.).

Dyspnoea of grades III plus IV was present in 18.1% of 160 men who smoke or have smoked cigarettes and in 5.1% of 41 men who have never smoked cigarettes. This means only 2 non-smokers have this grade of dyspnoea. In women, 23.3% of 60 present or former cigarette smokers have this grade of dyspnoea, compared with 19.4% of 175 who have never smoked (χ^2 0.39 n.s.). The more severe grades of dyspnoea are associated with smoking in men but not in women.

Discussion

Symptom prevalence in the present study of older people can be compared with other studies. LOWE *et al.* [1968] found in men aged 60–64 in two steel works a prevalence of persistent cough and phlegm of 39.3 and 37.1%, compared with the authors' 37.2% in the present whole sample of men. LOWE *et al.* [1968] reported this prevalence to have dropped in men aged 65–69 to 29.9%, which agrees with the present authors' finding of decreasing prevalence in older men. REID *et al.* [1964], in an Anglo-American study, reported the prevalence of persistent cough and phlegm in men in the United Kingdom to be 52% in men aged 55–64 and 27% in women of this age. These figures are higher than in the present study, but the subjects are younger. HIGGINS [1957], in an agricultural community, reported in men and women aged 65–74 prevalences of 37.8 and 13.0%, respectively, results very similar to the present group. He noted more chest illness in the previous three years (26.7% in men and 23.9% in women, compared with 17% in each in the present study) and a similar prevalence of wheeze (51.1% in men, 28.3% in women). FLETCHER *et al.* [1959] reported more cough and phlegm in men than women in postal workers aged 40–59 and nearly half of the men and women had wheeze. They found symptoms increased with age in men but not in women. The apparent difference between this report and the present finding of decreasing prevalence of symptoms in older men is perhaps explained by OSWALD *et al.* [1953] who found in 1,000 persons with chronic bronchitis, the maximum prevalence in the sixth decade. Presumably, after this decade, loss by death of persons with symptoms leads to decreasing symptom prevalence in the older survivors. HIGGINS and COCHRANE [1958] surveying men and women aged 55–64 in Dumfriesshire found more cough, phlegm and chest illness in men than in women, but more breathlessness in women. The greater prevalence of breathlessness in women, also found in the present sample, has been thought to mean a cause operating other than a respiratory one. A clue to this is found in the greater use by women, compared with men in the present sample, of medical services for cardiovascular reasons [MILNE *et al.*, 1971b].

The symptom prevalence in the present sample agrees with other surveys in the greater proportion of men affected compared with women. The lower prevalence in older men suggests the process occurring in chronic bronchitis is one which begins early in life [REID *et al.*, 1970; HOLLAND and ELLIOT, 1968] and continues throughout life thereafter, but elimination by death reduces prevalence in older survivors.

Although atmospheric pollution is now regarded as an important factor in chronic bronchitis [HOLLAND and REID, 1965], many studies have stressed the association of smoking with chronic respiratory symptoms [HIGGINS, 1957; HOLLAND *et al.*, 1965; OSWALD *et al.*, 1953; College of General Practitioners, 1961; PALMER, 1954; EDWARDS *et al.*, 1959; Royal College of Physicians, 1971]. HIGGINS [1959] has reviewed the earlier literature about smoking and bronchitis. The present study shows a higher symptom prevalence in cigarette smokers compared with non-smokers in men and women for persistent cough and phlegm, persistent cough and phlegm with chest illness, admission for respiratory disease and wheeze. Not all differences are statistically significant since the numbers are not always large enough for testing. Some studies have found increased symptom prevalence with increased tobacco consumption [HOLLAND *et al.*, 1965; HIGGINS and COCHRANE, 1958; PALMER, 1954; EDWARDS *et al.*, 1959]. This has been found in the present study associated with persistent cough and phlegm, but not with a history of admission for respiratory disease or wheeze. EDWARD *et al.* [1959] reported a smaller proportion of cigarette smokers and a larger proportion of pipe smokers as age increased, findings which agree with those in the present study. Although smoking history by questionnaire is sometimes regarded as an inaccurate method of gathering information, replies about cigarette consumption proved to have high reproducibility during preparation for the present study [MILNE *et al.*, 1970].

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10

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The Relationship of Respiratory Function Tests to Respiratory Symptoms and Smoking in Older People[1,2]

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Abstract. The $FEV_{1.0}\%$ was calculated from $FEV_{1.0}$ and FVC measured in a random sample of older people in Edinburgh. The proportion of persons with $FEV_{1.0}\% < 60$ and $\geqq 60$ in the sample was examined for association with smoking and respiratory symptoms. A significantly greater proportion of men with symptoms or who smoked cigarettes had $FEV_{1.0}\% < 60$ than $\geqq 60$. Women showed similar trends but a much smaller proportion admitted symptoms or smoked.

Key Words
Ventilatory function
Ageing
Bronchitis

During the first examination of a longitudinal study of aging persons currently being performed in Edinburgh, data were collected about respiratory symptoms and smoking habits. At the same time respiratory function tests were carried out. Details of symptom prevalence, smoking habits and respiratory function tests are to be published elsewhere. The present paper examines the association between the tests, symptoms and smoking using the forced expiratory volume ($FEV_{1.0}$) expressed as a percentage of the forced vital capacity (FVC), i.e. $FEV_{1.0}\%$.

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[2] The authors wish to thank Professor D. D. REID for the gramophone records used in training the observer.

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Methods

The subjects studied were 215 men and 272 women aged 62–90 years who formed a simple random sample of the 27,000 older people living in a defined area of Edinburgh. The method of sampling with a comparison of respondents and non-respondents has been described elsewhere [MILNE *et al.*, 1971].

A Vitalograph spirometer was used to measure $FEV_{1.0}$ and FVC. DREW and HUGHES [1969] reported this instrument as suitable for making these measurements in population studies of normal subjects and of those with obstructive airways disease. Tests were performed with subjects sitting. Five determinations were made, the first two being rejected [COTES, 1968]. Readings were corrected to BTPS and $FEV_{1.0}\%$ was calculated using the mean of three readings of each test in each subject.

Persons tested were questioned using the MRC questionnaire on respiratory symptoms [1965] and a structured questionnaire on the use of tobacco. The observer made use of gramophone records from the London School of Hygiene to train in the use of the MRC questionnaire before beginning the survey. Reproducibility of the questionnaire was also studied [MILNE *et al.,* 1970]. Reproducibility of the tests was examined by performing them in 10 persons on two occasions, the mean difference between paired results being 41 and 42 ml for $FEV_{1.0}$ and FVC, the standard deviations of these differences being 128 and 105. All examinations were made by one observer (J. S. M.).

The subjects studied were divided into those with $FEV_{1.0}\%$ less than 60 and equal to or greater than 60. Symptom prevalence and smoking habits were compared in these two groups.

The results for symptoms are shown in table I which gives, for men and women separately, the percentages of those with the ratio <60 and $\geqq 60$ who have each symptom. In men, there is for every symptom listed a statistically significant increase in the proportion of men with symptoms in the group with the ratio <60 compared with the group with the ratio $\geqq 60$. The absolute numbers of women with each symptom complex are smaller but the trend towards association of symptoms with airways obstruction follows that of the men.

The association between smoking and $FEV_{1.0}\%$ is shown in table II and III. The results in table II suggest that the proportion of persons with a ratio <60 is higher in cigarette smokers and that this proportion is higher in persons who have smoked cigarettes longer. The trends which are obvious in men are present but less marked in women. 32.4% of men, who smoke or have smoked cigarettes only, have a ratio <60 compared with 6.7% who never have smoked, 11.5% pipe smokers and 11.1% mixed smokers. The difference in the proportions of male cigarette smokers and men who have not smoked cigarettes, with ratios <60, is signifi-

Table I. $FEV_{1.0}$% compared with symptom prevalence in older people

Symptom	Percentage of those with FEV% who have symptoms		χ^2
	<60	≥60	
Men			
Number with $FEV_{1.0}\% < 60$, 51			
Number with $FEV_{1.0}\% \geq 60$, 156			
Persistent cough and phlegm	55.0	25.6	14.79[1]
Persistent cough and phlegm and chest illness	19.6	7.1	6.55[2]
Hospital admission for respiratory disease	29.4	14.7	5.44[2]
Wheeze	74.5	41.0	17.32[1]
Asthma	25.5	7.1	12.82[1]
Dyspnoea grades 3 plus 4	34.0	8.8	18.29[1]
Women			
Number with $FEV_{1.0}\% < 60$, 13			
Number with $FEV_{1.0}\% \geq 60$, 230			
Persistent cough and phlegm	46.0	7.4	–
Persistent cough and phlegm and chest illness	30.8	1.7	–
Hospital admission for respiratory disease	38.0	7.0	–
Wheeze	69.0	33.0	5.75[2]
Asthma	38.0	5.7	–
Dyspnoea grades 3 plus 4	41.7	17.4	–

[1] Significant at 0.1% level.
[2] Significant at 5% level.

cant ($\chi^2 5.13$, $p<0.05$). 33% of men who have smoked cigarettes for 40 years or more have ratios <60 compared with 7.4% of those who smoked for 20–39 years and 9.8% of those who never smoked cigarettes. The latter group includes men who smoke pipes only. In women the difference in the proportions with ratios <60 who have smoked for ≥40 years and 20–39 years seems to disappear.

The association between daily consumption of cigarette tobacco (as more or less than 15 g daily) and $FEV_{1.0}$% is shown in table III. Disregarding the amount of tobacco smoked daily significantly more men

Table II. Relationship between smoking and $FEV_{1.0}$ % in older men and women

Smoking details	FEV% <60	Percent of row total <60	FEV% ⩾60	Row total	Total
Men					
Type of smoker					
Never smoked	1	6.7	14	15	
Cigarettes	44	32.4	92	136	
Pipe	3	11.5	23	26	
Mixed	3	11.1	27	30	
		no data		8	215
Smoking history					
Never smoked	1	6.7	14	15	
Ex-smoker	16	27.1	43	59	
Present smoker	34	25.6	99	133	
		no data		8	215
Smokes or has smoked cigarettes	47	28.3	119	166	
Never smoked cigarettes	4	9.8	37	41	
		no data		8	215
Years smoked cigarettes					
0	4	9.8	37	41	
<20	1	(16.7)	5	6	
20–39	2	7.4	25	27	
⩾40	44	33.1	89	133	
		no data		8	215
Women					
Type of smoker					
Never smoked	7	3.9	172	179	
Cigarettes	6	9.4	58	64	
		no data		29	272
Smoking history					
Never smoked	7	3.9	172	179	
Ex-smoker	2	10.5	17	19	
Present smoker	4	8.7	41	45	
		no data		29	272
Years smoked cigarettes					
0	7	3.9	172	179	
<20	0	0	16	16	
20–39	3	12.0	21	24	
⩾40	3	13.6	19	22	
		no data		31	272

Table III. Relationship between $FEV_{1.0}$% and cigarette consumption in older people

Smoking details	Cigarette tobacco, g/day	$FEV_{1.0}$% <60	Percent of row total <60	$FEV_{1.0}$% ≥60	Totals
Men					
Years smoked cigarettes					
<40	<15	0	0	9	9
<40	≥15	3	12.5	21	24
≥40	<15	18	30.5	41	59
≥40	≥15	26	35.1	48	74
Pipe smokers and non-smokers					41
Missing data					8
					215
Ex and present cigarette smokers combined	<15	18	26.5	50	68
	≥15	29	29.6	69	98
Pipe smokers and non-smokers and missing data					49
					215
Present cigarette smokers	<15	12	20.0	40	52
	≥15	20	33.3	40	60
Pipe, non-, ex-smokers and missing data					103
					215
Never smoked cigarettes	–	4	9.8	37	41
Women					
Years smoked cigarettes					
<40	<15	2	6.9	27	29
<40	≥15	1	10.0	10	11
≥40	<15	1	6.7	14	15
≥40	≥15	2	(40)	5	7
Non-smokers					179
Missing data					31
					272
Ex and present cigarette smokers combined	<15	3	6.5	43	46
	≥15	3	16.7	15	18
Non-smokers					179
Missing data					29
					272
Present cigarette smokers	<15	1	3.1	31	32
	≥15	3	(23.1)	10	13
Non- and ex-smokers and missing data					227
					272
Never smoked cigarettes	–	7	3.9	172	179

who have smoked cigarettes for 40 years or more have ratios <60 compared with those who have smoked for less than 40 years ($p<0.05$). However, in men who have smoked for 40 years or more the proportion with ratios <60 does not differ significantly in the groups who have smoked less than 15 g or 15 g and more daily. No significant difference in the proportions with ratios <60 is found in men smoking less than 15 g or 15 g and more daily either as present cigarette smokers or as past and present cigarette smokers combined. The product moment correlation coefficients between number of years as a smoker and $FEV_{1.0}\%$ are –0.23 for men and –0.17 for women. These correlations are small but significant ($p<0.01$).

The relatively large amount of missing data in women (29 for most variables associated with $FEV_{1.0}\%$ and 31 for numbers of years smoked) is associated with the increasing prevalence of dementia as age increases in women. In both men and women the number of subjects in whom missing values are present when measuring respiratory function is larger than when using the questionnaire alone (2 men, 3 women). This means that totals in the present paper may differ from those in another paper on the same subject based on symptoms alone [MILNE and WILLIAMSON, 1972], e.g. 41 men are recorded as never smoking cigarettes in the present paper and 43 in the other one.

Discussion

The $FEV_{1.0}\%$ has been described as a useful index of airways obstruction, declining with age and unrelated to height or FVC but with the disadvantages of negative skewness in older people and an increasingly large standard deviation as age increases [LOWE *et al.*, 1968]. Since airways obstruction is the commonest chronic respiratory disorder, it was felt that this was a suitable index with which to assess the effect of smoking and respiratory symptoms on respiratory function tests in older people.

It is widely agreed that smoking cigarettes reduces ventilatory capacity [HIGGINS, 1959; PAYNE and KJELSBERG, 1964; FLICK and PATON, 1959; READ and SELBY, 1961; BOWER, 1961]. Some authors have mentioned in particular reduction of $FEV_{1.0}\%$ in smokers [WILSON *et al.*, 1960; ANDERSON and FERRIS, 1962] and with these the present study agrees. One paper suggests that since smoking reduces $FEV_{1.0}$ and FVC, the effect of smoking on $FEV_{1.0}\%$ is insignificant [HONG *et al.*, 1967].

Reports of the effects of the amount smoked vary. HIGGINS [1959] found no significant downward trend in MBC with increased tobacco consumption while FLICK and PATON [1959] found further reduction as smoking became heavier. Such evidence as the present study offers suggests duration of cigarette smoking is more important than the amount smoked. This takes no account of death associated with cigarette smoking and longitudinal study might support a different view.

OLSEN and GILSON [1960] emphasise the importance of discriminating amongst persons who smoke cigarettes, pipes or cigars and not treating them as a single group labelled smokers. Their work showed $FEV_{1.0}\%$ in non-smokers 70, cigar smokers 73, pipe smokers 69.3 and cigarette smokers 67.0. The present study agrees with this view in that the proportion of men with $FEV_{1.0}\% < 60$ is much higher in cigarette smokers than in non-smokers or pipe smokers. It is not possible in Scotland to comment on cigar smokers.

The relationship of sex to the association of smoking and symptoms is mentioned by PAYNE and KJELSBERG [1964] who found a lower prevalence of respiratory symptoms in women than in men when smoking equivalent amounts of cigarettes. The present study supports this in that with similar duration and amount of cigarette smoking a lower proportion of women compared with men have $FEV_{1.0}\% < 60$. ANDERSON and FERRIS [1962] mention a sex difference in which a decrease of $FEV_{1.0}\%$ associated with age is found in male smokers, and non-smokers of both sexes but not in female smokers.

It is well recognised that respiratory symptoms are associated with reduced ventilatory capacity [HIGGINS, 1959; PAYNE and KJELSBERG, 1964; BOWER, 1961]. READ and SELBY [1961] found that smoking reduced peak expiratory flow and that the additional presence of cough and phlegm further reduced it. The present study confirms the well-known association of symptoms with airways obstruction.

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11

LONGITUDINAL RESPIRATORY STUDIES IN OLDER PEOPLE

BY

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Longitudinal respiratory studies in older people

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Milne, J S (1978). *Thorax*, **33**, 547–554. **Longitudinal respiratory studies in older people.** A random sample of older people in Edinburgh (215 men, 272 women aged 62–90 years) was examined with the MRC questionnaire on respiratory symptoms. The FEV_1 and FVC were recorded. Spirograms were repeated after one and five years and the questions after five years, the sample by then having been reduced to ~~135~~ men and 148 women. 113

After five years 7% of the surviving men and women had developed persistent cough and phlegm. This syndrome had disappeared in 12% of men and 2% of women. Dyspnoea had increased beyond grade 2 in 13% of men and 7% of women and had lessened only in 6% of women.

One-quarter of male and one-seventh of female cigarette smokers had given up smoking, mostly in the first year. Nearly all who stopped were symptomless before and after. In those men who stopped smoking before the study began symptom prevalence was similar to that in those who continued smoking.

Mean values of FEV_1 and FVC declined as age increased, the decline being greater in FVC with resulting rise in FEV_1%. Five-year differences in FEV_1 and FVC were symmetrically distributed with mean differences increasing with age. Mean differences in FEV_1 were 280–350 ml in men and 150–230 ml in women. Prediction equations from the first examinations remained usable for clinical work. Mean values of FEV_1 and FVC at the first examination were smaller in those who died compared with survivors, whether symptoms were present or not. The prevalence of symptoms was greater in those who died.

Several publications report data from population studies of respiratory function (Needham *et al*, 1954; Kory *et al*, 1961; Berglund *et al*, 1963; Ferris *et al*, 1965; Morris *et al*, 1973), but information in these about the elderly tends to be derived from a few subjects in series covering large age ranges. A few papers (Milne and Williamson, 1972(b); Schmidt *et al*, 1973) report studies made exclusively on the elderly. The present paper describes the repetition after one and five years of respiratory function tests in the subjects from one of these studies of the elderly. Details are also given about respiratory symptoms and cigarette smoking at follow-up.

Subjects

The people studied in the first examination were 215 men and 272 women aged 62–90 years who in 1968 formed a simple random sample of the population of 27 000 people in that age range living in ten city wards in north Edinburgh. The method of sampling with a comparison of respondents and non-respondents has been described elsewhere (Milne *et al*, 1971). After the first examinations in 1968 and 1969 further examinations were made after one (1969/70) and five (1973/4) years. At the five-year examination it was possible to re-examine 113 men and 148 women. Information from these patients only has been used in analysing longitudinal data. During the five years 78 men and 60 women had died which left 24 men and 64 women surviving who for various reasons were not re-examined. Follow-up of the sample has been described in detail elsewhere (Milne and Chopin, 1975).

Methods

Subjects were questioned with the MRC questionnaire on respiratory symptoms (1965) at the first examination (1968/9). The questions were asked again at the five-year review (1973/4). At the first examination smoking habits were studied in detail (Milne and Williamson, 1972(a)), but at the one-year and five-year reviews subjects were asked only whether they still smoked cigarettes and if so, how many a day. The reproducibility of the questionnaires was tested before the survey began (Milne *et al*, 1970).

The respiratory function tests were the forced expiratory volume in one second (FEV_1) and the forced vital capacity (FVC) performed on a Vitalograph spirometer. This instrument was reported suitable by Drew and Hughes (1969) for measuring FEV_1 and FVC in population studies of normal subjects and of those with obstructive airways disease. Tests were performed with subjects sitting, and the best of three readings was used in the analysis. Height was measured with a Harpenden stadiometer. Reproducibility of the tests and calibration of the Vitalograph were satisfactory and have been reported elsewhere (Milne and Williamson, 1972(b)). The $FEV_1\%$ was calculated as $(FEV_1 \times 100)/FVC$.

Results

SYMPTOM PREVALENCE AND INCIDENCE

Replies to questions from the MRC questionnaire on respiratory symptoms (1965) have been analysed in table 1 in respect of persistent cough and phlegm, chest infections, and dyspnoea at the original and at the five-year examination.

Cigarette-smokers were sought by the question: "Do you smoke cigarettes now?", which was also asked on each occasion. The first two columns enumerate subjects in whom the symptom was present or absent on both occasions. The third column shows the proportion of subjects whose symptoms developed during the five-year period, while the fourth column gives the proportion whose symptoms disappeared during the same period.

Some points from the table need comment. Similar proportions of men (7·1%) and of women (6·3%) developed persistent cough and phlegm during the five years. In the same period the syndrome disappeared in 11·6% of men and 2·1% of women. Only three men and two women became subject to repeated chest infections during the five years, while in two men and one woman this symptom disappeared.

Dyspnoea increased beyond grade 2 during the five years in 13% of men and 7·3% of women. In a similar proportion of women (6·5%) dyspnoea lessened, but this improvement was claimed by only one man.

One-quarter of the men and just over one-seventh of the women who admitted smoking cigarettes at the original examination gave up during the five years. Eleven of 14 men who stopped smoking during the five years gave up after one year, the corresponding figures in women being three of four.

There were no significant age differences in the incidence figures, which were therefore reported separately only by sex.

Stopping smoking during the five years of the study showed little effect on symptoms since 13 of 14 men and all four women who stopped during the period did not have persistent cough and

Table 1 *Respiratory symptoms and cigarette smoking, in a longitudinal study of older men and women, recorded at start of study and at five-year follow-up.* (*Percentages in parentheses*)

Symptom	*Absent both times*	*Present both times*	*Present at 5-year exam only*	*Present at first exam only*	*No of Subjects*
Men					
Persistent cough and phlegm	72 (64·3)	19 (17·0)	8 (7·1)	13 (11·6)	112
Persistent cough and phlegm plus chest infection	103 (92·0)	4 (3·6)	3 (2·7)	2 (1·8)	112
Dyspnoea worse than grade 2	79 (79)	7 (7)	13 (13)	1 (1)	100
Smokes cigarettes	55 49·1)	42 (37·5)	1 (0·9)	14 (12·5)	112
Women					
Persistent cough and phlegm	123 (86·6)	7 (4·9)	9 (6·3)	3 (2·1)	142
Persistent cough and phlegm plus chest infection	139 (97·9)	0 —	2 (1·4)	1 (0·7)	142
Dysponoea worse than grade 2	99 (79·8)	8 (6·5)	9 (7·3	8 (6·5)	124
Smokes cigarettes	113 (79·6)	24 (16·9)	1 (0·7)	4 (2·8)	142

phlegm on either occasion of being questioned. The effect of stopping smoking earlier was not striking in older men. At the original examination 32 men smoked or had smoked cigarettes and admitted to persistent cough and phlegm. Ten of these men had stopped smoking cigarettes before the study began, but seven of these still had cough and phlegm at the five-year review. The mean time in years at the time of the original examination since stopping smoking was 11·6 (SD 10·0) with a range from one to 30 years. Of the remaining 22 men who continued to smoke, 12 had persistent cough and phlegm at the five-year review.

MEAN VALUES OF RESPIRATORY FUNCTION TESTS AT DIFFERENT STAGES OF THE STUDY

Mean values with 95% confidence limits of FEV_1 and FVC are given for men and for women, each sex being divided into subjects aged less than 70 years and 70 years and over at entry to the study (fig 1). For each age and sex group in the figure there are three means with confidence limits representing (reading from left to right) measurements made at the original examination and after one and five years. Values for FEV_1 are the lower and for FVC the upper groups in the diagram. The figure shows in each group a decline in the mean values as time passes.

The decline in mean values between those from the original examination and those obtained after

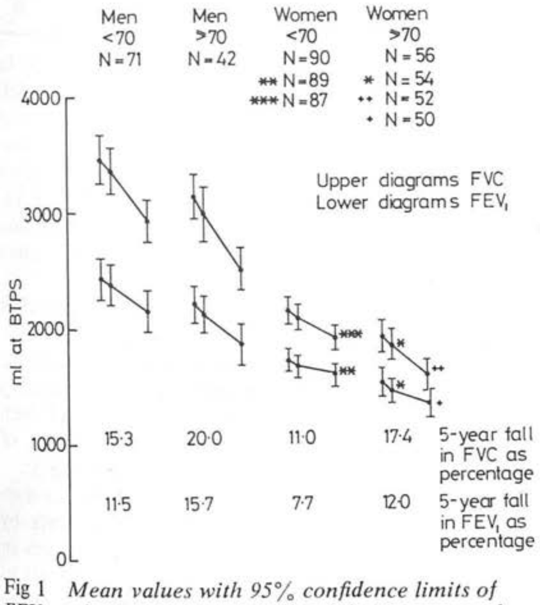

Fig 1 *Mean values with 95% confidence limits of FEV_1 and FVC in two age groups of older men and women. Results, from left to right in each group, are from a longitudinal study at zero, one, and five years.*

five years is steeper in all groups for FVC than for FEV_1. The actual figures in which the five-year difference is expressed as a percentage of the original reading are given in the lower part of figure 1.

Mean values of FEV_1% in the same age and sex groups are given in figure 2. All groups show an increase in the mean value during the five years, which corresponds to the greater reduction of FVC compared with FEV_1 during the five years.

THE ASSOCIATION OF RESPIRATORY FUNCTION TESTS AND SYMPTOMS WITH SURVIVAL

After five years the original sample was divided into those who had survived and those who had died during the period. Mean values with standard errors of FEV_1 and FVC are given in table 2 for those who died and for survivors in men and in women whose age at entry to the study was either less than 70 years or 70 years and more. In corresponding age and sex groups the values in those who died were significantly smaller, except in women aged under 70. There were only 16 deaths in this group, which makes the confidence limits large. The 14 women and two men missing from the table were unable to perform the tests because of intellectual impairment.

Mean values of FEV_1 and FVC were examined in the above age and sex groups of those who died, and survivors with each group were divided into those with and without persistent cough and phlegm. In those who subsequently died mean values were less than in the survivors, whether symptoms were present or not. Lower mean values were present in any age/sex group with symptoms compared with the corresponding group without symptoms. Of 32 differences examined in this way, only two reached statistical significance.

Values of FEV_1% were compared in members of the original sample who died or survived during fivè years. There being no age effect with this variable, division was by sex only. In men the mean value in those who died (63·3 SE 1·9 N 76) was significantly less than that in survivors (69·9 SE 1·1 N 137). The mean value in women who died (76·9 SE 2·2 N 44) was less than in surviving women (80·6 SE 0·8 N 199) but not significantly so.

Further division of those who died and survivors into those with and without persistent cough and phlegm showed mean values smaller in those who died than in survivors in corresponding groups, but none of the differences was significant.

The prevalence of respiratory symptoms and cigarette smoking, obtained at the original examination, is given for those who died and those who survived the next five years (table 3). In every

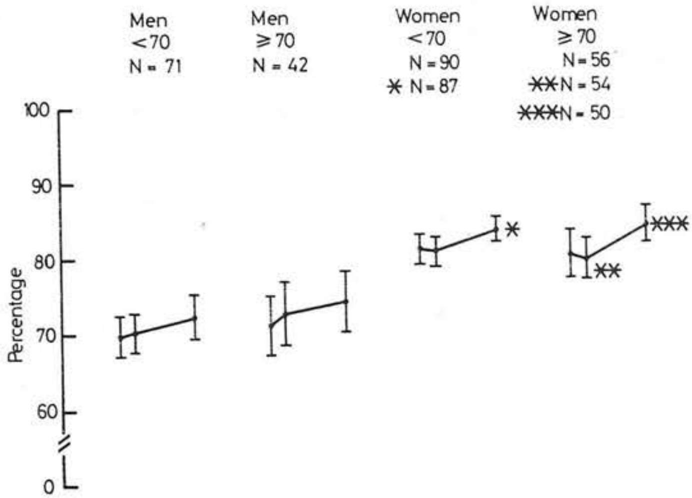

Fig 2 *Mean values with 95% confidence limits of $FEV_1\%$ in two age groups of older men and women. Results, from left to right in each group, are from a longitudinal study at zero, one, and five years.*

Table 2 *Mean values with standard errors (SE) of FEV_1 and FVC, from first examination, in two age groups of men and of women divided into those who died during and those who survived subsequent five years (ml at BTPS)*

Test	Age at entry	*Men*						*Women*					
		Survived			*Died*			*Survived*			*Died*		
		Mean	*SE*	*N*	*Mean*	*SE*	*N*	*Mean*	*SE*	*N*	*Mean*	*SE*	*N*
FEV	< 70	2397	80	88	1820	129	33	1713	44	119	1551	109	16
	≥ 70	2200	81	49	1719	122	43	1504	49	90	1104	80	33
FVC	< 70	3406	87	88	2880	166	33	2131	54	119	1993	118	16
	≥ 70	3171	96	49	2679	148	43	1895	56	90	1440	91	33

group, except cigarette smoking in women, the prevalence is greater in those who died than in those who survived. This difference reaches statistical significance in men in respect of persistent cough, persistent cough and phlegm with chest illness, and severe dyspnoea and in women in respect of severe dyspnoea only. Other points from the table are the higher prevalences of cough, phlegm, chest illness, and smoking in men and the higher prevalence of severe dyspnoea in women.

DIFFERENCES IN FEV_1, FVC, AND $FEV_1\%$ AFTER ONE AND FIVE YEARS

The differences in FEV_1, FVC, and $FEV_1\%$ after one and five years were calculated by subtracting, in each subject, the reading of each variable after one or five years from the reading at the first examination. Distributions of the one-and five-year differences, in men and in women, of each of the three variables are displayed in figures 3, 4, and 5. For FEV_1 and FVC the distribution moved further to the right after five years—that is a greater proportion of the sample showed a decrease in FEV_1 or FVC (figs 3 and 4). The distributions show that the percentage of the sample with a difference in FEV_1 which was greater than zero—that is, which reflected a decrease in FEV_1 as time passed—rose from 66·4% of men and 63·5% of women after one year to 88·5% of men and 81·8% of women after five years. Corresponding percentages for FVC are 61·9% of men and 58·1% of women after one year and 92·0% of men and 86·5% of women after five years.

The distributions of $FEV_1\%$ moved to the left as time passed—that is, the value of $FEV_1\%$ rose. The percentages of the sample with a difference less than zero—that is, reflecting an increase in $FEV_1\%$ as time passed—rose from 53·1% of men and 44·1% of women after one year to 69·9% of men and 67·4% of women after five years (fig 5).

Attempts were made to relate symptoms to five-year differences in respiratory function tests by comparing mean values of five-year differences in FEV_1 and $FEV_1\%$ in those who did not admit to cough and phlegm on either occasion with those who admitted these symptoms on at least one occasion. A similar comparison was made between those who smoked or had smoked cigarettes with

Table 3 *Prevalence of respiratory symptoms and cigarette smoking at first examination in those who died and those who survived the next five years. (Percentages in parentheses)*

Variable under comparison	*Dead*		*Survivors*		*P*
	Absent	*Present*	*Absent*	*Present*	
Men					
Persistent cough	40	36 (47·4)	93	44 (32·1)	< 0·05
Persistent phlegm	38	38 (50)	85	52 (38)	NS
Persistent cough and phlegm	46	30 (39·5)	99	38 (27·7)	NS
Persistent cough and phlegm with chest illness	65	11 (14·5)	130	7 (5·1)	< 0·05
Dyspnoea worse than grade 2	52	19 (26·8)	118	12 (9·2)	< 0·01
Smokes or smoked cigarettes	14	62 (81·6)	29	108 (78·8)	NS
Women					
Persistent cough	47	10 (17·5)	177	34 (16·1)	NS
Persistent phlegm	45	12 (21·1)	181	30 (14·2)	NS
Persistent cough and phlegm	50	7 (12·3)	193	18 (8·5)	NS
Persistent cough and phlegm with chest illness	56	1 (1·8)	210	1 (0·5)	NS
Dyspnoea worse than grade 2	28	16 (36·4)	159	32 (16·8)	< 0·01
Smokes or smoked cigarettes	47	11 (19)	152	59 (28)	NS

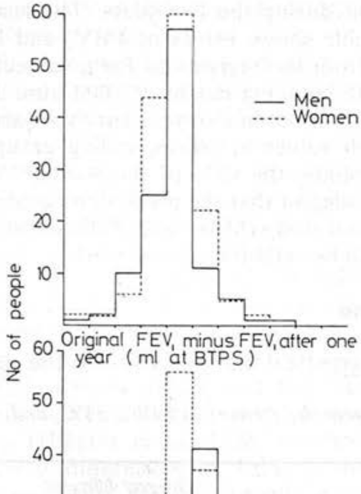

Fig 3 *Distributions of one-year and five-year differences in FEV_1 in older men and women.*

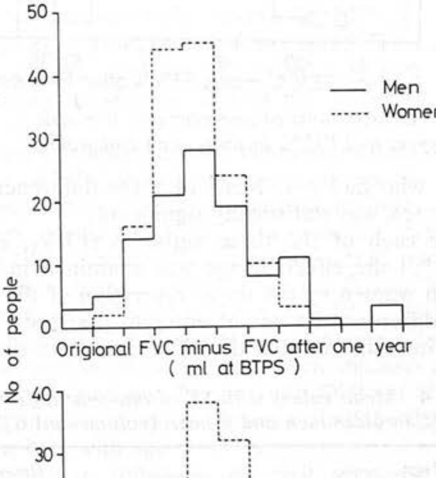

Fig 4 *Distributions of one-year and five-year differences in FVC in older men and women.*

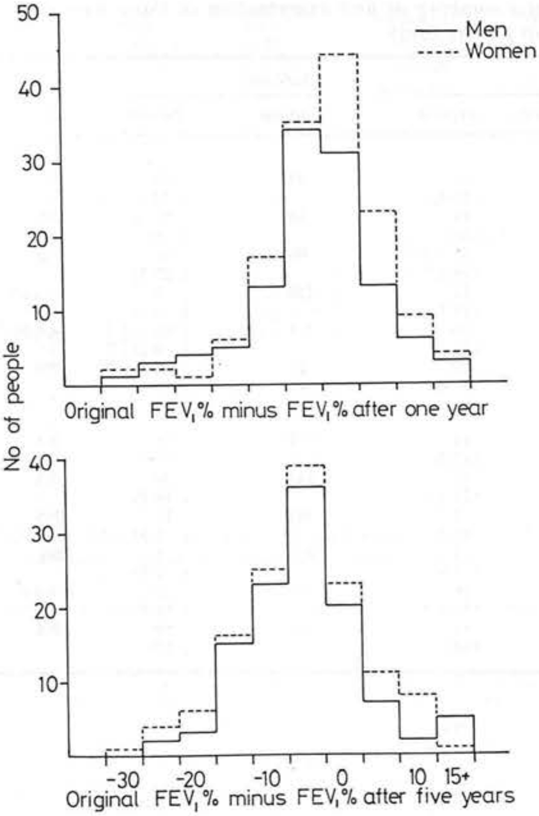

Fig 5 *Distributions of one-year and five-year differences in $FEV_1\%$ in older men and women.*

those who had not. None of these differences in either sex was statistically significant.

For each of the three variables (FEV_1, FVC, $FEV_1\%$) the effect of age was examined in men and in women by the linear regression of the five-year difference on age at entry to the study. The equations showed that the differences with time in FEV_1 and FVC increased significantly with increasing age at entry, but no age effects were found in respect of differences in $FEV_1\%$. Mean values of one-year and five-year differences are therefore displayed in table 4 in two age groups of men and women for FEV_1 and FVC and in all men and all women for $FEV_1\%$.

In both men and women mean values of differences in FEV_1 and FVC are larger in the older subjects (table 4). Seven of the ten means of one-year differences differ significantly from zero. The mean values of five-year differences are all significantly different from zero ($p<0.001$).

COMPARISON OF PREDICTION EQUATIONS FROM THE ORIGINAL EXAMINATION AND FROM THE EXAMINATION OF FIVE-YEAR SURVIVORS

Prediction equations for FEV_1 and FVC were calculated, using age and height as the independent variables, in men and women without persistent cough and phlegm examined at the five-year review. The results are compared with the prediction equations from the original study in table 5. The differences between the regression coefficients are not statistically significant. The coefficient of regression on age of FEV_1 in men has become significant during the five years. The last column in the table shows values of FEV_1 and FVC calculated from the regressions for a subject aged 80 years with standing height of 1600 mm. Although calculated values in five-year survivors are smaller than such values in corresponding groups of the original study, the sizes of the standard errors of estimate suggest that the prediction equations from the original study (Milne and Williamson, 1972(b)) might still be valid for clinical work.

Discussion

This longitudinal study has shown the decline, as

Table 4 *Mean values with SE of one-year differences and of five-year differences in FEV_1, FVC, and $FEV_1\%$ in older men and women (volumes ml BTPS)*

Sex and age at entry		*Variable*	*One-year difference* Mean	SE	N	*Five-year difference* Mean	SE	N
Men	<70	FEV_1	54*	27	71	280***	35	71
	≥70		89*	38	42	347***	55	42
Women	<70		47*	19	89	150***	28	88
	≥70		94**	32	54	229***	42	52
Men	<70	FVC	102NS	53	71	531***	49	71
	≥70		156*	60	42	627***	75	42
Women	<70		58*	25	90	251***	33	86
	≥70		104**	31	54	379***	54	50
All men		$FEV_1\%$	−0·90NS	0·80	113	−2·79***	0·74	113
All women			0·50NS	0·71	143	−3·03***	0·83	136

*$p<0.05$; **$p<0.01$; ***$p<0.001$; NS not significant.

Table 5 *Prediction equations for FEV₁ and FVC, based on age and height, calculated from data from original examination and from examination of five-year survivors*

	Sex and age range	Test	Prediction equation: Const	Regr Coeff (Age)	SE	Regr Coeff (Height)	SE	R	N	SE about regression	Calculated value in subject aged 80, height 1.6 m
Original study (1968/9)	Men 62–90	FEV	−3412·5	−14·10NS	8·28	3·987***	0·756	0·43	142	643	1839
		FVC	−5009·0	−18·35*	8·95	5·681***	0·817	0·53	142	696	2613
	Women 62–90	FEV	− 91·97	−26·57***	4·96	2·307***	0·441	0·50	226	427	1474
		FVC	− 841·1	−26·97***	5·84	3·062***	0·519	0·50	226	485	1901
Five-year review (1973/4)	Men 67–95	FEV	−1108·3	−30·34**	11·15	3·322***	0·920	0·48	84	597	1780
		FVC	− 486·6	−44·36***	10·81	3·994***	0·892	0·60	84	579	2355
	Women 67–95	FEV	1035·4	−30·33***	7·12	1·760*	0·678	0·46	118	403	1425
		FVC	643·3	−34·17***	7·74	2·381**	0·737	0·50	118	438	1719

NS=not significant; *$p < 0·05$; **$p < 0·01$; ***$p < 0·001$.

age increased, in values for respiratory function tests described by Fletcher and Peto (1977).

Prediction equations based on data from the five-year review did not differ significantly from the original equations (table 5). The exception was the coefficient of regression of FEV_1 on age in men, which was significant at the five-year but not at the original examination. The prediction equations of Schmidt *et al* (1973) produce values greater than those recorded in the first examination in the present study, but the size of the standard errors of estimate in the present study (table 5) means the differences are less than at first sight.

A study from Sweden (Wilhelmsen *et al*, 1969) reported five-year differences of 330 ml in vital capacity and 230 ml in FEV_1 in men aged 50 at entry to their study. These differences are smaller than those in older men in the present study, which has, however, shown that the differences increase with increasing age at entry. Other studies in industry (Higgins *et al*, 1968, Howard, 1970) have reported differences in $FEV_{0·75}$ after five years. These results are not directly comparable with those from the present study but are of the same order of size. Cotes (1968) quotes a mean loss of FEV_1 with age in men of 300 ml per decade. The symmetrical distribution of differences in FEV_1 over six months in the study of Fletcher and Peto (1977) caused these authors to think that sudden large irreversible falls in FEV_1 were rare. The distributions of one- and five-year differences in the present study were also symmetrical.

In the present study the decline in FEV_1 and FVC increased with increasing age. This finding is in agreement with the work of Fletcher and Peto. Howard (1970) reported a similar age effect on FEV_1 and FVC changes and that FVC fell more in a given time than FEV_1. He thought this was due to the greater size of FVC compared with FEV_1 and noted little change in $FEV_1\%$. The present study showed a similar greater fall with a corresponding increase in $FEV_1\%$, which was statistically significant and of the order of 3% (table 4).

Howard thought that the variation in the rate of decline of FEV_1 in individuals meant that the normal population without symptoms included subjects in whom the FEV_1 was declining rapidly. Hence the "normal" regression coefficient in prevalence studies could be too high. Recent work by Fletcher and Peto has shown that FEV_1 declines more rapidly as time passes in cigarette smokers than in non-smokers and that such smokers need not have symptoms. Higgins and Oldham (1962) found, in men aged 20–69 years, that the decline did not vary with age.

A ten-year follow-up of civil servants with chronic bronchitis (Oswald *et al*, 1967) showed that dyspnoea was the symptom that best estimated prognosis. The death rate in that study rose as the degree of dyspnoea at the original examination increased. The severer grades of dyspnoea were the symptom most likely to be associated with death in the present study.

Changes in symptom prevalence over a period are difficult to explain. Sharp *et al* (1973) in a seven-year longitudinal study of middle-aged men, in which the MRC questionnaire on respiratory symptoms was used, found that symptom prevalence recorded at the start declined during the period of study. The original proportions of those with cough and phlegm and of those who smoked cigarettes fell during the seven years. This was true of cough and phlegm in men more than in women in the present study, while the proportion who smoked declined in both sexes. Dyspnoea worse than grade 2 tended to disappear in a greater proportion of women compared with men (table 1).

With respect to incidence of symptoms in men during the period of study, Sharp *et al* found that 6·6% of their men developed cough and phlegm and 16·5% developed dyspnoea during seven years, the corresponding figures during five years in the present study being 7·1% and 13%.

Many subjects in the present study who appear as non-smokers at the first and at the five-year examinations (30 of 55 men and 13 of 113 women in table 1) had once smoked cigarettes but stopped before the study began. The relatively small numbers who stopped during the study (14 men, 4 women) made it difficult to assess the effect of stopping. Fletcher and Peto in their eight-year longitudinal study of working men in London were able to separate the effect of smoking in increasing the rate of decline of FEV_1 with age from its effect in producing the syndrome of persistent cough and phlegm. The design of the present study and the possibly inaccurate information gathered about when smoking had ceased before the study began made it impossible to use the present study to describe such separation.

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12

PREVALENCE OF CLINICAL AND ELECTROCARDIOGRAPHIC EVIDENCE OF ISCHAEMIC HEART DISEASE IN THE OLDER POPULATION

BY

A. H. KITCHIN, C. P. LOWTHER, and J. S. MILNE

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Prevalence of clinical and electrocardiographic evidence of ischaemic heart disease in the older population

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In 487 subjects aged 62 to 90 years who formed a random sample of the 27,000 older people living in a defined area of Edinburgh, the prevalence of positive responses to Rose's questionnaire on angina and infarction and of coded electrocardiographic abnormalities was recorded as part of a clinical survey, including blood pressure, height, weight, skinfold thickness, heart size, and presence of cardiac murmurs. The results were compared with similar data available in younger age groups.

A history of angina was given by 10 per cent of the sample. Electrocardiographic abnormalities strongly suggestive of ischaemic heart disease were present in 6 per cent and others possibly due to ischaemic heart disease in a further 24 per cent. Forty-four per cent of subjects had no codable electrocardiographic abnormality. Electrocardiographic evidence of ischaemic heart disease increased with age. Smoking habits, obesity, and hypertension were unrelated to manifestations of ischaemic heart disease in this group. The pattern of left axis deviation was present in 8·8 per cent and exceeded $-45°$ in 4·4 per cent of the sample.

Age-specific incidence and mortality rates for coronary heart disease increase with age in both sexes, approximately doubling for every 10 years of advancing age (Rose, 1972). Since the natural history of the disease is still largely unknown its prevalence in the elderly as the result of the operation of risk factors, known and unknown, and selective mortality is of interest. It is believed, for example, that 'stable' angina is associated with a relatively long survival (Rose, 1971), while on the other hand sudden death from myocardial infarction or ischaemic arrhythmia may be the first clinical manifestation of the disease (Lovell and Prineas, 1971).

Various risk factors have been more or less certainly identified. These include high blood pressure, raised level of serum cholesterol or triglyceride, a diet rich in saturated fats, a sedentary mode of life, smoking, and carbohydrate intolerance. Most studies relate to patients in middle-age though the maximal incidence of the disease is in the older age groups. Is clinical ischaemic heart disease more prevalent in the old than in the middle-aged, and does it show the same relation to risk factors as has been identified in the latter?

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Numerous studies report the prevalence of manifestations of the disease in various groups. The great majority of these, however, are not representative of the general population but relate to particular industrial or occupational groups (Stamler *et al.*, 1960; Acheson, 1961; Paul *et al.*, 1963) or to patients presenting to general practitioners or in hospital (Painter *et al.*, 1960; Eisenberg *et al.*, 1961). A few large-scale longitudinal studies such as the Framingham one (Dawber *et al.*, 1962) are in progress and report the incidence in family groups followed as age-cohorts. Even here, however, the representative nature of the subjects studied is open to question and the fact that they are under long-term study may influence the outcome. They refer also to a different climatic, genetic, and cultural background from our own. To gain a reliable estimate of the prevalence of ischaemic heart disease, the selection of an unbiased sample of the population in question is crucial but is seldom possible. The setting up of a study of older people living in a defined area of Edinburgh offered such an opportunity.

It is proposed to study over a five-year period a randomly selected sample of the older population over the age of 60. The objectives are:—

a) to ascertain the prevalence of the various manifestations of ischaemic heart disease at the start of the five-year period;
b) to measure and record a number of other features including age, sex, weight, height, obesity, heart size, blood pressure, glycosuria, and smoking history, and
c) to record the incidence of the development of new cardiac manifestations over the five-year period.

The questions which it is hoped to answer are –

1) How widespread is ischaemic heart disease in the older population?
2) What are the commoner manifestations, and are they the same as those recorded in younger patients?
3) Are the risk factors which have been identified in younger groups of hospital patients confirmed in the older population?
4) What is the prognosis of ischaemic heart disease in its various manifestations in this age group?

The present paper reports the first part of this study concerned with the prevalence of manifestations of the disease and their relation to other factors.

Subjects and methods

The subjects were 215 men and 272 women aged 62 to 90 years who formed a random sample of the 27,000 older people living in a defined area of the city. The method of sampling, including a comparison of respondents and non-respondents, has been reported elsewhere (Milne, Maule, and Williamson, 1971b). The study took place during a 24-month period.

Standardized validated techniques were used and measurements of reproducibility were obtained.

1) Rose's questionnaire in respect of angina pectoris and possible myocardial infarction (Rose, 1962; Rose and Blackburn, 1968) was administered to all subjects by one medically qualified observer (J.S.M.). Before beginning the study the observer made use of training material supplied by Professor Rose.
2) A 12-lead electrocardiogram was recorded for each subject using a direct writing portable electrocardiograph. The records were read and coded according to the Minnesota classification (Blackburn *et al.*, 1960) by two physicians experienced in electrocardiography (C.P.L. and A.H.K.). They coded the records independently and where the results disagreed (40%) the record was re-examined and an agreed coding supplied.
3) A posteroanterior chest radiograph was carried out using a 6-foot tube-film distance. The Harpenden anthropometer with straight branches was used to measure the maximum transverse cardiac diameter and lateral chest diameter (maximum diameter between inner rib margins). The ratio of these measurements gave the cardiothoracic ratio (CTR).
4) Other measurements recorded were height, weight to nearest 100 g on a lever balance, the skinfold thickness measured as the sum of the log transformations of triceps, biceps, subscapular and suprailiac skinfolds on the right side using a Harpenden caliper (Edwards *et al.*, 1955), and arterial blood pressure measured with the London School of Hygiene instrument.
5) A questionnaire covering cardiovascular disease and cigarette smoking (Medical Research Council, 1965) was administered to all subjects.
6) A general medical examination of the subjects was carried out and recorded on proformata.

Reproducibility of both questionnaires was previously tested (Milne *et al.*, 1971a). Reproducibility of the measurements of blood pressures, CTR, and skinfold thickness, made by using the same group of persons on two occasions, was tested. The SD of the mean difference in no case exceeded 4·2 per cent of the mean of the dimension concerned. The complete data were coded, stored on magnetic tape, and analysed using standard computer techniques.

Results

1) Angina and probable infarction

The replies to Rose's questionnaire are shown for two age groups of men and women in Table 1. The difference in prevalence of angina between men (10·3%) and women (11·6%) is not significant but a significantly greater proportion of men (10·8%) compared with women (3·4%) gave a history of possible myocardial infarction ($\chi^2 = 10{\cdot}50$, $P < 0{\cdot}01$). The severer grade of angina, i.e. that occurring on walking at an ordinary pace on level ground, was present in 6 per cent of men and 4·5 per cent of women. No significant age difference in prevalence was found in either sex for either diagnosis.

TABLE 1 *Percentage frequency of manifestations of ischaemic heart disease by age and sex*

Age and Sex	*No.*	*Rose's questionnaire*		*Electrocardiogram*	
		Angina	*Infarction*	*Probable**	*Possible**
Men					
62–69	122	9·1	10·8	5·0	16·5
70+	93	12·0	10·9	8·4	26·0
All	215	10·3	10·8	7·1	20·5
Women					
62–69	137	11·0	1·5	4·4	19·0
70+	135	12·2	5·4	5·9	32·2
All	272	11·6	3·4	5·3	26·0
Total	487	11·0	6·7	6·1	24·0

* Reid *et al.* (1966b).

2) Electrocardiographic abnormalities

Electrocardiographic data were incomplete in 5 subjects. Two hundred and fourteen cardiographs were completely normal (44%).

Following Reid *et al.* (1966b) the electrocardiographic changes which were recognized as indicative of ischaemic heart disease were as follows.

1) Probable ischaemic heart disease (Type 1) – Minnesota coding (I 1.1–I 2.8 or VII 1).

2) Possible ischaemic heart disease (Type 2) – Minnesota coding (I 3.1–I 3.6 or IV 1–3 or V 1–3).

Broadly speaking Type 1 represents major Q or QS patterns or left bundle-branch block, while Type 2 represents minor Q abnormalities or ST-T changes. Type 1 was present in 6·1 per cent of cardiographs and Type 2 in 24 per cent making a total of 30·1 per cent (Table 1).

The prevalence of various abnormalities is shown in Table 2.

3) Effect of age and sex

The prevalence of electrocardiographic abnormalities increases with age (Table 1). Many more men than women give a history of possible infarction.

4) Cardiothoracic ratio

The numbers of men and women in the sample with cardiothoracic ratio over 50 per cent are shown in Table 3 in respect of the presence or absence of angina, possible myocardial infarction, and electrocardiographic evidence of 'probable' ischaemic heart disease (Type 1) and 'probable + possible' ischaemic heart disease (Types 1 and 2). In the last named category a significantly higher proportion of men ($\chi^2 = 9{\cdot}91$, $P < 0{\cdot}01$) and women ($\chi^2 = 11{\cdot}82$, $P < 0{\cdot}01$) classed as having ischaemic heart disease had a cardiothoracic ratio > 50 per cent. This difference was not present in the other three categories of ischaemic heart disease.

The sex difference in CTR in this age group shown in Table 3 is associated with changes in the transthoracic rather than in the cardiac diameter (unpublished observation).

TABLE 3 *Cardiothoracic ratio and ischaemic heart disease*

		Per cent with CTR > 50%	
		Men	*Women*
History	Angina	15·8	71·4
	No angina	22·7	56·4
	Myocardial infarct	20·0	75·0
	No myocardial infarct	22·2	57·6
Electrocardiogram	Type 1 changes	21·1	69·4
	Type 2 changes	22·2	56·6
	Types 1 + 2	31·9 } *	69·7 } *
	Neither	13·0 }	48·5 }

* Significant differences (P < 0·01).

TABLE 2 *Prevalence of coded electrocardiographic abnormalities in men and women*

Abnormality	*Code*		*Male (214)*	*%*	*Female (268)*	*%*	*Total (482)*	*%*
No codable abnormality	—		104	49	110	41	214	44
Major Q/QS patterns	I	1–2	12	5·6	14	5·2	26	5·4
Minor Q/QS patterns	I	3	5	2·3	6	2·2	11	2·3
Left axis deviation	II	1	22	10·2	19	7·1	41	8·5
Right axis deviation	II	2–3	4	1·9	0	0	4	0·8
Left ventricular hypertrophy	III	1	8	3·7	39	14·5	47	9·7
Right ventricular hypertrophy	III	2	7	3·3	5	1·9	12	2·5
ST depression	IV	1–3	28	13	64	24	92	19·1
T inversion or flattening	V	1–3	50	23	80	30	130	27
AV block	VI	1–3	8	3·7	8	3·0	16	3·3
Bundle-branch block L	VII	1	3	1·4	0	0	3	0·6
,, ,, ,, R	VII	2	5	2·3	6	2·2	11	2·3
,, ,, ,, R incomplete	VII	3	3	1·4	4	1·5	7	1·5
Atrial fibrillation	VIII	3	5	2·3	7	2·6	12	2·5
Other arrhythmias	VIII		13	6·1	11	4·1	24	5·0
'Probable ischaemic heart disease'*	I 1–2 or VII 1		15	7·1	14	5·3	29	6·1
'Possible ischaemic heart disease'	I 3 or IV 1–3 or V 1–3		44	21·0	71	26·0	115	24·0

* Reid *et al.* (1966b).

5) **Association of history and electrocardiographic abnormalities**

There was a higher prevalence of electrocardiographic changes in those with a history of angina or infarction (46%) than in those without (28%). However, a large number of subjects with a history suggestive of ischaemic heart disease had a normal electrocardiogram (39/72 = 54%) and a large number of subjects with an abnormal, presumed ischaemic, electrocardiogram gave no corresponding history (115/405 = 28%).

In the presence of pathological Q waves (Type 1) there is little doubt of the existence of ischaemic heart disease. Type 2, however, consists of ST-T changes which might be associated with other conditions, notably hypertension and valvular heart disease, especially aortic. The 115 subjects with Type 2 electrocardiograms were therefore analysed further. Of these 115 subjects only 66 had no explanation other than coronary artery disease for their electrocardiographic abnormality, and of these 55 were asymptomatic. The other cases were, in the majority, patients with left ventricular hypertrophy caused by hypertension or valvular disease.

6) **Total prevalence of ischaemic heart disease**

If we take as evidence of ischaemic heart disease, (1) a positive history of angina or possible infarction, (2) probable electrocardiographic evidence (Type 1), or (3) possible electrocardiographic evidence (Type 2) not explicable on a basis of hypertension or valvular disease, the prevalence is made up as shown in the Fig. This shows diagrammatically the relation between the three manifestations of ischaemic heart disease considered in this study.

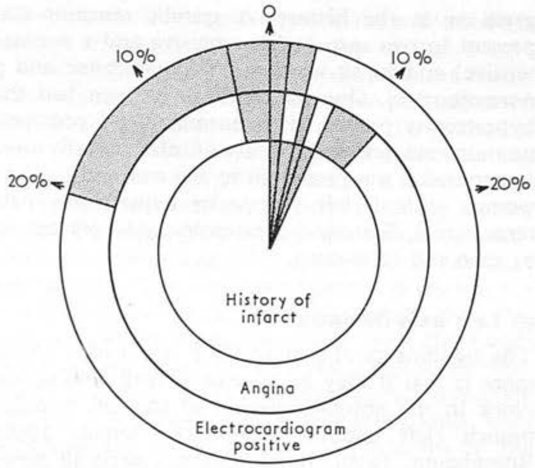

FIG. *Relative frequency and correspondence of manifestations of ischaemic heart disease*

7) **Risk factors**

Table 4 shows the relative frequency of three known risk factors for ischaemic heart disease between the groups of subjects who had or who had not presumptive evidence of ischaemic heart disease, either historically or electrocardiographically. There was no difference between the two groups as regards smoking or obesity. Systolic and diastolic hypertension were defined as pressures of 160 or over and 100 or over respectively. There was a higher prevalence of systolic and diastolic hypertension in women (57% and 19%) than in men (38% and 11%). Increasing age raised the prevalence of systolic hypertension in women (46 to 68%) but not in men (41 to 33%). In patients with probable ischaemic heart disease (i.e. those with a history of angina or infarction or pathological Q waves on the electrocardiogram) there was a lower prevalence of diastolic and diastolic + systolic hypertension than in the non-ischaemic group, but no difference as regards systolic hypertension alone.

8) **Increased left ventricular voltage pattern**

Twelve men and 46 women had the voltage criteria of left ventricular hypertrophy. The majority had hypertension, either systolic (9 men, 32 women), diastolic (4 men, 16 women), or both (4 men, 16 women). Two men and four women had the hypertrophy pattern with normal blood pressures and evidence of myocardial infarction on electrocardio-

TABLE 4 *Comparison of subjects with and without evidence of ischaemic heart disease*

Percentage frequency of		*Smoking*		*Hypertension*				*Obesity*			
				Systolic		*Diastolic*		*Skinfold**		*W/H²†*	
	No.	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*
Subjects with evidence of ischaemic disease	144	85	21	38	61	7·8	18	21	65	24	30
Subjects without evidence of ischaemic heart disease	343	93	29	38	55	12	23	28	66	27	34

* Sum of log transformations of 4 skinfold thicknesses.
† Weight/height^2.

gram or in the history. A systolic murmur was present in two men (1 hypertensive and 1 normotensive) and in 17 women (12 hypertensive and 5 normotensive). One man and six women had the hypertrophy pattern with normal blood pressure, no murmurs, and no evidence of infarction. Systolic hypertension was present in 70/203 men and 124/227 women without left ventricular hypertrophy pattern, while diastolic hypertension was present in 21 men and 42 women.

9) Left axis deviation

The significance of a mean QRS vector of $-30°$ or more is that it may be associated with conduction block in the anterior portion of the left bundle-branch (left anterior hemiblock; Grant, 1956; Rosenbaum, 1970). It may occur acutely in myocardial infarction or chronically in ischaemic heart disease; if associated with right bundle-branch block there is a danger of trifascicular block and idioventricular rhythm. The prevalence of left axis deviation in the general population is unknown. It was present in 44 of the present 477 cardiograms (8·8%). In 22 of these the $\hat{A}_{QRS}$ exceeded $-45°$ and in 8 it exceeded $-60°$. There were 22 men and 22 women. In 27 of them the cardiogram was otherwise normal, and in 24 there was no history of ischaemic heart disease. In a further 15 cases it was associated with ST-T changes, and 6 of these had an ischaemic history. It was not associated with an increased prevalence of hypertension. In 3 cases there was also incomplete right bundle-branch block.

10) Summary

A history of angina was given by 10·3 per cent of men and 11·6 per cent of women in the sample. Severe angina was present in 6 per cent and 4·5 per cent, respectively. More men than women gave a history of possible myocardial infarction, 10·8 per cent as opposed to 3·4 per cent. 6·1 per cent of the cardiograms showed Type 1 changes while 24 per cent showed Type 2 changes, i.e. possible ischaemic disease.

There was no sex difference in the prevalence of electrocardiographic abnormalities which, however, increased with age while a history of angina or infarction did not. Cardiac enlargement was more frequent in the presence of electrocardiographic changes but no more frequent in those giving a history of angina or infarct. Fifty-four per cent of subjects with a history of angina or infarction had no ischaemic changes in the electrocardiogram, while 28 per cent of subjects with such changes gave no history of angina or infarction. If a history of angina or infarction and/or the presence of Type 1 electrocardiographic changes is taken as evidence of probable ischaemic heart disease, the total probable prevalence in the sample was 18 per cent. If we include in addition Type 2 or possible electrocardiographic changes the figure rises to 28 per cent.

Smoking history, obesity, and hypertension were unrelated to the presence of manifestations of ischaemic heart disease in this group. Hypertension was commoner in women and was associated with voltage changes of left ventricular hypertrophy on the electrocardiogram. Other electrocardiographic abnormalities were rare with the exception of the pattern of left axis deviation present in 8·8 per cent of the sample and marked in 4·4 per cent which is recognized as commonly due to damage or degeneration of the anterior division of the left bundle-branch.

Discussion

We report the response to a standardized angina and infarction questionnaire and the occurrence of specific coded electrocardiographic abnormalities in a randomly selected sample of the older population in a defined area. For comparison two studies in the same age group, using careful sampling methods, are of particular relevance. One is the postal questionnaire carried out by Reid *et al.* (1966a) on a random sample of subjects aged 65 to 74 (Table 5). The main differences are the lower prevalence among women of angina shown by Reid *et al.* and the lesser sex difference shown by them in respect of possible infarction. Our figures confirm the Framingham findings (Dawber *et al.*, 1962) that in men angina and history of infarct are equally common while in women the latter is much less common.

Kennedy and Caird (1972) in an electrocardiographic survey of 400 subjects over 65 forming stratified random samples from two towns in Scotland found a similar prevalence of abnormal electrocardiograms, to that found in the present study (Table 6). They showed a higher prevalence of pathological Q waves and of bundle-branch block both right and left, while non-specific ST and T changes were less common than in the present data.

TABLE 5 *Percentage frequency of history of ischaemic heart disease*

History of	*Source*	*Men*	*Women*
Angina	Reid *et al.* (1966a)	10·4	5·8
	Present data	10·3	11·6
Possible infarction	Reid *et al.* (1966a)	7·9	4·0
	Present data	10·8	3·4

TABLE 6 *Percentage frequency of coded electrocardiographic abnormalities*

	Kennedy and Caird (1972)	*Present data*
Normal	43·0%	44·0%
Left axis deviation	6·5%	8·6%
Left bundle-branch block	2·5%	0·6%
Right bundle-branch block	3·5%	2·3%
Incomplete right bundle-branch block	3·0%	1·5%
Left ventricular hypertrophy (voltage)	7·8%	9·7%
Q (I 1·1–3·6)	9·5%	7·7%
ST-T or T	10·5%	27·3%
Atrial fibrillation	3·0%	2·5%

As regards younger age groups the survey of male postal workers aged 40 to 59 carried out by Reid *et al.* (1966b) affords some comparison with the 215 older male subjects in the present series (Table 7). In the older group of men a majority have a codable abnormality in the electrocardiogram and there are steep rises in the prevalence of major Q/QS patterns, ST-T patterns, and history of myocardial infarction. Comparable studies of the prevalence of ischaemic heart disease in Europe are reported by Rose (1967). Again the present figures show a much higher prevalence of angina (10% as opposed to 0·3–6·3%), possible infarction (10·8% to 1·5–9·6%), probable

TABLE 7 *Effect of age on percentage prevalence of electrocardiographic abnormalities in men*

	Age group			
	*40–49** *(374)*	*50–59** *(293)*	*62–69* *(122)*	*70+* *(93)*
Electrocardiogram				
No codable abnormality	79	71	56	33
Major Q/QS	1·1	2·0	3·3	7·5
Minor Q/QS	0·5	0·7	0·8	3·7
LV hypertrophy	—	0·7	3·3	3·7
ST depression	3·2	8·2	8·0	17
T inversion or flattening	1·1	4·4	19	26
AV block	0·3	2·4	2·5	4·6
Bundle-branch block	1·8	1·7	5·0	5·6
Probable ischaemic heart disease	1·1	2·7	5·0	8·4
Possible ischaemic heart disease	4·2	9·2	19	29
History				
Angina		4·0	9·1	11·8
Infarct		2·0	10·8	10·7

* Data from Reid *et al.* (1966b).

ischaemia on electrocardiogram (6·1% to 1·4–2·6%), and possible ischaemia (25% to 5·5–12·2%).

How probable is it that the present results validly represent the prevalence of ischaemic heart disease? The first problem is what is meant by ischaemic heart disease. Coronary atheroma which is the underlying pathology of the great bulk of the disease is present at an early age in many clinically healthy people. Its progression to the point of causing symptoms cannot be documented short of serial coronary angiography. The cardinal symptom is angina, yet severe occlusive disease may be present with this symptom which correlates poorly with the extent of the disease. Angina itself is not a risk to survival. Death occurs as a result of myocardial infarction or local critical ischaemia causing arrhythmia, both of which are unpredictable complications of the disease, and which may be its first and only manifestation (Lovell and Prineas, 1971). Silent myocardial infarction may occur without symptoms (Lindberg *et al.*, 1960). Atypical presentations of myocardial infarction occur commonly in elderly people (Pathy, 1967). The resting electrocardiogram is frequently normal in patients at risk of death from

TABLE 8 *Final diagnosis of patients admitted to coronary care unit, Western General Hospital, Edinburgh, 1966–68*

Condition			*No.*	*%*
Myocardial infarction			508	59
Other cardiac:	ischaemia	143		
	arrhythmias	52		
	pericarditis	20		
	LV failure	17		
	dissecting aneurysm	3		
	other	12	247	28
Respiratory:	pulmonary infarct	15		
	pneumonia	11		
	bronchitis	10		
	pneumothorax	3		
	other	6	45	5
Gastrointestinal:	peptic ulcer	10		
	oesophagitis	6		
	hiatus hernia	5		
	other	12	33	4
Skeletal pain			10	1
Miscellaneous:	syncope	12		
	cerebrovascular accident	4		
	hyperventilation	2		
	other	11	29	3
Total			872	100

ischaemic heart disease. Clearly the identifiable manifestations will yield many false negatives.

False positive responses in terms of ascribing chest pain from other causes to ischaemic heart disease are notoriously common (Rose, 1968; Zeiner-Henriksen, 1972). Pain simulating myocardial infarction but due to other causes and resulting in admission to a coronary care unit is common (Table 8; also Säwe, 1971), and a retrospective history of such pain must include a large number of false positives in patients who are not fully investigated in hospital. Friesinger and Smith (1972) found positive arteriographic evidence of coronary artery disease in 92 per cent of patients with typical angina and 40 per cent of those with atypical pain. In those with pathological Q waves in the electrocardiogram all were positive if there was anginal pain. Similarly with ST-T changes; if accompanied by angina they were always associated with angiographic changes but were so in only a minority of those without pain.

Even the electrocardiographic changes of ischaemic heart disease are not specific. Broad pathological Q waves are the most convincing evidence of previous infarction but Horan, Flowers, and Johnson (1971) report that an isolated broad Q in inferior or anterior leads has only a 50 per cent chance of being associated with an infarct. Horizontal ST depression in the left praecordial leads is likewise highly suggestive in the absence of left ventricular hypertrophy or digitalis. Primary T wave abnormalities however may, in addition to ischaemia, be due to pericarditis, cardiomyopathy, mitral regurgitation, hypokalaemia, drugs such as digitalis or quinidine, or hypertensive crises (Surawicz, 1972). Other changes which may be ischaemic include atrial fibrillation in the absence of rheumatic heart disease (Davies and Pomerance, 1972) and complete AV block particularly in the form of bilateral bundle-branch block. These, however, are rare. Left bundle-branch block has been included in the criteria used here as probable evidence of ischaemic heart disease, yet Haft, Herman, and Gorlin (1971) and Lewis *et al.* (1970) in studies of this abnormality ascribe only some 50 per cent of cases to this cause.

It is of interest that the presence of left anterior hemiblock (Rosenbaum, 1970) was far commoner than either left or right bundle-branch block in this series of elderly patients, and after ST-T changes and left ventricular hypertrophy pattern it was the most common abnormality. The significance of this is not yet fully apparent. It is a common sequel to myocardial infarction but on the other hand may be present in other patients, presumably as a result of degenerative disease of the conducting tissue.

It is clear both that the specificity of the factors which can be taken as evidence of ischaemic heart disease is low and that the point in the evolution of this common condition at which the disease can be diagnosed as present is vague. Accepting these limitations, the best that can be done is to record the prevalence of various possible manifestations using standard criteria so that comparison may be made with other surveys. The points that emerge from the present survey are the striking increase in the prevalence of all stigmata of ischaemic heart disease with age. Though not unexpected, this represents a remarkable incidence of the disease when it is remembered that the cohorts studied are the survivors of high annual mortality rates from ischaemic heart disease. In this older age group there is little sex difference in prevalence figures, and the well-established relation between blood pressure and ischaemic heart disease brought out in prospective studies of mortality in younger subjects (Morris *et al.*, 1966) is not evident.

Although the true prevalence of the disease in different age and sex groups probably runs parallel with the prevalence of the presumed manifestations, it would be rash to attempt to deduce actual prevalence rates from this or other cardiovascular surveys. The most unequivocal evidence is probably the existence of electrocardiographic abnormalities with angina, and in the present series this occurred in 7 per cent of cases. At the other extreme some 30 per cent have at least one manifestation which is suggestive of the disease. Some cases of serious coronary occlusive disease may be undetected by all of the current methods, and in a population sample such as this which is being studied longitudinally, the incidence of fresh changes may be evaluated much more precisely than the retrospective data.

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13

HEART SIZE IN OLDER PEOPLE

BY

J. S. MILNE and I. J. LAUDER

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Heart size in older people

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The transverse cardiac diameter, the transverse chest diameter, and the cardiothoracic ratio have been measured from chest x-rays in 446 persons from a random sample of 487 older people aged 62 to 90 years. Cardiac diameter and cardiothoracic ratio showed significant increases with increasing age while the chest diameter showed a significant decrease. Since the cardiothoracic ratio is therefore unreliable in estimating heart size, transverse cardiac diameter was used. This diameter was larger in the presence of higher diastolic blood pressures. After excluding persons with diastolic pressures greater than 100 mmHg, prediction equations were calculated for normal cardiac diameter using age and weight as the independent variables. The addition of height or chest diameter to the equations did not improve prediction.

The use of posteroanterior chest *x*-rays to estimate heart size is attractive because of its simplicity. The present paper describes measurements of the transverse cardiac diameter, the transverse chest diameter, and the cardiothoracic ratio in a study of older people, and examines their statistical relations and their suitability for measuring heart size.

Methods

The persons examined were 215 men and 272 women aged 62 to 90 years who formed a simple random sample of the 27,000 older people living in a defined area of Edinburgh. The method of sampling with a comparison of respondents and non-respondents has been fully described elsewhere (Milne, Maule, and Williamson, 1971). This group of people has been undergoing longitudinal study for the past 5 years. The first examination in 1968 to 1969 comprised a history of physical health using a structured questionnaire, clinical examination, and a number of additional examinations including chest *x*-ray. The results described in this paper are based on this first and therefore cross-sectional examination. A posteroanterior chest *x*-ray was taken, at a tube-film distance of 183 cm, at the height of a less than maximal inspiration. The transverse cardiac diameter and the transverse chest diameter were measured to the nearest millimetre on the film using a Harpenden anthropometer (Tanner and Whitehouse, 1957) with straight branches. This instrument is a sliding caliper fitted with a counter window from which the measurement in millimetres can be read directly. The branches are long enough to allow the transverse cardiac diameter to be measured in one single operation, without the more complex manoeuvres needed with a ruler and set square (Cowan, 1959). The transverse chest diameter was measured from the internal surfaces of the ribs, superior to the costal attachment of the diaphragm, at the point where the chest width is greatest (Cowan, 1959). Measurements were not made on the films which were technically unsatisfactory as a result of the position of the subject, poor penetration, or exposure during the wrong phase of respiration. A few of the persons examined could not be *x*-rayed because of physical or mental disability. These exclusions reduced the films available for measurements to those from 191 men and 255 women. The cardiothoracic ratio was computed as $100 \times$ transverse cardiac diameter/transverse chest diameter.

Additional measurements made were height to the nearest millimetre with the Harpenden stadiometer, weight in a minimum of underclothing, to the nearest 100 g with a lever balance, and blood pressure with the London School of Hygiene sphygmomanometer (Rose, Holland, and Crowley, 1964). Diastolic blood pressure was recorded at the point where muffling of the sounds began.

Rose's questionnaire (Rose, 1962; Rose and Blackburn, 1968) was administered to all subjects by one medically qualified observer (J.S.M.). A 12-lead electrocardiogram was recorded from each subject using a direct writing portable electrocardiograph. The tracings were coded, using the Minnesota code by two observers independently. When codings disagreed the observers discussed the tracings and supplied a coding agreed between them (Kitchin, Lowther, and Milne, 1973). The answers to the questions and the coded electrocardiograms allowed the grouping of subjects as having probable ischaemic heart disease, possible ischaemic heart disease, or no evidence of such disease (Reid *et al.*, 1966).

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Reliability

Reproducibility of the questionnaire was tested before the survey began (Milne, Hope, and Williamson, 1970). The reliability of height, chest diameter, and transverse cardiac diameter was assessed using analysis of variance techniques.

A sample of 10 people was measured by the same observer on two separate occasions. In studying chest and heart diameters *x*-ray films were exposed on each occasion. The analysis of variance demonstrated that there was no systematic variation from occasion to occasion for any variable. Further, if the residual variance, which represents random measurement error, is expressed as a percentage of the population variance plus the residual variance, then the figures for height, chest diameter, and cardiac diameter are 0·6, 0·7, and 12·0, respectively. The lesser reliability of cardiac diameter as a measurement may be associated with chance variation in the points on the cardiac cycle at which films taken on two occasions are exposed.

The reliability of diastolic blood pressure was tested by considering the differences between the observer's times and standard London School of Hygiene times in a series of 12 timed sets of Korotkow sounds (Rose, 1965). The mean of these differences did not differ significantly from zero.

Results

The distributions of the transverse cardiac diameter, transverse chest diameter, and the cardiothoracic ratio (CTR) are approximately Gaussian. The mean values, with standard deviations and the numbers from which these statistics were derived, are given for these three variables, in three age groups of men and women in Table 1. Chest and heart diameters are significantly larger in corresponding age groups of men compared with women while the reverse is true of the cardiothoracic ratio. In both sexes, there are age-related increases in the mean values of cardiac diameter and cardiothoracic ratio, with a fall with age in the mean values of the chest diameter. The significance of these differences is confirmed by the coefficient of regression on age of these variables and the corresponding correlation coefficients which are given in Table 2. The effect of age on the cardiothoracic ratio is also given in Table 3 which shows in men and women above and below 70 years of age the numbers with a cardiothoracic ratio above or below 50 per cent.

The value of the cardiothoracic ratio as an estimate of heart size, which can be used to study the progress of patients in clinical work, depends on the transverse chest diameter being, in any one individual, a constant standard with which the transverse cardiac diameter can be compared. Data given in Tables 1 to 3 show a significant decline in transverse chest diameter as age increases. Admittedly the study is cross-sectional but it is unlikely that the age difference in chest diameter is entirely due to secular trend or selection by death. The age-related decrease in chest diameter suggests that the

TABLE 1 *Mean values and standard deviations (SD) of chest diameter, cardiac diameter, and cardiothoracic ratio in older people*

Age and sex	*Chest diameter*		*Cardiac diameter*		*Cardiothoracic ratio (%)*		*No.*
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	
Men							
62–69	301·6	17·8	136·0	15·1	45·1	4·6	108
70–79	293·6	20·1	138·5	14·5	47·3	5·2	66
80–90	292·1	13·6	144·3	12·6	49·4	3·8	17
Women							
62–69	256·4	19·3	128·1	14·2	50·1	5·0	132
70–79	250·1	18·3	131·6	13·6	52·7	5·2	97
80–90	239·8	23·2	133·9	15·3	56·0	5·9	26

TABLE 2 *Linear regressions of variables related to heart size on age, in older people*

Age and sex	*Dependent variable*	*Coefficient of regression on age*	*SE of regression coefficient*	*r*	*No.*
Men 62–90	Cardiac diameter	0·4490	0·1643	0·19	191
	Chest diameter	−0·5240	0·2074	0·18	191
	Cardiothoracic ratio	0·2366	0·0533	0·31	191
Women 62–90	Cardiac diameter	0·3507	0·1435	0·15	255
	Chest diameter	−0·9229	0·1962	0·28	255
	Cardiothoracic ratio	0·3373	0·0526	0·37	255

TABLE 3 *Cardiothoracic ratio in older people*

Age and sex	*Cardiothoracic ratio*			χ^2
	<50	*≥50*	*% ≥50*	
Men				
<70	93	15	13·9	9·40**
≥70	56	27	32·5	
Women				
<70	70	62	47·0	14·74**
≥70	36	87	70·7	

** P<0·01.

increase in the cardiothoracic ratio with increasing age overestimates changes in heart size. Transverse cardiac diameter therefore seems to be a more appropriate measurement with which to study the normal limits of heart size in older people.

It might be expected that the transverse cardiac diameter would be larger in the presence of ischaemic heart disease or of hypertension. The mean values of the diameter were examined in persons with probable, possible, and no evidence of ischaemic heart disease (Reid *et al.*, 1966) and in persons with diastolic blood pressure above and below 100 mmHg. No significant difference emerged in respect of persons in the study with and without ischaemic heart disease, but the mean cardiac diameter was significantly larger with diastolic pressures of 100 mmHg and more. These persons with higher blood pressure were, therefore, excluded, leaving 188 men and 201 women on whom the description of the range of the cardiac diameter was based and in whom the regressions of cardiac diameter on age remained significant. In addition to age, transverse cardiac diameter has been described as varying with transverse chest diameter (Cowan, 1960) and with weight and height (Ungerleider and Gubner, 1942; Ueda, Russell, and Yano, 1958–60).

In the age group 62 to 69 years, the coefficient of regression of transverse cardiac diameter on age was not significant in either sex. This age group, in whom age effects were absent, was therefore used to study the relation of transverse cardiac diameter to weight, height, and transverse chest diameter. This was done by calculating the linear regression of cardiac diameter in men and in women aged 62 to 69 years on each of these variables singly in separate equations (Table 4). The coefficients of regression in this table are significant with the exception of those for height in women.

The relation of cardiac diameter, age, and these other variables was further examined by multiple regression in men and in women aged 62 to 90 years with transverse cardiac diameter as the dependent variable. The fit of the lines was not improved by adding height or transverse chest diameter to the regressions after age and weight. In the sample examined, age and weight explained as much of the variance of the transverse cardiac diameter as would all four variables.

For prediction of values in clinical work the linear regressions of the transverse cardiac diameter on weight in three age groups of men and women are shown in Table 5. In the Fig. are displayed, in the same age groups of men and women, the regression lines with 95 per cent confidence limits.

When the simple random sample used in this study was drawn, a further simple random sample of 64 men and women born in 1904 and 1905, i.e. 62 to 65 years of age in the period of study, was examined for another purpose which included chest *x*-ray. After the exclusion of subjects with diastolic blood pressures of 100 mmHg or more, there remained 25 men and 24 women. In these subjects the transverse cardiac diameter measured from chest films, was

TABLE 4 *Regressions of transverse cardiac diameter on weight, height, and transverse chest diameter in men and women aged 62 to 69 years, with diastolic BP < 100 mmHg*

Sex	*Independent variable*	*Regression coefficient*	*SE of regression coefficient*	*r*	*No.*
Men	Weight	0·8230	0·1065	0·62	96
	Height	0·0491	0·0251	0·20	96
	Chest diameter	0·3555	0·0787	0·42	96
Women	Weight	0·7476	0·0826	0·66	106
	Height	0·0303	0·0186	0·16	106
	Chest diameter	0·2967	0·0598	0·44	106

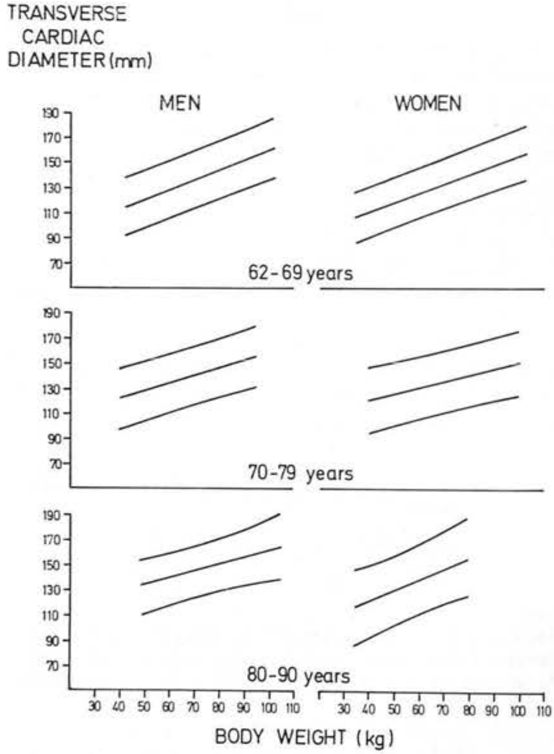

FIG. *Linear regressions with 95 per cent confidence limits to predict transverse cardiac diameter from age and weight in older men and women.*

TABLE 5 *Regressions of transverse cardiac diameter on weight in 3 age groups of men and women (excluding those with diastolic BP ≥ 100 mmHg)*

Sex and age	*Constant*	*Regression coefficient*	*SE of regression coefficient*	*No.*	*r*	*Mean cardiac diameter (SD)*	*Mean weight (SD)*	*SE about regression*
Men								
62–69	82·8218	0·7756	0·0899	108	0·64	136·7 (14·8)	69·5 (12·2)	11·41
70–79	97·0063	0·6238	0·1221	63	0·55	138·5 (13·6)	66·6 (12·0)	11·45
80–90	107·3236	0·5469	0·1796	17	0·62	144·1 (12·2)	67·2 (13·8)	9·90
Women								
62–69	80·3190	0·7511	0·0817	107	0·67	126·4 (13·5)	61·4 (12·0)	10·06
70–79	100·0138	0·5041	0·1141	76	0·46	131·4 (13·4)	62·2 (12·1)	11·99
80–90	88·1093	0·8469	0·2982	18	0·58	134·6 (14·7)	54·9 (10·1)	12·37

TABLE 6 *Comparison of measured and predicted values of transverse cardiac diameter in a second random sample*

Sex	*Mean measured diameter ± SE*	*Mean predicted diameter ± SE*	*Mean difference between measured and predicted diameter*	*SE of mean difference*	*t*	*No.*
Men	130·2 ±2·28	130·6 ±1·46	−0·4	1·76	0·23	25
Women	124·8 ±2·61	125·6 ±1·72	−0·8	2·11	0·39	24

compared with the diameter predicted from the regression equations given in this paper in Table 5. In both men and women, the mean difference between measured and predicted values of the transverse cardiac diameter did not differ significantly from zero (Table 6).

Discussion

The cardiothoracic ratio has been described as unsatisfactory by various authors. Ungerleider and Gubner (1942) refer to it as crude and inexact. Edge *et al.* (1964) conclude that the crude evaluation of cardiac enlargement in elderly people on the basis of a 50 per cent cardiothoracic ratio appears to be of no value. Since the ratio is still described in modern textbooks of radiology (Sutton and Grainger, 1969; Shanks and Kerley, 1962), it is worth restating that in older patients the cardiothoracic ratio is of little value as an indicator of cardiac enlargement. In the present study a cardiothoracic ratio of 50 per cent and over was found in 71 per cent of women of over 70 years. This is comparable with 40 of the 53 women of 75 years and over described by Edge *et al.* Mayer, Blazsik, and Rappaport (1958) after describing narrowing of the lower chest cage in aged men and women say that 'by comparison the heart often appears enlarged'.

Edge *et al.* (1964) described a slight reduction with increasing age in the transverse chest diameter in men and a more striking fall in women. Cowan (1959) found a significant reduction with age in women only. The present study, based on a random sample of the population, shows significant age-related reductions in the chest diameter in both sexes, the reduction being greater in women. This age difference presumably cannot all result from secular trend towards larger chests or from the death of persons with wider chests. It seems likely, particularly in older women, that developing kyphosis increases the anteroposterior chest diameter with resultant alteration in chest shape and narrowing of the transverse chest diameter. There is a significant negative relation between measurements of kyphosis and thoracic index, calculated as transverse divided by anteroposterior chest diameter (Milne, 1973).

Factors affecting the transverse cardiac diameter have been described by various authors. Ueda *et al.* studied citizens of Hiroshima in the ABCC Health Study (1958–60). They found that when the transverse cardiac diameter was examined in relation to weight, height, and age, it altered with alteration in any one of these variables, if the other two variables were specified. Their prediction equations therefore included age, weight, and height. Their subjects were aged 20 to 69 years. Cowan (1960), who studied elderly men and women from 60 to 79 years of age, found an increase in cardiac diameter with increasing age in men but not in women. In calculating prediction equations, he considered weight, chest diameter, height, and blood pressure as independent variables, but found that the addition of the latter two after weight and chest diameter did not improve prediction. These results differ from those in the present study in which the transverse cardiac diameter increases with age in both sexes. The present study revealed no improvement in prediction with the addition of height or chest diameter as independent variables after age and weight. The correlation between weight and transverse chest diameter is in fact greater than that between weight and height (Garn, 1962). In Cowan's (1960) equations, to predict cardiac diameter in women, allowance is made for age by computing the regressions separately in each decade. Ungerleider and Gubner (1942) found the influence of age and sex on heart size in adults to be relatively small compared with that of weight and height. They thought that age and sex could be disregarded in calculating prediction standards. These authors used insurance data based on younger subjects. The present study has shown that their findings are not true of older subjects, in whom a sex difference was present, and age and weight were the variables for prediction. Cowan (1960) also found a sex difference in the cardiac diameter of older people in his study.

The measurements described in this paper were made in the first round of a longitudinal study. It is hoped that eventually this study will allow the description of age changes in the same subjects instead of the age differences of cross-sectional study.

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14

LONGITUDINAL SURVEY OF ISCHAEMIC HEART DISEASE IN RANDOMLY SELECTED SAMPLE OF OLDER POPULATION

BY

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Longitudinal survey of ischaemic heart disease in randomly selected sample of older population

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A group of 215 men and 272 women aged 62 to 90 forming a randomly-selected sample of the older population was studied by cardiovascular survey methods and followed for 5 years. The 5-year mortality of 28 per cent was related to age and was higher in men. Ischaemic heart disease was the certified cause of 28 per cent of the deaths. Mortality was greater in those with systolic hypertension. Among electrocardiographic features ST depression, T inversion, and atrial fibrillation increased overall and ischaemic heart disease mortality independently of their association with age. A positive response to an angina and infarct questionnaire was poorly related to subsequent mortality.

Re-examination of 72 per cent of 5-year survivors was possible. Systolic and diastolic blood pressures were significantly lower and the frequency of electrocardiographic abnormalities, particularly left axis deviation, left ventricular hypertrophy, and ST and T wave changes, was increased.

In an earlier paper we reported (Kitchin *et al.*, 1973) on the prevalence of various manifestations of ischaemic heart disease in 487 subjects aged 62 to 90 who formed a randomly selected sample of the 27 000 older people living in a defined area of Edinburgh. Briefly this showed that 10 per cent gave a history of angina; 44 per cent had no codable electrocardiographic abnormality, 6 per cent had electrocardiographic abnormalities strongly suggestive of ischaemic heart disease, and a further 24 per cent had changes possibly caused by ischaemic heart disease. Pronounced left axis deviation was found in 8·8 per cent. Electrocardiographic evidence of ischaemic heart disease increased with age. Smoking habits, obesity, and hypertension were unrelated to manifestations of ischaemic heart disease.

This group of subjects was followed for 5 years from the initial survey and the survivors were restudied by the same methods and by the same observers. The object was to record mortality rates and the incidence of new manifestations of ischaemic heart disease in the 5-year period, and to relate these to subject characteristics at the start of the study.

Subjects and methods

The subjects were 215 men and 272 women aged 62 to 90 years. The method of sampling, including a comparison of respondents and non-respondents, has been described elsewhere (Milne *et al.*, 1971).

Standardised validated techniques were used (Kitchin *et al.*, 1973) and measures of reproducibility were obtained. The cardiovascular survey, which formed part of a larger survey, comprised the following:

(1) Rose's questionnaire in respect of angina pectoris and possible myocardial infarction (Rose and Blackburn, 1968).
(2) Twelve-lead electrocardiogram coded independently by two observers using the Minnesota code (Blackburn *et al.*, 1960). The same instrument was used throughout the study.
(3) Six-foot posteroanterior radiograph of the chest.
(4) Height, weight, skinfold thickness, and blood pressure using the London School of Hygiene instrument.
(5) Questionnaire on respiratory disease and smoking (Medical Research Council, 1965).
(6) General medical examination recorded on prepared proformata.

The χ^2 test was used to estimate the statistical significance of observed differences in the results.

Results

(1) MORTALITY AND CAUSE OF DEATH

Of the original 487 subjects, 138 died during the

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5-year period, an overall mortality of 28·3 per cent. Of these, 37 were certified as dying from myocardial infarction or ischaemic heart disease and 2 others from myocardial failure; the remaining 99 were non-cardiac deaths except for 2 from valvular heart disease. The expected death rate from national mortality statistics was 29·0 per cent (males 36%, females 24%). Table 1 shows mortality related to age and sex separating ischaemic heart disease from other deaths. In calculating death rate from ischaemic heart disease allowance has been made for the fact that those dying from non-cardiac causes were at risk of ischaemic heart disease death for 2½ years on average.

Mortality was higher in men and increased with age in both sexes. A possible relation to the following factors noted at the first examination was sought: positive response to Rose's questionnaire in respect of angina or infarction, systolic or diastolic hypertension, and specific electrocardiographic abnormalities.

Five-year mortality in those with a history of angina was 10/53 (19%) and in those without such a history it was 122/427 (29%). Deaths in those giving a history of infarction were 8/32 (25%) as compared with 125/449 (28%) in those without this history.

Table 2 shows the increased mortality in subjects with systolic or diastolic hypertension. In the case of the former, ischaemic heart disease accounts for a large proportion of the increased mortality. If we take levels of 160 and 100 as upper normal values, mortality from ischaemic heart disease was higher both for men and women with pressures over these levels.

Table 3 shows the 5-year overall and ischaemic heart disease mortality first in subjects with no codable electrocardiographic abnormality and then in groups with specific abnormalities. All types of electrocardiographic abnormality greatly increased the death rate from ischaemic heart disease, which was low (3·8%) and accounted for only 14 per cent of deaths in those with normal electrocardiograms at the start of the study. Atrial fibrillation was particularly unfavourable though numbers are small and comparison difficult. Left anterior hemiblock pattern, present in 8·8 per cent of subjects, did not significantly affect 5-year mortality.

Since both the prevalence of electrocardiographic abnormalities and mortality increase with age, the expected mortality in the absence of the specific electrocardiographic code was calculated for separate age groups, and the resulting total expected mortality compared with the observed number of deaths in those having the electrocardiographic abnormality. This shows that ST depression, T inversion, and atrial fibrillation have an unfavourable effect independent of their association with age.

Reid *et al.* (1966) made a further classification based on the Minnesota code with the object of selecting electrocardiograms indicating probable ischaemic heart disease (I_{1-2} or VII_1) and possible ischaemic heart disease (I_3 or IV_{1-3} or V_{1-3}). These two groups showed the highest estimated death rates from ischaemic heart disease (13·2%) and overall death rates (43%) and this applied to women as much as to men and to the lower as well as to the higher age group.

Table 1 *5-year mortality in 487 subjects*

	No.	*Per cent mortality*	*Deaths from ischaemic heart disease as per cent of all deaths*	*Estimated death rate from ischaemia heart disease (%)*
All subjects	487	28	28	8·9
Men				
60–69	122	28	35	10·8
70+	93	47	27	15·6
All	215	36	31	12·7
Women				
60–69	137	12	6	0·8
70+	135	33	32	11·7
All	272	22	25	6·4
All 60–69	259	19	26	5·4
All 70+	228	40	30	13·2

Table 2 *5-year mortality and blood pressure*

Blood Pressure (mmHg)	*No.*	*Per cent mortality*	*Deaths from ischaemic heart disease as per cent of all deaths*	*Estimated ischaemic heart disease death rate (%)*
Systolic				
⩾160	226	31	38	12·7*
⩽160	261	23	19	5·6*
Diastolic				
⩾100	76	38	31	13·8
⩽100	411	27	28	8·1

*P < 0·005.

CHANGES IN 5-YEAR SURVIVORS (252 subjects) Of the 349 subjects who survived 5 years, it was possible to re-examine 252 (72%). In these subjects a comparison was possible as regards response to angina questionnaire, blood pressure, and electrocardiographic coding (Tables 4, 5).

There was little overall change in frequency of positive questionnaire responses, but this conceals a considerable amount of individual change, e.g. nearly half the patients who gave a history of angina

Table 3 *5-year mortality and electrocardiogram Minnesota coding*

Code		*No.*	*Deaths*	*Deaths from ischaemic heart disease*	*Ratio observed/expected deaths (age adjusted)* *All deaths*	*Deaths from ischaemic heart disease*
No abnormality		264	63 (24%)	9 (3·4%)	—	—
I	Q/QS	37	14	4	1·24	1·03
II	Left axis deviation	46	15	6	1·07	1·30
III_{1+3}	LV hypertrophy	57	21	9	1·06	1·44
IV	ST depression	103	43	16	1·45‡	1·75‡
V	T inversion	138	58	20	1·59*	1·78†
VI	AV block	22	7	3	1·11	—
VII_{1+2}	Bundle-branch block	25	6	2	0·81	—
$VIII_3$	Atrial fibrillation	12	8	8	2·30‡	7·27†
I_{1+2} or VII_1§		29	11	5	1·49*	4·18*
I_3 or IV, V_{1-3}¶		120	52	15		

*P <0·005; †P <0·010; ‡P <0·02.
§I_{1+2} or VII_1, probable ischaemic heart disease; ¶I_3 or IV, V_{1-3}, possible ischaemic heart disease. Classification of Reid *et al.* (1966). 'Probable' ischaemic heart disease represents major Q and QS patterns or left bundle-branch block, 'possible' minor Q abnormalities or ST-T changes.

at the first survey did not do so at the second, while none of those who gave a positive response for infarction at the first interview did so at the second.

Blood pressure fell from 151·6 ± 2·4 mmHg systolic and 79 ± 1·3 mmHg diastolic to 145·6 ± 2·5 and 77·8 ± 1·3 respectively in men, and from 163·3 ± 2·2 systolic and 88·3 ± 1·3 diastolic to 148·3 ± 2·1 and 82·6 ± 1·3 in women. The magnitude of the fall was related statistically to the height of the initial pressure.

There was an increased frequency of all electrocardiographic abnormalities at the second survey, particularly for left axis deviation, left ventricular hypertrophy, ST-T changes, bundle-branch block, and atrial fibrillation. Where criteria depend on precise voltage measurement (ventricular hypertrophy and ST-T changes) it is perhaps not surprising that some which are outside the normal range on the first examination are within it at the second, despite careful attention to standardisation.

Discussion

The observed 5-year death rate in this randomly selected sample of the older population coincides closely with that predicted from national mortality statistics (Registrar General for Scotland, 1974). This gives confidence in the unselected nature of the sample.

The causes of death were found from certification data and the calculated death rates from ischaemic heart disease must, therefore, be regarded as tentative only. With this caveat, ischaemic heart disease accounted for 28 per cent of the 138 deaths in the 5-year period (31% in men and 25% in women), a figure that is rather less than expected from national statistics (37 and 36% respectively). The data confirm the sharp rising death rate with age and the higher rates in men than those in women.

An object of the longitudinal study was to examine the predictive value of patient characteristics related to ischaemic heart disease at the start of the study in respect of subsequent mortality. Positive responses to the angina and infarction questionnaire of Rose and Blackburn (1968) were unrelated to mortality in this series of subjects, though it should be noted that numbers at risk were relatively small (53 and 32). It might have been expected that those with a positive response would fare worse. However, the variability of response shown when the subjects were tested a second time must cast doubt on the reliability of the answers in older subjects, in addition to the well-known difficulty in relating chest pain to cardiac pathology in the individual case. Repeatability of the angina questionnaire has been found to be poor in both middle-aged (Rose, 1968; Zeiner-Henriksen, 1972) and elderly (Milne *et al.*, 1969) subjects.

Systolic hypertension significantly increased mortality from ischaemic heart disease. Diastolic hypertension appeared to do so also (Fig. 1), though perhaps because of the small numbers statistical

Table 4 *Change in 5-year survivors (252 subjects) response to angina and infarct questionnaire*

	Initial positive response	*Change after 5 years*	*Final positive response*
Angina	31/252 (12%)	−14 +16	33/252 (13%)
Infarct	14/252 (6%)	−14 + 6	6/252 (2%)
Neither	215/252 (86%)	−18 +19	216/252 (86%)

Table 5 *Changes in electrocardiographic Minnesota coding in 5-year survivors (252 subjects)*

		Initial positive finding	*Change after 5 years*	*Final positive finding*	*5-year increase in frequency (%)*
I	Q/QS	16/252 (6%)	−6 +9	19/252 (8%)	2
II	Left axis deviation	21/252 (8%)	−3 +22	40/252 (16%)	8
III_{1+3}	Left ventricular hypertrophy	31/252 (12%)	−9 +25	47/252 (19%)	7
IV	ST depression	39/252 (15%)	−11 +28	56/252 (22%)	7
V	T inversion	52/252 (21%)	−13 +31	70/252 (28%)	7
VI	Atrioventricular block	11/252 (4%)	−6 +7	12/252 (5%)	1
VII_{1+2}	Bundle branch block	16/252 (6%)	−3 +10	23/252 (9%)	3
$VIII_3$	Atrial fibrillation	12/252 (5%)	−6 +17	23/252 (9%)	4

significance was not reached. The effect of systolic hypertension on overall mortality was significant only in women. During a 14-year period in the Framingham study a raised systolic blood pressure was more strongly associated with development of ischaemic heart disease than was raised diastolic pressure (Kannel *et al.*, 1971), and the importance of systolic pressure in this association was greater with increasing age.

Ischaemic changes in the initial cardiogram, defined by Rose and Blackburn, had a strong predictive value, increasing the ischaemic heart disease death rate fourfold and the overall death rate by 50 per cent. ST and T wave abnormalities and atrial fibrillation indicated a particularly poor prognosis. Higgins *et al.* (1963), studying a younger sample of the male population aged 35 to 64, also noted an increased risk of dying, and of being recorded as dying a cardiac death, where the electrocardiogram was compatible with ischaemic heart disease, showing Minnesota Code items I, IV, and V.

We can, from the present data, record the new occurrence of electrocardiographic abnormalities in the 5-year period in the 252 examined survivors. Numerically the greatest increase is in T wave inversion (7%) and ST depression (7%) followed by left ventricular voltage increases (7%) and left axis deviation (8%). Proportionately high increases, however, also occur in atrial fibrillation (5 to 9%) and bundle-branch block (6 to 9%). These changes reflect predominantly ischaemic or conduction system disease.

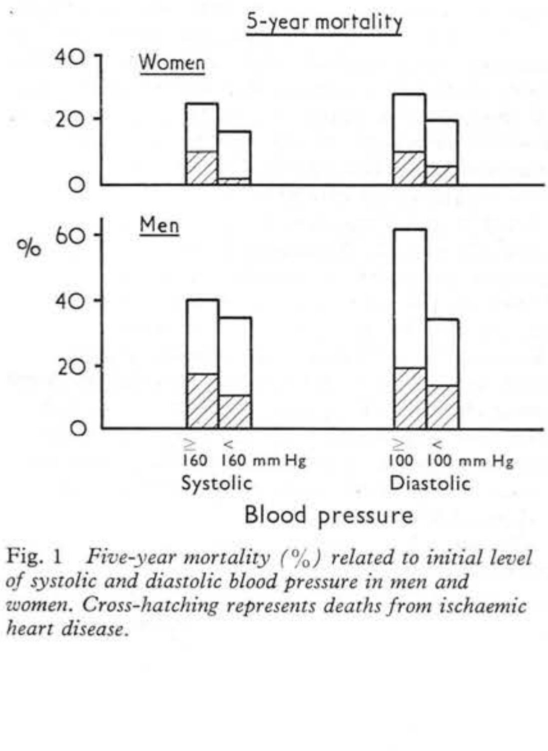

Fig. 1 *Five-year mortality (%) related to initial level of systolic and diastolic blood pressure in men and women. Cross-hatching represents deaths from ischaemic heart disease.*

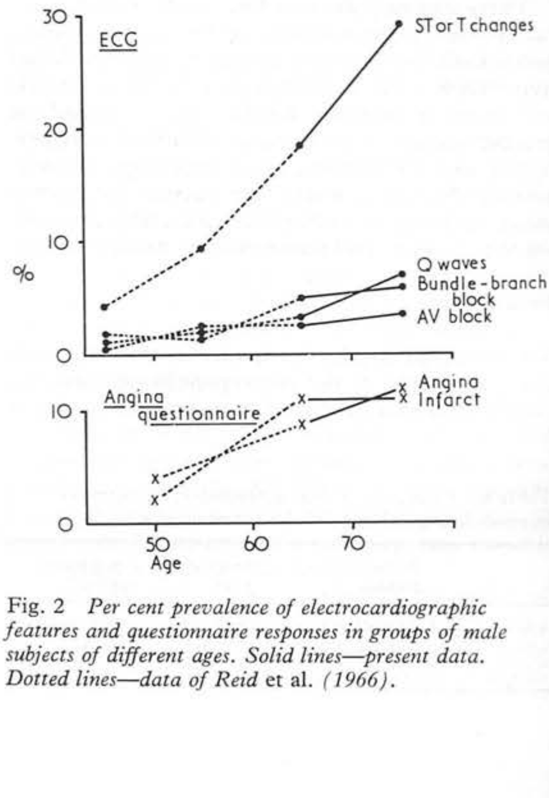

Fig. 2 *Per cent prevalence of electrocardiographic features and questionnaire responses in groups of male subjects of different ages. Solid lines—present data. Dotted lines—data of Reid* et al. *(1966).*

It is interesting to compare the increased incidence recorded in the 5-year longitudinal study with the prevalence rates in different age groups at the start of the study (Fig. 2; Kitchin *et al.*, 1973). The rates of increase with age of the prevalence of T and ST changes, Q waves, bundle-branch block, and atrioventricular block correspond closely with the observed incidence figures.

Conclusion

(1) The 5-year death rate in the older population is age- and sex-related. Both the overall death rate and deaths from ischaemic heart disease are strongly related to specific electrocardiographic abnormalities at the start of the period, ST depression, T inversion, and atrial fibrillation, but unrelated to the angina questionnaire response. Mortality from ischaemic heart disease is related to systolic blood pressure.

(2) Questionnaire responses elicited at a 5-year interval were inconsistent in many cases.

(3) In this sample, representative of the older population, the cardiographic features of ST and T wave changes, left ventricular hypertrophy, and left axis deviation each rose at a rate of approximately 1·5 per cent per annum. Conduction disturbances, atrial fibrillation, and Q wave changes developed much less frequently.

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LONGITUDINAL STUDY OF HEART SIZE IN OLDER PROPLE

BY

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Longitudinal study of heart size in older people

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Transverse cardiac diameter and transverse thoracic diameter were measured in a longitudinal study of older men and women at the original examination and after five years. The cardiothoracic ratio overestimated 5-year changes in heart size, because of significant decreases with age in transverse thoracic diameter. A regression equation to predict transverse cardiac diameter from age and weight had been previously computed from the data obtained at the initial examination. This was a satisfactory predictor of recorded 5-year changes except in women of 70 years and over at entry to the study in whom the predicted change was significantly larger than the recorded change. This had resulted from the death during the 5 years of women in that age group with larger transverse cardiac diameters.

A previous paper described measurements of transverse cardiac diameter and transverse chest diameter in a random sample of older people (Milne and Lauder, 1974). The conclusion drawn from analysis of these cross-sectional data was that the cardiothoracic ratio was an unsatisfactory estimate of heart size in the elderly because of decrease in the transverse chest diameter as age increased. Transverse cardiac diameter was a better estimate of heart size, and equations were derived to predict this diameter from age and weight. In both sexes, the transverse cardiac diameter increased significantly as age increased.

The present paper describes the result of re-measurement of the survivors of the original study after 5 years. A comparison has also been made of cross-sectional with longitudinal data.

Methods

The original study was made on 215 men and 272 women aged 62 to 90 years who formed a simple random sample from 27 000 older people living in a defined area of Edinburgh. The method of sampling has been fully described elsewhere (Milne, Maule, and Williamson, 1971). The persons examined in the present study were those members of the original sample who were alive after 5 years and who were willing to attend for re-examination. These numbered 113 men and 148 women. The follow-up of persons in the sample has been fully described elsewhere (Milne and Chopin, 1975).

Posteroanterior chest *x*-rays were taken at both examinations, at a tube-film distance of 183 cm (6 ft) at the height of a less than maximal inspiration. The transverse cardiac diameter and the transverse chest diameter were measured to the nearest millimetre on the films, using a Harpenden anthropometer (Tanner and Whitehouse, 1957) with straight branches. This sliding caliper allowed measurement of the transverse cardiac diameter in one simple operation (Milne and Lauder, 1974). The transverse chest diameter was measured from the internal surfaces of the ribs, superior to the costal attachment of the diaphragm, at the point where the chest width was greatest (Cowan, 1959). Suitable measurements of cardiac diameter were obtained in 113 men and 139 women and of chest diameter in 95 men and 137 women. The cardiothoracic ratio was expressed as $100 \times$ (transverse cardiac diameter/transverse chest diameter). In the original sample the mean cardiac diameter was significantly larger in persons with diastolic pressures of 100 mmHg or more. This was no longer true in the 5-year examination and measurements of persons with these pressures (5 men, 18 women) were not excluded from the analysis. Unpublished data from the study show that the mean diastolic blood pressure in survivors after 5 years is significantly lower than at the original examination.

Reproducibility of the measurements was satisfactory. The method of testing this has been fully described elsewhere (Milne and Lauder, 1974).

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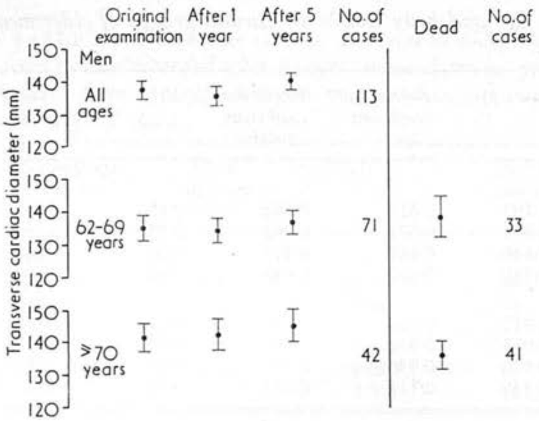

FIG. 1. *Mean transverse cardiac diameters with 95 per cent confidence limits in surviving men in a longitudinal study, and in those who died.*

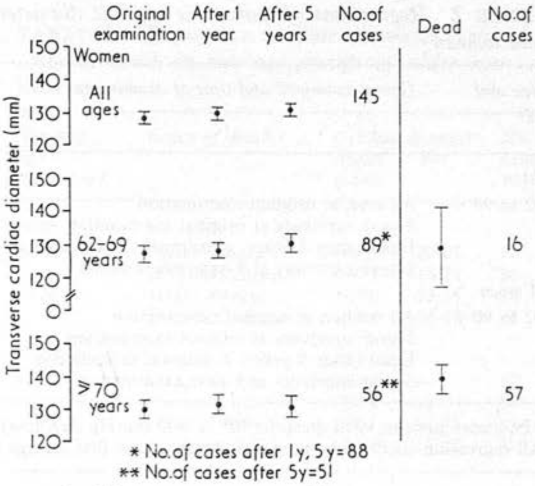

FIG. 2. *Mean transverse cardiac diameters with 95 per cent confidence limits in surviving women in a longitudinal study, and in those who died.*

Results

Mean values of transverse cardiac diameter with 95 per cent confidence limits are given for men in Fig. 1 and for women in Fig. 2. Apart from the dead all measurements refer to those survivors who were examined after 5 years and ages given are on entry to the study. The age categories were 'below 70 years' and '70 years and over'.

The mean values suggested an increase in cardiac diameter over the 5-year period, but this did not reach statistical significance. In the men and younger women who died, cardiac diameters at the original examination did not differ from those in survivors. In women who died and who were 70 years and over on entry to the study, the mean cardiac diameter was significantly greater at the original examination than in surviving women of the same age group, both at the original examination and when measured again five years later.

Mean values and 95 per cent confidence limits of transverse chest diameter were similarly examined. No significant difference was found, when comparing appropriate age groups, among surviving or dead subjects. These values are, therefore, not reported further.

In each surviving subject the measurement of transverse cardiac diameter at the original examination was subtracted from the measurement at the 5-year examination. This was done also for the transverse chest diameter and for the cardiothoracic ratio. Mean differences with standard errors of these three variables are given in Table 1. Student's two-tail t test was used to test whether mean differences differed significantly from zero.

The tests showed that the mean differences in the cardiac diameter in 5 years were significant in men of 70 years and over ($P<0{\cdot}05$) and in women of 62 to 69 years ($P<0{\cdot}001$). The ages are those

TABLE 1 *Mean differences in transverse cardiac diameter, transverse chest diameter, and cardiothoracic ratio, after 5 years, in two age groups of older men and women*

Age (at entry)	*Cardiac diameter (mm)* Mean difference	SE	*No. of cases*	*Chest diameter (mm)* Mean difference	SE	*No. of cases*	*Cardiothoracic ratio (%)* Mean difference	SE	*No. of cases*
Men									
62 to 69 y	1·282	1·035	71	−2·421*	1·161	57	1·137*	0·436	57
≥70 y	3·643*	1·509	42	−1·237	2·184	38	1·253*	0·552	38
Women									
62 to 69 y	3·483***	0·793	88	−2·553*	1·108	85	1·939***	0·407	85
≥70 y	1·784	1·228	51	−3·462**	1·194	52	1·439***	0·461	51

*$P<0{\cdot}05$ **$P<0{\cdot}01$ ***$P<0{\cdot}001$.

TABLE 2 *Regressions of transverse cardiac diameter on age and body weight in various groups of older men and women*

Sex and age	*Group examined and time of examination*	*Intercept*	*Regression coefficient (age)*	*Regression coefficient (weight)*	*R*	*No. of cases*
Men						
62 to 90 y	All men at original examination	61·762	0·413	0·692	0·62	188*
	5-year survivors at original examination	58·581	0·372	0·762	0·65	113
	Dead (after 5 years) at original examination	57·346	0·485	0·719	0·57	74
	5-year survivors at 5-year examination	47·781	0·699	0·643	0·57	113
Women						
62 to 90 y	All women at original examination	42·942	0·646	0·661	0·61	201*
	5-year survivors at original examination	70·003	0·334	0·567	0·57	145
	Dead (after 5 years) at original examination	20·876	0·930	0·766	0·64	52
	5-year survivors at 5-year examination	94·339	0·111	0·481	0·44	139

*Excludes persons with diastolic BP $\geqslant$ 100 mmHg (see text).
All regression coefficients were significant except that for age in women 5-year survivors at the 5-year examination.

at entry to the study. Significant differences in the mean chest diameter were found in all groups except men of 70 years and over. Differences in the mean cardiothoracic ratio occurred in both groups of men ($P<0{\cdot}05$) and of women ($P<0{\cdot}001$). When the signs of the differences are taken into account, the findings of the analysis are increases with age in mean heart size estimated by the cardiothoracic ratio in all groups, but increases in mean cardiac diameter only in older men and younger women. The difference in behaviour of these two variables is the result of the different levels of decrease in transverse chest diameter (Table 1). The large number of missing values of transverse chest diameter is the result of failure to include the whole width of male thoraces on some of the films taken at the original examination.

Data collected at the original examination from all persons taking part then, except those with diastolic blood pressure of 100 mmHg or more, were used to derive an equation to predict transverse cardiac diameter from age and body weight (Milne and Lauder, 1974). The regression coefficients are shown in Table 2, rows 1 and 5.

A similar equation was derived, for 5-year survivors, with age and body weight as the independent variables, using the data which had been collected at the original examination (Table 2, rows 2 and 6). In men the regression coefficients were similar to those in the first equation based on the whole sample, while in women, though the coefficient of regression on body weight was similar, the coefficient of regression on age was about half the value of that in the equation based on the whole sample.

An equation was similarly derived, using data obtained at the original examination from persons who died during the 5 years of the study (Table 2, rows 3 and 7); again regression coefficients in men resembled those in the first equation in Table 2, but in women the coefficient of regression on age was larger than that in the first equation. These differences in the coefficients of regression on age in women, though not statistically significant, suggest larger cardiac diameters in older women who died.

Finally, the regression of transverse cardiac diameter on age and body weight was calculated in surviving men and women using data gathered at the 5-year examination (Table 2, rows 4 and 8). Once again in men the regression coefficients were similar to those in the first equation in Table 2 but in women age ceased to make a significant contribution to the regression. This again suggested a loss from the sample of older women with larger hearts.

To test this hypothesis the regressions of transverse cardiac diameter on age and body weight based on the original data (Table 2, rows 1 and 4) were used to calculate the expected cardiac diameter in survivors examined 5 years after the original examination. The age used in the equation was age at entry plus 5 years. This predicted value was subtracted in each subject from the transverse cardiac diameter recorded at the 5-year examination (Table 3). This Table shows reasonable agreement between predicted and actual values except in women aged 70 years and over at original examination, in whom the mean predicted value was significantly larger than the mean recorded value.

The mean cardiac diameter was next examined using the original data, in the dead and in the survivors of men and women in both age groups on entry to the study. These survivors were not only those re-examined after 5 years but also included those who survived and after the first examination

TABLE 3 *Transverse cardiac diameter in older men and women recorded after 5 years minus diameter predicted from the regression on age† and weight based on original data*

Sex and age (at entry)	*Mean difference (mm)*	*SD*	*No. of cases*
Men			
62 to 69 y	−0·977	12·315	69
⩾70 y	1·608	12·191	39
Women			
62 to 69 y	0·323	9·984	76
⩾70 y	−3·631*	9·957	44

*$P<0.05$.
†Age used in regression equals age at entry + 5 years.

TABLE 4 *Transverse cardiac diameter at original examination in two age groups of men and women separated into those who died and those who were alive 5 years later*

Sex and age (at entry)	*Alive Mean (mm)*	*SE*	*No. of cases*	*Dead Mean (mm)*	*SE*	*No. of cases*
Men						
62 to 69 y	136·2	1·50	88	139·0	2·91	33
⩾70 y	142·6	1·96	49	136·7	2·21	41
Women						
62 to 69 y	128·2	1·18	118	129·5	5·66	16
⩾70 y	128·8	1·36	86	139·7**	2·30	37

**$P<0.01$.

were lost to the study for reasons other than death. Table 4 gives mean values with standard errors for these groups. The mean values in the dead and the survivors did not differ significantly except in women of 70 years and over ($P<0.01$, two-tail test). In this group the mean cardiac diameter of the dead women appeared to be larger than that of the survivors. This confirmed the impression, described above, gained from studying coefficients of regression of cardiac diameter on age, using the data from the original examination, in women who survived for 5 years and in those who died.

Mean cardiac diameters were compared in men and in women, aged 62 to 69 and 70 years and over on entry to the study, who were recorded as dying of heart disease and of diseases other than heart disease during the subsequent 5 years (Table 5). A significant difference ($P<0.05$) in the transverse cardiac diameter was found only comparing women of 70 years and over who died of heart disease with those who died of another cause. In these women the

TABLE 5 *Transverse cardiac diameter related to cause of death in two age groups of older men and women*

Sex and age (at entry)	*Cause of death*	*Cardiac diameter Mean (mm)*	*SD*	*No. of cases*
Men				
62 to 69 y	Heart disease	142·4	20·01	11
	No heart disease	140·1	15·51	20
⩾70 y	Heart disease	140·8	12·35	12
	No heart disease	134·9	14·63	29
Women				
62 to 69 y	Heart disease	(152·0)	—	(2)
	No heart disease	126·3	16·70	14
⩾70 y	Heart disease	148·1	14·87	14
	No heart disease	134·5	11·02	22

mean transverse cardiac diameter was larger in the group who died of heart disease; no significant difference was found in the other three groups.

Discussion

This study has confirmed from a 5-year follow-up what was suspected from cross-sectional data (Milne and Lauder, 1974), namely that the cardiothoracic ratio overestimates changes in heart size in the elderly. The data given above suggest that this is because of decrease in transverse thoracic diameter in many people as age increases. Other workers have also thought, on the basis of cross-sectional studies, that transverse thoracic diameter decreases with increasing age (Cowan, 1959; Mayer, Blazsik, and Rappaport, 1958; Edge *et al.*, 1964) but longitudinal studies such as the present one are a more certain method of confirming the hypothesis.

The various methods of data analysis used above suggested that the greatest difference between changes in cardiac diameter predicted from age differences in a cross-sectional study of the elderly and the actual changes recorded after 5 years, was found in women 70 years and over on entry to the study. This resulted from the death of women in this age group who had larger cardiac diameters. In the same age group of women the mean cardiac diameter was larger in those whose deaths were the result of heart disease than in those whose deaths were from other causes.

The regression of transverse cardiac diameter on age and weight based on cross-sectional data from men in the present study has been a reasonable predictor of changes in cardiac diameter over 5 years. In women a similar equation predicted 5-year changes greater than those that actually occurred. The loss by death of older women with larger cardiac diameters eliminated age from the regression in the survivors. Though the present study offers no confirmatory data, one might speculate that the difference described between men and women was a reflection of different time relations in the sexes between heart disease and mortality.

The increase in transverse cardiac diameter over 5 years in women aged 62 to 69 years at entry to the study does not preclude the possibility that the relation observed in this sample between transverse cardiac diameter and mortality in women aged 70 years and over at entry to the study may be a general phenomenon in the female population.

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A LONGITUDINAL STUDY OF BLOOD PRESSURE AND STROKE IN OLDER PEOPLE

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ABSTRACT

Blood pressure was measured with the LSH sphygmomanometer in Edinburgh in a random sample consisting of 215 men and 272 women aged 62-90 years. The measurement was repeated in 113 men and 148 women after one and five years. The prevalence of stroke at the start of the study and its incidence during five years were also recorded.

Significant cross-sectional falls in diastolic pressure occurred in both sexes at the first examination. Longitudinal readings showed regression towards the mean if change over an interval was related to blood pressure at the start of that interval but not if the change was related to an earlier blood pressure reading. Over four years significant falls occurred only in women and only in diastolic pressure.

Systolic hypertension ($\geqslant$160 mm Hg) was found in 35% of men and 53% of women, who were re-examined after 5 years, at the first examination but only in 9% of men and 17% of women did it persist in all three examinations. It first appeared in 11% of subjects at one year and 18% of subjects at 5 years but was present on both occasions in only 4% of subjects.

Stroke had already occurred in 27 subjects at the first examination. Of these 3 died and 9 were re-examined at the five year review by which time 13 new cases of stroke had appeared and survived, while 21 new cases had appeared and died. No relationship between stroke and blood pressure was found in this study.

INTRODUCTION

The importance of blood pressure as a clinical measurement in older people is shown by recent papers associating stroke or cardio-vascular disease in the elderly with hypertension (Colandrea et al 1970, Dall 1979). This association has been demonstrated in early and late middle age (Cutler 1967, Chapman et al 1966, Kannel et al 1965) and has been used to justify the treatment of high blood pressure in these age groups in apparently well persons. Longitudinal studies of samples of the elderly population are therefore needed to discover whether a relationship between blood pressure and future morbidity persists into old age.

The present paper reports measurements of blood pressure in a longitudinal study of ageing persons in Edinburgh and attempts to relate the results to the prevalence and incidence of stroke. This study, which included examinations by a physician, a psychiatrist and a dietician, was designed to record changes in physical and mental health and in normal measurements over a period of years in a random sample of older people.

SUBJECTS AND METHODS

The subjects studied in the first examination (1968-69) were 215 men and 272 women, aged 63-90 years, who formed a simple random sample of the 27,000 older people living in ten city wards in Edinburgh. Details of sampling with a comparison of respondents and non-respondents have been published elsewhere (Milne et al 1971). Further examinations were made after one year (1969-70) and five years (1973-74). At the five year examination it was possible to see 113 men and 148 women and only these subjects were included in reports of follow-up data. During the five years 78 men and 60 women had died, leaving 24 men and 64 women who for various reasons were not re-examined. Follow-up of the sample has been described in detail elsewhere (Milne and Chopin 1975).

Blood pressure was measured at each examination using the London School of Hygiene (LSH) sphygmomanometer (Rose et al 1964). All measurements were made by the author who used the training tape-recordings supplied by the LSH (Rose 1965) to improve his interpretation of Korotkov sounds. The testing tape-recordings supplied were used to check reproducibility before, during and after the study. Following pilot measurements of upper arm circumference in many elderly people, a cuff was used containing an inflatable bag 45 cm long and 13 cm wide, with Velcro fastening. The length chosen ensured that the rubber bag was likely to encircle completely all the arms in the study.

Blood pressure was measured, in the right arm, once only on each occasion, immediately after the questionnaire with which the examination started. Subjects were seated with the right forearm on a table. The temperature of the room did not vary much from 21^{o}C at any season.

RESULTS

Blood pressure at the first examination

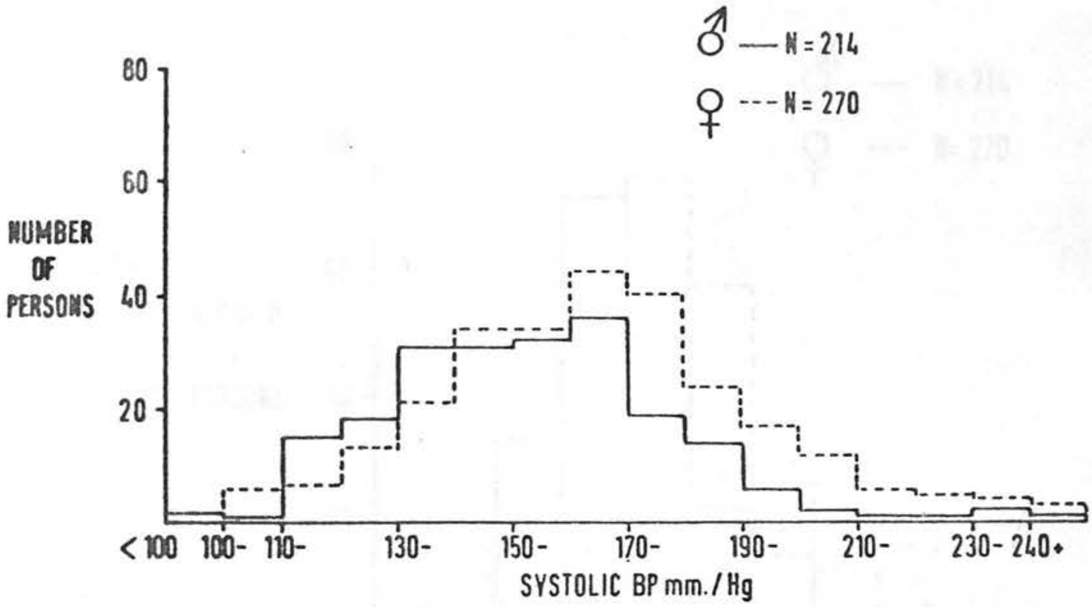
The distributions of systolic and diastolic (phase 5) blood pressure are given in figures 1 and 2. Mean values with standard deviations of systolic and diastolic pressures are shown in table 1, in three age groups of men and women. The apparent fall of diastolic pressure as age increases is significant in men for phases 4 and 5 and in women for phase 5. There are no age effects for systolic pressure in men and those in women are complicated by the high mean value in the eighth decade. All mean values in women in the table are higher than corresponding values in men.

Longitudinal blood pressure readings

Changes in blood pressure over periods of time in the study were computed by subtracting, for each subject, the one year reading from the original reading (one year change) the five year reading from the original reading (five year change) and the five year reading from the one year reading (four year change). These calculations were made for systolic and diastolic phase 5 pressures. The method of calculation makes a fall in pressure over any period of time appear as a positive change.

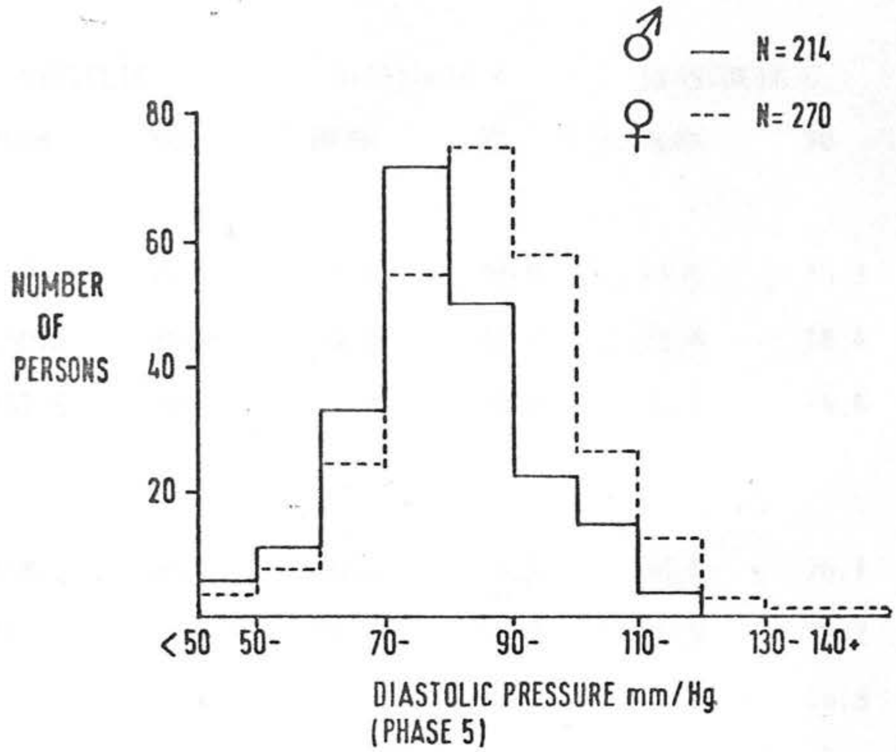
The distributions of the changes were Gaussian. Linear regressions of the changes on age were calculated for each sex and each blood

FIGURE 1



Distributions of systolic blood pressure at the first examination of a random sample of older men and women.

FIGURE 2



Distributions of diastolic pressure (phase 5) at the first examination of a random sample of older men and women.

TABLE I

Mean values with standard deviations (SD) of blood pressure readings in older men and women at the first examination.

SEX and AGE	N	SYSTOLIC MEAN	SYSTOLIC SD	DIASTOLIC 4 MEAN	DIASTOLIC 4 SD	DIASTOLIC 5 MEAN	DIASTOLIC 5 SD
Men							
62-69	121	152.3	25.2	82.4	13.8	79.9	13.3
70-79	73	150.5	26.7	78.5	18.9	77.4	16.4
$\geq$80	20	157.5	22.5	74.0	17.1	70.7	16.5
Women							
62-69	136	158.5	26.0	89.0	16.7	86.8	16.1
70-79	101	173.6	31.3	86.8	19.2	86.8	19.2
$\geq$80	33	163.1	25.5	82.8	16.9	80.2	15.8

pressure. Since none of the lines had a significant slope, data concerning the changes are reported in table II without division by age. A 't' test was used to find out whether the mean values given differed significantly from zero. All the mean changes in the table were positive and hence showed falls in mean blood pressures.

In both sexes mean changes in systolic pressure were significantly different from zero for the one year and the five year changes but not for the four year ones.

None of the diastolic changes was significantly different from zero in men. In women significant mean falls in diastolic pressure occurred in all three periods. All mean decreases were larger in women.

Variability in changes in blood pressure with time in the present study is examined in figures 3 and 4 in which changes in blood pressure over a period of time are plotted against blood pressure readings. In each figure the lines marked 1 and 2 show respectively the linear regression of five year changes on the original blood pressure readings and the linear regression of four year changes on the one year readings. The lines marked 3 show the linear regression of the four year changes (i.e. between the one year and five year examinations) on the blood pressure at the original examination.

All lines marked 1 and 2 have significant slopes ($p < 0.001$) and display the phenomenon, well known in studies of blood pressure, of regression towards the mean i.e. values of blood pressure initially

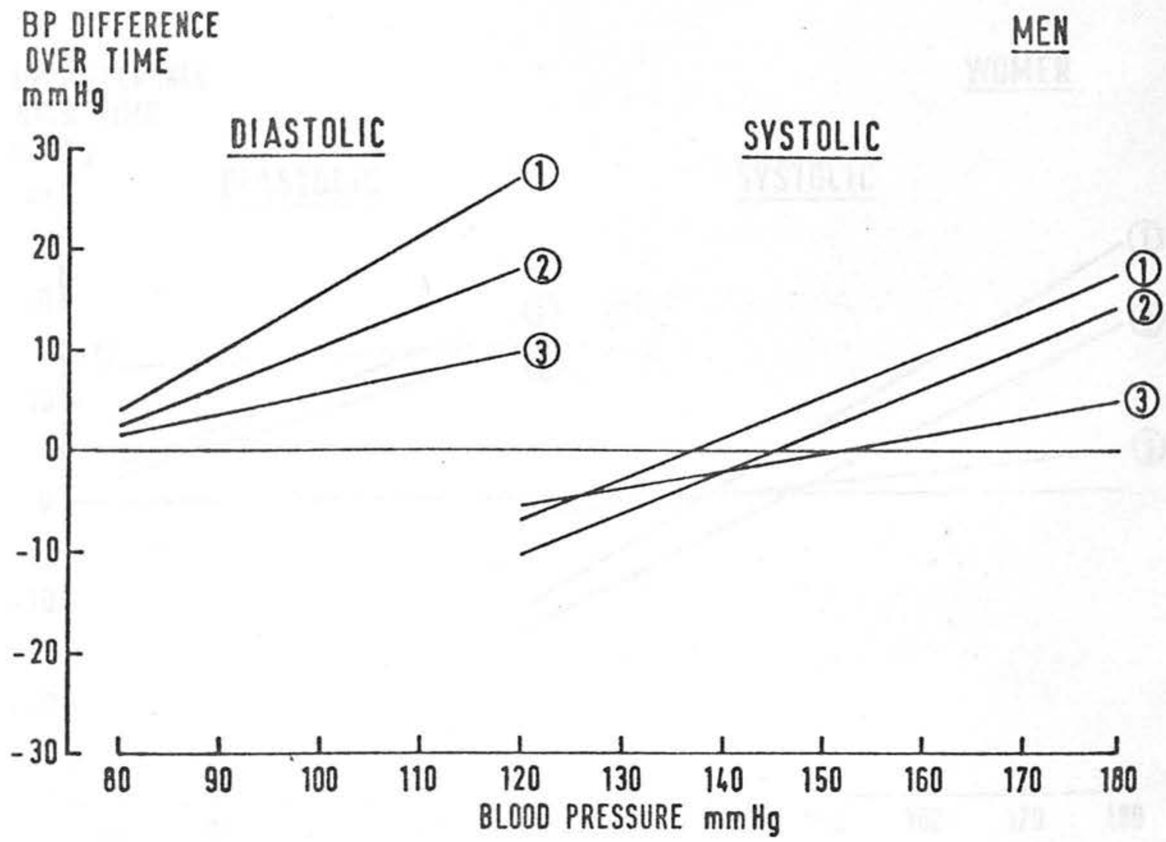
TABLE II

Mean values with standard deviations (SD) and standard errors (SE) of 1 year, 5 year and 4 year changes in blood pressure in a longitudinal study of older people. Subscripts refer to original (o), one year (1) or five year (5) examination.

CHANGE	MEN MEAN	N = 113 SD	SE	WOMEN MEAN	N = 148 SD	SE
SBP_o minus SBP_1	5.9**	19.2	1.8	12.4**	23.2	1.9
SBP_o minus SBP_5	5.9*	24.6	2.3	15.0**	28.2	2.3
SBP_1 minus SBP_5	0.01	24.2	2.3	2.6	25.8	2.1
DBP_o minus DBP_1	1.7	9.7	0.9	2.5*	11.7	1.0
DBP_o minus DBP_5	2.7	14.4	1.4	5.8**	14.1	1.2
DBP_1 minus DBP_5	1.0	12.2	1.2	3.3**	13.8	1.1

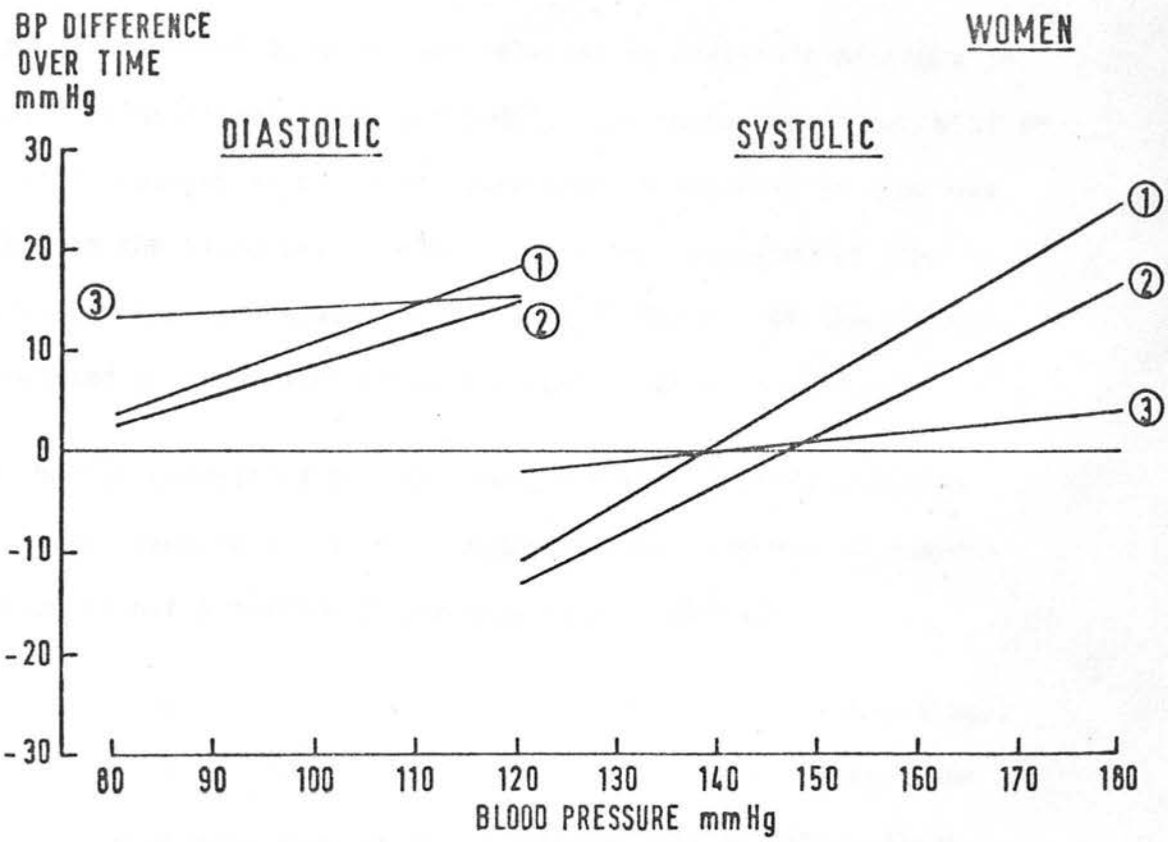
* $p < 0.05$ ** $p < 0.01$

FIGURE 3



Linear regressions, in men, of five year changes in blood pressure on the original readings (1), of four year changes on the one year readings (2), and of four year changes on the original readings (3).

FIGURE 4



Linear regressions, in women, of five year changes in blood pressure on the original readings (1), of four year changes on the one year readings (2), and of four year changes on the original readings (3).

low tend to rise and those initially high tend to fall during the period of the study.

Of the lines marked 3, only that relating to diastolic pressure in men has a significant slope ($p < 0.05$). The suggested interpretation is that if changes in blood pressure over an interval of time are related to the blood pressure reading at the beginning of that interval, regression towards the mean will occur. If the changes are related to an earlier blood pressure reading it will not.

Mean changes calculated as above over a range of blood pressure, have large standard deviations suggesting that regression towards the mean is not a uniform phenomenon in all subjects.

Four year changes in blood pressure were calculated as percentages of the original readings in three groups : increase greater than 5%, decrease greater than 5% and no change (+5% to -5%). There were no sex differences in the proportions in these groups. For all subjects the percentages with increase, decrease and no change were respectively 33, 37 and 30 for systolic and 29, 30 and 41 for diastolic pressure.

Blood pressure and stroke

At the first examination 10 men and 17 women of 487 persons examined had already had a stroke. Of the 261 persons examined at the five year review 2 men and 7 women remained of those who had a stroke before the study began while 7 men and 6 women had had a stroke in the succeeding five years. There were 24 persons with fatal strokes during the five years of whom 3 women had had a stroke before the study began and 21 (9 men, 12 women) were new cases who died during the five years. Stroke prevalence and incidence are related to the distributions of systolic and diastolic pressures, measured at the first examination, in tables III and IV. The sexes are combined because no sex difference was found in the distributions. There is no significant relationship in the tables between blood pressure and stroke.

Mean values of blood pressures +- standard errors, measured at the first examination, in certain groups with and without stroke are reported in table V. The groups with stroke have higher mean values than corresponding groups without stroke, but none of the differences is significant. The only significant difference in the table is that the mean systolic pressure in women who later died from a cause other than stroke was significantly higher than that in those who later died of stroke ($p < 0.05$).

Effects of hypertension

The subjects were divided into those with systolic pressures <160 and $\geqslant 160$ mm Hg and those with diastolic pressures <100 and $\geqslant 100$ mm Hg.

At the first examination 82 (38.5%) of 213 men and 153 (57.3%) of 267 women had systolic hypertension as defined while 19 (8.9%) of the men and 45 (16.9%) of the women had diastolic hypertension. The greater prevalence in women in significant in respect of both types of hypertension ($p < 0.01$). The first examination revealed 17 men (8.0%) and 38 women (14.2%) in whom systolic pressure was $\geqslant 160$ mm Hg and diastolic pressure was $\geqslant 100$ mm Hg. The sex difference is

TABLE III

Prevalence and incidence of stroke related to systolic pressure in older men and women. (Percentages of row totals in brackets).

	SYSTOLIC <120	120-	BP 140-	mm 160-	Hg ≥180	TOTALS
1st Examination Stroke	3 (11.1)	3 (11.1)	5 (18.5)	8 (29.6)	8 (29.6)	27
No stroke	34 (7.5)	86 (19.0)	125 (27.6)	125 (27.6)	83 (18.3)	453
Three Examinations Old stroke*	-	1	4	2	2	9
New stroke	1 (4.5)	1 (9.1)	4 (36.4)	6 36.4)	1 (13.6)	13 **
No stroke	21 (8.9)	43 (18.1)	74 (31.2)	58 (24.5)	41 (17.3)	237
Fatal strokes	2^+ (8.3)	6 (25)	5 (20.8)	5^+ (20.8)	6^+ (25)	24

* before first examination

** percentages of old and new stroke combined.

Each$^+$ means one stroke before first examination.

TABLE IV

Prevalence and incidence of stroke related to diastolic pressure in older men and women. (Percentages of row totals in brackets).

	DIASTOLIC BP mm Hg					TOTALS
	< 60	60-	80-	100-	⩾120	
1st Examination						
Stroke	1 (3.7)	13 (48.1)	8 (29.6)	5 (8.5)	-	27
No stroke	31 (6.8)	174 (38.4)	190 (41.9)	54 (11.9)	4 (0.9)	453
Three Examinations						
Old stroke*	-	7	1	1	-	9
New stroke	1 (4.5)	2 (40.9)	6 (31.8)	3 (18.2)	1 (4.5)	13 **
No stroke	13 (5.5)	96 (40.5)	105 (44.3)	21 (8.9)	2 (0.8)	237
Fatal stroke	2^{+} (8.3)	6 (25)	10^{++} (41.7)	6 (25)	-	24

* before first examination.

** percentage of old and new stroke combined.

Each + means one stroke before first examination.

TABLE V Mean values ± standard errors (SE) of blood pressure (recorded at first examination) in three groups of older men and women with and without stroke.

	STROKE			NO STROKE		
	SYSTOLIC MEAN ± SE	DIASTOLIC MEAN ± SE	N	SYSTOLIC MEAN ± SE	DIASTOLIC MEAN ± SE	N
Men						
1st examination	160.1 ± 11.8	78.3 ± 3.5	10	152.0 ± 1.8	78.2 ± 1.1	203
Died during 5 yrs	159.4 ± 9.8	85.8 ± 5.2	9	150.7 ± 3.4	77.1 ± 1.9	68
5 yr survivors	165.1 ± 10.3	83.7 ± 6.2	9	150.4 ± 2.4	77.3 ± 1.3	104
Women						
1st examination	172.8 ± 10.1	88.6 ± 4.2	17	163.8 ± 1.7	85 ± 1.1	250
Died during 5 yrs	154.4 ± 7.4	78.2 ± 6.8	15*	178.2 ± 5.4	86.2 ± 2.8	44
5 yr survivors	164.5 ± 5.8	89.4 ± 4.7	13	163.2 ± 2.4	85.7 ± 1.4	133

* 3 strokes before 1st examination.

significant ($p<0.05$).

The difficulty in clearly identifying hypertension is shown by longitudinal data from five year survivors in table VI. Although 35% of surviving men and 53% of surviving women had systolic hypertension at the original examination, it was found at all three examinationss in only 9% of men and 17% of women. A similar drop occurred in the prevalence of diastolic hypertension. Of 143 surviving men and women without systolic hypertension at the original examination 11% were hypertensive at one year and 18% at five years but only 4% were hypertensive at both one and five years. Corresponding percentages for 232 surviving men and women who did not have diastolic hypertension at the original examination were 2, 4 and none.

Hypertension and stroke

Tables III and IV were collapsed into 2 x 2 tables in which groups with and without stroke were matched against groups with and without hypertension at the first examination. No relationship between stroke and hypertension was found.

The relationship between death, stroke and hypertension at the first examination was studied. Death occurred during the five years in 5 men with systolic hypertension of 9 who died of stroke compared with 27 men with systolic hypertension of 68 who died of some other cause. Corresponding figures in women were 6 of 15 and 34 of 44. The figures in men do not differ significantly but in women a significantly larger proportion ($p<0.05$) of hypertensive women died of a cause other than stroke.

TABLE VI

Prevalence of systolic and diastolic hypertension at three examinations in a longitudinal study of older men and women (percentage of totals examined in brackets).

BP SEX	NO WITH HYPERTENSION AT ORIGINAL EXAM	ONE YEAR EXAM	FIVE YEAR EXAM	ALL 3 EXAMS	TOTALS EXAMINED
Systolic					
MEN	39 (35)	18 (16)	15 (13)	10 (9)	113
WOMEN	79 (53)	42 (28)	30 (20)	25 (17)	148
Diastolic					
MEN	7 (6)	5 (4)	2 (2)	2 (2)	113
WOMEN	22 (15)	8 (5)	7 (5)	3 (2)	148

Diastolic hypertension had been found in 4 of 9 men who died of stroke and 7 of 68 men who died of another cause. This association between death from stroke and diastolic hypertension is significant ($p<0.05$). The corresponding figures in women of 2 of 15 and 9 of 44 do not differ significantly.

If hypertension is re-defined as systolic pressure $\geqslant$160 mm Hg and diastolic pressure $\geqslant$100 mm Hg, 55 men and women were hypertensive at the original examination. Stroke had occurred in 4 (7.3%) of the 55 compared with 23 (5.4%) of 425 subjects without such hypertension. These prevalences do not differ significantly.

Similarly in five year survivors, 4 strokes (16.7%) had occurred at some time (1 before and 3 during the five years) in 24 persons who were hypertensive at the original examination while 18 strokes (7.7%) had occurred at some time (8 before and 10 during the five years) in 235 persons without hypertension. Again these percentages do not differ significantly.

DISCUSSION

In the present survey one observer has measured blood pressure, under standard conditions, using the LSH sphygmomanometer with a cuff 45 cm in length. This technique avoided inter-observer variation and some causes of error (Rose et al 1964). Miall and Oldham (1958) suggested that one observer with standardised conditions of measurement was the most suitable arrangement in surveys.

There has long been evidence that if the rubber cuff does not completely encircle the arm falsely high blood pressure readings result (Martin 1905, Orma et al 1960, King 1967). For this reason a rubber cuff of 45 cm length, longer than the circumference of the largest arm in the survey, was used in the present study.

Despite efforts to standardise measurement, blood pressure varies considerably in individuals during each day (Littler et al 1975). An obvious difficulty in the present longitudinal study is that only three readings of a widely varying variable were recorded in five years.

Reported age effects in cross-sectional studies of blood pressure differ considerably. The study most comparable with the present study is that of Anderson and Cowan (1972) in which pressures were slightly higher especially in men. The U.S. National Health Survey (1977) recorded lower values for systolic and similar values for diastolic pressure. Kannel (1976) quotes cross-sectional data in older subjects from the Framingham study in which diastolic pressures decline with increasing age especially in men while systolic pressures rise, especially in women, but level off over 70 years in men. The present study corresponds fairly well with this apart from recording lower systolic pressures in very old women.

The interpretation of longitudinal changes in blood pressure is complicated by the widely reported regression towards the mean (McKeown et al 1963, Colandrea et al 1970, Johnson et al 1973, Abernethy et al 1976, Ambrosio et al 1976) which is also found in the present study (figure 3 and 4). This regression was less obvious when changes over a four year interval were related to pressures recorded a year before the interval began. The linear regression on which this statement is based should be mathematically more sound than one where change over an interval is related to pressure at the start of the interval.

The four year changes are not related to age at entry to the study nor to the original blood pressure level except for the relationship of the latter to diastolic pressure changes in men. Change in pressure has been reported as independent of age but dependent on pressure levels attained (Miall et al 1968). The four year changes in the present study differ significantly from zero only in the fall in diastolic pressure in women (table II).

The large standard deviations of the changes show that increases and decreases occur over time in individuals. A report from the Tecumseh study (Johnson et al 1973) reported percentages of increase, decrease and no change in systolic pressure similar to those in the present study. Distributions of blood pressure changes in a study in Renfrew in Scotland were comparable with those in the present study (Hawthorne et al 1974).

The greater size of the mean changes in the one year and five year periods compared with those in the four year period in the present study suggests a greater proportion of higher blood pressure readings at the original compared with later examinations. The smaller four year changes may be based on points on the blood pressure distributions of individuals different from those contributing to the one year and five year changes.

In any person a single blood pressure reading is a point on the distribution of blood pressure in that person. The difficulty in longitudinal study is that the distribution in each person is not known. Hence comparison of pressures measured at different times may not be made from comparable points on the individual distributions. The large standard deviations of the mean changes suggest the possibility of such errors in comparison. A large change in an individual could occur, for example, because he was calm on one occasion and agitated on another. Continuous recording over several hours on two or more separate occasions might provide data more suitable for longitudinal comparison. The present study certainly confirms the danger of inferring longitudinal change from cross-sectional age differences.

Reported prevalence of hypertension in the elderly varies. Cut off points of 160 mm and 100 mm Hg for systolic and diastolic pressures produced 38% of men and 57% of women with systolic and 9% of men and 17% of women with diastolic hypertension at the first examination. Similar systolic hypertension was found in 14% of a retired community (Colandrea et al 1970) 29% of men and 37% of women in the U.S. National Health Survey (1977) and 50% of men and 70% of women in Glasgow (Anderson and Cowan 1972). Diastolic hypertension was reported in 5% of men and 17% of women (Anderson and Cowan 1972) 19% of men and 29% of women (Martin and Millard 1973) and 16% of men and women (U.S. National Health Survey 1977).

The diminution in the prevalence of hypertension in successive examinations in the present study has been reported previously

(Colandrea et al 1970, Armitage et al 1966).

The incidence of stroke in 261 survivors over 5 years in the present study was 13. The expected number, using annual incidences from the Mayo Clinic study would be 18 (Matsumoto et al 1973).

Various studies have reported an increased risk of stroke with higher blood pressure (Colandrea et al 1970, Cutter 1967, Chapman et al 1966). Indeed Kannel et al (1965) in the Framingham study found, in a group aged 32-60 years followed for 16 years, that hypertension increased the risk of stroke five fold. This relationship is a major justification for the treatment of high blood pressure in early and late middle age. In a later description of the Framingham study, Kannel (1976) regarded increase in blood pressure as a major risk factor in brain infarction in the elderly.

In Scotland, Dall (1979) in his own geriatric wards in Glasgow found 66% of stroke patients to be hypertensive compared with 13% of those without stroke. However Grimley Evans et al (1980) in a community study in Newcastle in England of persons aged 65 and over found no evidence of an association between blood pressure and stroke. In the present study, although numbers are small, there was a similar lack of association between blood pressure and stroke. Hence although, in early and late middle age, treatment of hypertension decreases the risk of stroke, this would not necessarily be true of the elderly in Great Britain.

There is some danger in applying to one country the results of studies made in another country using different sampling techniques.

Kannel (1976) says that "57% of the incidence of brain infarction arises in the 19% of the population having systolic pressures exceeding 160 mm Hg". In the present study 59% of strokes at the first examination had occurred in persons with systolic hypertension, but systolic hypertension was present in 47% of the total sample. Again 50% of strokes in five year survivors occurred in those with systolic hypertension at the first examination but 42% of survivors examined at the five year review had had systolic hypertension at the start. Further longitudinal study is therefore needed to decide whether the treatment of hypertension would reduce the incidence of stroke in the elderly in Great Britain. Larger samples would increase the power of the statistical tests.

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INTERMITTENT CLAUDICATION AND PERIPHERAL PULSES IN OLDER PEOPLE

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Summary

The prevalence of intermittent claudication and the palpability of pulses in the feet were determined in Edinburgh in a random sample of 487 older people aged 62 and upwards. Claudication was admitted by 10·4 per cent of the men and 2·6 per cent of the women. No association was found with cigarette smoking. The proportion of absent foot pulses rose with age and with the presence of claudication. No relationship was found between foot pulses and angina pectoris, nor between ischaemic heart disease and claudication.

During the first examination in a longitudinal study of older people presently being performed in Edinburgh a record was made of which peripheral pulses were palpable in the feet and of whether intermittent claudication was present. The subjects studied were 215 men and 272 women aged 62–90 years who formed a simple random sample of the 27,000 older people living in a defined area of the city. The method of sampling has been described elsewhere with a comparison of respondents and non-respondents (Milne, Maule & Williamson, 1971).

Methods

Rose's questionnaire on ischaemic heart disease and intermittent claudication was administered to all subjects (Rose & Blackburn, 1968). The replies allowed division of persons with intermittent claudication into those troubled on hills only and those who were troubled at an ordinary pace on level ground. Another structured questionnaire was used to record use of tobacco. Pulses in the feet were recorded towards the end of the examination with the subject lying supine. At this time the subject had been in a room of temperature 21°C for about 1½ hours. Thirty seconds were spent, if necessary, searching for each pulse, making a total of two minutes for both feet. Any pulse which could not be definitely located in this time was recorded as absent.

The questions were asked and examinations made by one observer (J.S.M.). Before the survey began the observer made use of training material supplied by Professor Rose. Reproducibility of the questionnaire was studied before the survey began (Milne, Hope & Williamson, 1970). The well-known observer variation in palpation of pulses was confirmed when the authors each palpated the pulses in 53 feet in 27 older people who were not part of the random sample. The results of this comparison are given in Table I.

Table I. Observer variability in palpation of arterial pulses in the feet

		Observer JSM			
		Present	Absent	Present	Absent
Observer JW	Present	30	4	17	0
	Absent	3	16	5	31
		Dorsalis pedis pulse		Posterior tibial pulse	

Table II. Intermittent claudication in older men and women

Sex	Claudication: Absent	On hills only	On level ground	Percentage with claudication	No data
Men	190	8	14	10·4	3
Women	260	5	2	2·6	5

Table III. Intermittent claudication and cigarette smoking in older men and women

Sex and smoking habit		Claudication: Absent	Present	Percentage with claudication	χ^2	No data
Men						
Present	No	98	15	13·3	2·22	1
cigarette smoker	Yes	92	7	7·1	N.S.	2
Women						
Present	No	48	2	4·0	—	0
cigarette smoker	Yes	212	5	2·3	—	5

Table IV. Foot pulses and age in older people (percentages of row totals in brackets)

Sex and age	Dorsalis pedis pulse: Both absent	One present	Both present	χ^2 (2 d.f.)	Posterior tibial pulse: Both absent	One present	Both present	χ^2 (2 d.f.)	No data
Men									
62–69	32 (26·7)	24 (20·0)	64 (53·3)	10·89	21 (17·5)	16 (13·3)	83 (69·2)	8·67	
⩾70	38 (41·8)	25 (27·5)	28 (30·7)	(signif. 1%)	32 (35·2)	11 (12·1)	48 (52·7)	(signif. 5%)	
All men	70 (33·2)	49 (23·2)	92 (43·6)		53 (25·1)	27 (12·8)	131 (62·1)		4
Women									
62–69	13 (9·6)	24 (17·8)	98 (72·6)	5·61	43 (31·9)	22 (16·3)	70 (51·8)	13·14	
⩾70	24 (18·3)	28 (21·4)	79 (60·3)	(not signif.)	68 (51·9)	22 (16·8)	41 (31·3)	(signif. 1%)	
All women	37 (13·9)	52 (19·5)	177 (66·6)		111 (41·7)	44 (16·6)	111 (41·7)		6

Table V. Number of pulses present in feet in older men and women (percentages of row totals in brackets)

Sex	Pulses present in both feet 0	1	2	3	4	χ^2 (4 d.f.)	No data	Totals
Men	30 (14·2)	17 (8·1)	58 (27·5)	35 (16·6)	71 (33·6)	4·53	4	215
Women	25 (9·4)	25 (9·4)	81 (30·5)	55 (20·7)	80 (30·1)	N.S.	6	272

Results

The numbers of men and women with the two grades of claudication are given in Table II. A significantly larger proportion of men have the symptom compared with women ($P<0{\cdot}001$). A comparison is made in Table III of those men and women with and without claudication who at present do or do not smoke cigarettes. The figures in women are too small for satisfactory testing. Although the table suggests that a higher proportion of male cigarette smokers have claudication compared with non-smokers, the difference is not significant.

The numbers of dorsalis pedis and posterior tibial pulses in men and in women above and below 70 years are given in Table IV. The table shows that a significantly greater proportion of men less than 70 years compared with men of 70 years or more have both dorsalis pedis pulses. While this difference is not significant in women, it is significant for posterior tibial pulses in both sexes. Inspection shows that in all four groups in the table the proportion of absent pulses rises with age.

Using the figures in Table IV it can be shown that for the dorsalis pedis pulse a significantly greater proportion of women in the sample compared with men have both pulses present and a significantly smaller proportion of women have no pulses present. The exact reverse is true of the posterior tibial pulses. All these differences are significant at the 1 per cent level. If the numbers of pulses present in both feet are compared in men and women (Table V), no significant sex difference emerges. Hence the differences found by comparing the sexes for dorsalis pedis and posterior tibial pulses separately disappear when the data are combined. Four women had absent femoral pulses. In three men and two women one femoral pulse was present. The remainder of the sample had both femoral pulses present.

No significant association is present in the sample between cigarette smoking and palpable pulses in the feet (Table VI).

Table VII records the number of foot pulses present in men and women with and without claudication. The trend in men, which is statistically significant ($P<0{\cdot}001$), is for a decreasing number of pulses to be present when claudication is present and vice versa. No significant trend is present in women in this table but the numbers with claudication are small.

Information is given in Table VIII comparing in men and women those with and without angina pectoris in respect of the number of pulses palpable in the feet. No statistically significant difference is found in this table suggesting that the palpability of foot pulses is distributed in the sample independently of the distribution of angina

Table VI. Cigarette smoking and pulses in the feet

		Pulses in feet						
		0	1	2	3	4	χ^2 (4 d.f.)	No data
Men								
Present cigarette smoker	No	14	5	27	19	33	2·82	4
	Yes	16	12	31	16	38	N.S.	
Women								
Present cigarette smoker	No	18	21	61	50	67	7·17	6
	Yes	7	4	20	5	13	N.S.	

Table VII. Claudication and palpable pulses in the feet in older men and women (percentages of row totals in brackets)

		Pulses palpable in feet							
		0	1	2	3	4	χ^2 (4 d.f.)	No data	Totals
Men									
Claudication	No	18 (9·6)	13 (6·9)	54 (28·7)	34 (18·1)	69 (36·7)	33·80 (signif.	5	188
	Yes	11 (50·0)	4 (18·2)	4 (18·2)	1 (4·5)	2 (9·1)	0·1%)		22
									215
Women									
Claudication	No	21 (8·2)	23 (9·0)	78 (30·6)	55 (21·6)	78 (30·6)	5·69	10	255
	Yes	2 (28·6)	0	3 (42·9)	0	2 (28·6)	N.S.		7
									272

Table VIII. Angina pectoris and palpable pulses in the feet in older men and women (percentages of row totals in brackets)

		Pulses palpable in feet							
		0	1	2	3	4	χ^2 (4 d.f.)	No data	Totals
Men									
Angina	No	26 (13·8)	14 (7·4)	51 (27·1)	34 (18·1)	63 (33·5)	3·30	5	188
	Yes	3 (13·6)	3 (13·6)	7 (31·8)	1 (4·5)	8 (36·4)	N.S.		22
									215
Women									
Angina	No	20 (8·7)	23 (10·0)	71 (30·7)	45 (19·5)	72 (31·2)	5·52	10	231
	Yes	3 (9·7)	0	10 (32·3)	10 (32·3)	8 (25·8)	N.S.		31
									272

Table IX. Intermittent claudication and ischaemic heart disease in older people

		Angina pectoris		Probable myocardial infarction		Probable ischaemic heart disease	
		Absent	Present	Absent	Present	Absent	Present
Men							
Claudication	Absent	171	19	170	20	152	38
	Present	19	3	19	3	17	5
Women							
Claudication	Absent	232	28	252	8	224	36
	Present	4	3	6	1	4	3

pectoris. A comparison is made in Table IX of the numbers with and without intermittent claudication and with and without ischaemic heart disease of three categories. The categories of 'angina pectoris' and 'probable myocardial infarct' are derived from answers to Rose's questionnaire. 'Probable ischaemic heart disease' is said to be present if the answers to the questionnaire are positive for angina or myocardial infarction and/or I 1–2 or VII 1 are present in the Minnesota coding of the electrocardiogram. No significant association is found between intermittent claudication and any of these categories of heart disease in men. The numbers in women are too small for testing.

Discussion

The prevalence of intermittent claudication in the present study agrees well with that reported by Hobson & Pemberton (1955) who recorded it in 10·4 per cent of older men and 3·2 per cent of older women. Fodor *et al.* (1968) described a prevalence of 10·6 per cent in men in Prague aged 60–64.

The sex difference is confirmed by a recent publication from Framingham (Kannel, Skinner, Schwartz & Shurtleff, 1970) in which the 14-year incidence in a group now aged 60–74 was 1·3 per cent in men and 0·8 per cent in women. Mathieson & Mune (1966), studying patients referred with peripheral arterial disease, reported a male/female ratio in persons over 70 years of age of 1·2 : 1. The ratio in the present study, using a population sample is 4 : 1. This contrasts with a male/female ratio of 11 : 1 in Mayo Clinic Records of 1939–48 of all patients less than 60 years of age clinically diagnosed as having arteriosclerosis obliterans (Juergens, Barker & Hines, 1960).

It has been suggested (Wilkins, 1967) that there is congenital absence of the dorsalis pedis in 10 per cent of the population and of the posterior tibial in 2 per cent. In the present study, disregarding sex, the dorsalis pedis pulses are absent in 22 per cent and the posterior tibial pulses in 34 per cent of the sample. No pulses were felt in the feet in 14 per cent of men in the sample and in 9 per cent of the women. The present study shows a significant decrease in palpable foot pulses as age increases. Mathieson & Mune found one dorsalis pedis pulse present in 18 per cent and both dorsalis pedis pulses present in 8 per cent of persons with peripheral arterial disease, the corresponding figures for men in the present study being 12 per cent and 3 per cent. Using palpation of arteries as well as more sophisticated methods, Widmer, Greensher & Kannel (1964) found occlusion of peripheral arteries in 7·5 per cent of men aged 60–64 but two-thirds of these had no symptoms. Of 14 per cent of men in the present sample with no palpable pulses in the feet about two-thirds did not have intermittent claudication. E. B. French (1972, personal communication) found at least one pulse missing in the feet of 30 per cent of persons over 60 years of age.

The figures in the present study show a decline in the prevalence of claudication as the number of palpable pulses in the feet increase. On the other hand no relationship was found in the present study between the prevalence of angina pectoris and the number of palpable pulses in the feet. A close association has been described between ischaemic heart disease, particularly angina, and intermittent claudication (McDonald, 1953; Juergens *et al.*, 1960; Widmer *et al.*, 1964; Mathieson & Mune, 1966; Kannel *et al.*, 1970). This association is not found in the present study of older people. Longitudinal study of this sample should eventually show the effect of intermittent claudication on life expectancy at this age.

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Visual Acuity in Older People[1]

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Abstract. Visual acuity has been measured in a random sample of 487 older people in Edinburgh. Visual was acuity found to diminish significantly with age in both sexes. Cataract was found in 19% of the men and 32% of the women. Its prevalence was significantly greater with increasing age in both sexes and in women compared with men. Visual acuity was significantly less in the groups with cataract.

Simple investigation of vision was carried out during the first examination in a longitudinal study of aging persons being made in Edinburgh. The subjects in the study were 215 men and 272 women aged 62–90 years who formed a random sample of the 27,000 older people living in a defined area of the city. The method of sampling with a comparison of respondents and nonrespondents has been described elsewhere [MILNE *et al.*, 1971].

Methods

Visual acuity (VA) was measured, wearing distance glasses if appropriate, with Snellen's types reduced to a size for a distance of 3 m. A different set of types was used for each eye, the eye not being tested being covered with a card. No information was available about the date of the last prescription for glasses.

Cataract was defined as any opacity in the lens of either eye. Examination was made by looking into each eye using a +12 lens in an electric ophthalmoscope. The pupils were not dilated, hence the periphery of the lens was not examined.

VA was recorded in the usual groups of 6/6 to 6/60 with 2 other groups which were 'worse than 6/60' and 'blind', i.e. no perception of light. Cataract was recorded as absent,

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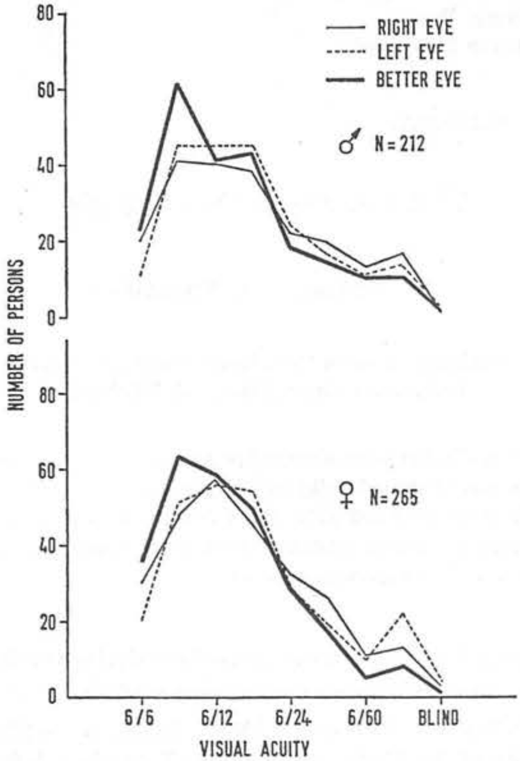

Fig. 1. The distribution of visual acuity in each eye and the better eye in older people.

present or removed in right eye and left eye. From this record a further variable was recorded as 'cataract absent' or 'cataract ever present' which referred to both eyes.

Results

Visual Acuity

The frequency polygons in figure 1 give for men and women separately the distributions of VA in right eye, left eye and better eye. In each sex the three distributions correspond fairly closely. Table I gives the distribution of VA in three age groups of men and women for the better eye only. Inspection of this table suggests an increasing proportion of men and women with diminished VA as age increases. The table shows that 11 % of men under 70 years have a VA of 6/24 or worse compared with 34 % of men of 70 years and over. The

Table I. VA of better eye in older people (percentages of row totals in brackets)

Age and Sex	6/6	6/9	6/12	6/18	6/24	6/36	6/60	6/>60	Blind	No data	Total
Men											
62–69	19 (16)	42 (34)	26 (21)	21 (17)	8 (7)	4 (3)	1 (1)	0	0	1 (1)	122
70–79	3 (4)	17 (23)	12 (16)	18 (25)	8 (11)	3 (4)	6 (8)	3 (4)	1 (1)	2 (3)	73
80+	1 (5)	2 (10)	3 (15)	4 (20)	2 (10)	3 (15)	3 (15)	2 (10)	0	0	20
Total men	23 (11)	61 (28)	41 (19)	43 (20)	18 (8)	10 (5)	10 (5)	5 (2)	1 (0.5)	3 (1)	215
Women											
62–69	28 (20)	36 (26)	31 (23)	23 (17)	10 (7)	4 (3)	0	3 (2)	0	2 (1)	137
70–79	8 (8)	24 (24)	24 (24)	19 (19)	12 (12)	6 (6)	2 (2)	3 (3)	0	3 (3)	101
80+	0	3 (9)	3 (9)	7 (21)	6 (18)	7 (21)	3 (9)	2 (6)	1 (3)	2 (6)	34
Total women	36 (13)	63 (23)	58 (21)	49 (18)	28 (10)	17 (6)	5 (2)	8 (3)	1 (0.36)	7 (3)	272

Table II. Three categories of VA compared in three age groups of men and women

Combined categories of VA	Age groups 62–69 M	62–69 F	70–79 M	70–79 F	80+ M	80+ F	Total men	Total women
6/6 6/9	87	95	32	56	6	6	125	157
6/18 6/24	29	33	26	31	6	13	61	77
6/36 6/60 6/>60	5	7	13	11	8	13	26	31
No data	1	2	2	3	0	2	3	7
Totals	122	137	73	101	20	34	215	272
χ^2 (2 d.f.)	0.20		2.92		0.43		0.07	

Table III. Cataract in three age groups of older men and women

Age and sex	Right eye			Left eye			Persons		
	cataract absent	cataract present	present, %	cataract absent	cataract present	present, %	cataract absent	cataract ever	ever, %
Men									
62–69	112	9	7.4	113	8	6.6	111	10	8.3
70–79	53	20	27.4	53	20	27.4	50	23	31.5
80+	12	8	40	11	9	45	12	8	40
Total men	177	37	17.3	177	37	17.3	173	41	19.2
Women									
62–69	117	19	14	115	21	15.4	111	25	18.4
70–79	69	31	31	70	31	30.7	64	37	36.6
80+	13	20	60.6	12	20	62.5	9	23	71.9
Total women	199	70	26	197	72	26.8	184	85	31.6

No data in 1 man and 3 women.

corresponding figures for women are 13 and 32%. In each sex the difference in proportion is highly significant ($p < 0.001$).

VA in the two sexes is compared in table II in corresponding age groups and in all the men and all the women in the sample. Categories of VA have been grouped as in the table. No significant sex difference is found in any age group.

Cataract

The numbers of persons in whom cataract is present or absent are given for right and left eyes in three age groups of men and women in table III. The last three columns of the table detail, for individuals in the groups given, whether cataract was absent at the time of examination or whether it was present then or had been previously. In 1 man and 4 women cataract had been removed at operation. The prevalence of cataract in the right eye is very similar to that in the left. Prevalence in the last three columns of the table is greater than in either eye, presumably because this section deals with individuals, not eyes.

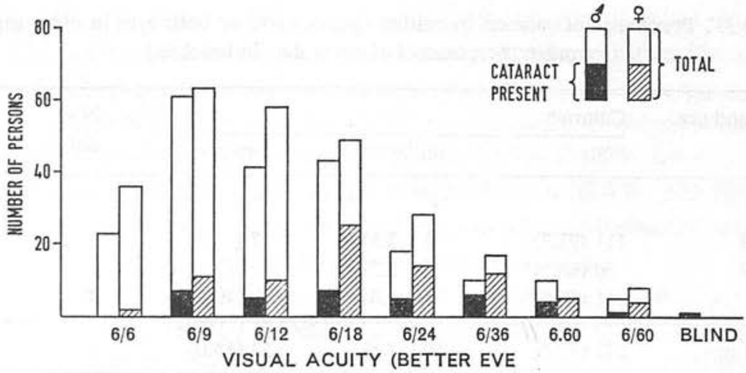

Fig. 2. The prevalence of cataract related to visual acuity in older people.

Cataract was or had been present in 8 % of men under 70 years compared with 33 % of men of 70 years and over. The corresponding figures for women are 18 and 46 %. In both sexes this age difference is highly significant ($p<0.001$).

The last three columns of table III suggest that in the corresponding age groups women have a greater prevalence of cataract than men. The prevalence in all the women in the sample is significantly higher than that in all the men ($p<0.01$). If individual age groups are compared the differences are significant for age groups 62–69 and 80+ ($p<0.05$) but not for age group 70–79.

In table IV are given, in three age groups, the numbers of men and women with cataract in neither eye, one eye or both eyes. The age and sex differences described above are present in the table but no significant difference is found in the ratio of numbers with unilateral to numbers with bilateral cataract when compared in men and women. No difference is found in the ratio in either sex above and belwo the age of 70 years.

Cataract Related to Visual Acuity

This relationship is shown in table V and figure 2 where for the better eye in men and women, the frequency distribution of VA is given for those in whom cataract was absent and those in whom it was or had been present. 14 % of men without cataract have VA of 6/24 or worse compared with 51 % of men with cataract. The figures in women are 13 and 42 %. Both differences are highly significant ($p<0.001$). Among the persons with cataract there is no significant sex difference in the prevalence of VA of 6/24 or worse.

Table IV. Prevalence of cataract in neither eye, one eye or both eyes in older men and women (percentages of row totals in brackets)

Age and sex	Cataract			No data	Total
	none	unilateral	bilateral		
Men					
62–69	111 (91.7)	3 (2.5)	7 (5.8)	1	122
70–79	50 (68.5)	6 (8.2)	17 (23.3)	0	73
80+	11 (55.0)	1 (5.0)	8 (40.0)	0	20
Total men	172 (80.4)	10 (4.6)	32 (15.0)	1	215
Women					
62–69	111 (81.6)	10 (7.4)	15 (11.0)	1	137
70–79	63 (62.4)	14 (13.9)	24 (23.8)	0	101
80+	8 (25.0)	8 (25.0)	16 (50.0)	2	34
Total women	182 (67.7)	32 (11.9)	55 (20.4)	3	272

Table V. VA in older men and women with and without cataract

	VA in the better eye									No data	Total
	6/6	6/9	6/12	6/18	6/24	6/36	6/60	6/> 60	blind		
Men											
Cataract absent	23	54	36	36	13	4	6	1	0	3	215
Cataract present	0	7	5	7	5	6	4	4	1		
Women											
Cataract absent	34	52	48	24	14	5	0	4	0	8	272
Cataract present	2	11	10	25	14	12	5	4	0		

Discussion

Figures for VA are given in detail in the US National Health Survey [1968]. They are not strictly comparable by age group with the present study but the US measurements (made at a distance of 6 m) do suggest a greater proportion of older persons with VA of 6/6 or 6/9 than was found in Edinburgh. The studies agree in finding better vision in monocular testing of the better eye than in right or left eye alone. KORNZWEIG *et al.* [1967] found 71.4% of 1,000 persons in a New York Home for Aged and Infirm Hebrews to have a VA between 6/6 and 6/18. The equivalent figure in the present study is 78.4%. GORDON [1967] in a series of 307 patients aged 65–92 years examined during 5 months of 1967 found 77.5% to have VA of 6/9 or better in the better eye. The equivalent figure in the present study is 38.4%. The figures are not strictly comparable since GORDON's group selected themselves as patients and the present study is a random population sample.

Previous reports suggest a decline in VA as age increases [KORNZWEIG *et al.*, 1957; GORDON, 1967; US National Health Survey, 1968]. The present survey agrees with this and the age differences are statistically significant in each sex.

One difficulty in estimating the prevalence of cataract, pointed out by GORDON [1967], is that of defining what degree of lenticular opacity is to be called cataract. The present study avoids this by defining cataract as any degree of lenticular opacity visible using the examination described above. Longitudinal examinations should eventually determine which opacities progress. GORDON [1967] found cataract in 29% of his series. In the present study cataract as defined was found in 26% of the whole sample. Estimates vary from more than 60% [KORNZWEIG, 1964] to 32% of men and 52% of women [ELWOOD, 1967], 36.5% with lens sclerosis or cataract [HOBSON and PEMBERTON, 1955], 5–18% of men and 8–21% of women [VAN ZONNEVELD, 1961]. SHELDON [1948] found by questioning without examination a prevalence as low as 5.6%.

Age differences in prevalence of cataract, with a greater proportion in older people, have been described by VAN ZONNEVELD [1961] and KORNZWEIG *et al.* [1957]. ELWOOD [1967] found an age difference in women but not in men. The present study found a significantly greater prevalence in men and women of 70 years and over compared with those less than 70 years.

There is agreement about the relatively small proportion of the population who come to operation for cataract [ELWOOD, 1967, 4%; KORNZWEIG *et al.*, 1957, 4.4%]. The figure in the present-day study is as low as 1% of the whole sample.

The sex difference of greater prevalence of cataract in women compared with men, reported by ELWOOD [1967] and VAN ZONNEVELD [1961], is statistically significant in the present study.

Blindness in older men and women has been variously estimated. KORNZWEIG *et al.* [1957] reported 1.5% of their group as blind and 6.6% with vision of 15/300 or worse. VAN ZONNEVELD [1961] found 2% of men and 3% of women in his sample to be blind. SHELDON's [1948] prevalence was 1 %. HOBSON and PEMBERTON [1955] give the low figure of 0.4 % which is exactly that of the present study. The present study has 2 % of men and 3 % of women with vision poorer than 6/60.

The present study forms a small part of a comprehensive general medical examination lasting several hours. The value of the findings in respect of vision would have been greater if refraction had been carried out, the pupil dilated and retinal pathology reported. This would be particularly useful as many patients besides having slight cataract would be found to have macular degeneration as well which often would be the major contributing factor in their decrease in vision. Mydriatics were avoided because of the associated dangers and it was difficult to spend much time on examination of vision when so many other variables were being recorded. For these reasons examination of vision in the present study was confined within the limits as reported.

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LONGITUDINAL STUDIES OF VISION IN OLDER PEOPLE

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Summary

Visual acuity was measured and cataract recorded in a simple random sample of 215 men and 272 women aged 63–90 years in Edinburgh. One year and five years later the observations were repeated in 113 men and 148 women surviving and available from the original sample. This paper deals with survivors only.

Worsening of visual acuity occurred over five years in 12% of men and 14% of women. Improvement was noted in 15% of men and 10% of women. The proportion of those with worsening of visual acuity increased significantly with increasing age at entry to the study. Assessments made by subjects of visual change in five years proved inaccurate when checked by measurement.

Prevalence of cataract rose from 15% at the original examination to between 36% and 46% after five years. Increases in prevalence of cataract were greater in older subjects.

If cataract was present at any examination, visual acuity worsened in five years in 24% of subjects compared with 11% without cataract at any examination. The proportion of persons with cataract and vision worse than 6/12 was 76% of 37 persons at the original examination and 66% of 105 after five years. Corresponding figures in those without cataract were 37% of 223 and 36% of 155. The actual number with poorer vision associated with cataract more than doubled in five years.

INTRODUCTION

Visual acuity is known to decline as age increases (Kornzweig 1964, Gordon 1967, Milne & Williamson 1972, U.S. National Health Survey 1977, Stone & Shannon 1978). Increasing prevalence of cataract as age increases has also been recorded (Kornzweig 1964, Elwood 1967, Milne & Williamson 1972). The present paper reports measurements of visual acuity in a study of a random sample of older people in Edinburgh, made one and five years after an initial examination and relates changes in visual acuity to the presence or development of cataract. This study, which included examinations by a physician, a psychiatrist and a dietitian, was designed to record changes in physical and mental health and in normal measurements over a period of time in older people. Visual acuity was included among these measurements.

Subjects and Methods

The subjects studied in the first examination (1968–9) were 215 men and 272 women aged 63–90 years who formed a simple random sample of the 27 000 older people living in ten city wards in Edinburgh. Details of sampling with a comparison of respondents and non-respondents have been published elsewhere (Milne et al. 1971). Further examinations were made after one year (1969–70) and five years (1973–4). At the five-year examination I was able to see 113 men and 148 women and only these subjects are included in reports of follow-up data. During the five years 78 men

and 60 women had died, leaving 24 men and 64 women who for various reasons were not re-examined. Follow-up of the sample has been described in detail elsewhere (Milne & Chopin 1975).

Visual acuity (VA) was measured, wearing distance glasses if appropriate, with Snellen's types reduced for a distance of 3 metres. A different set of types was used for each eye, the eye not tested being covered with a card. No information was available about the date of the last prescription for glasses.

Cataract was defined as any opacity in the lens of either eye. It was sought by looking into each eye using a +12 lens in an electric ophthalmoscope. No mydriatric was used, hence the periphery of the lens was not examined. Visual acuity was recorded in the groups 6/6, 6/9, 6/12, 6/18, 6/24, 6/36, 6/60, with two other groups which were 'poorer than 6/60' and 'blind', i.e. no perception of light. Cataract was recorded as absent, present or removed in right eye and left eye. Identical techniques were used at each of the three examinations and all observations were made by one observer.

Reproducibility was tested in 14 subjects of the same age group. On two occasions of testing, separated by a few days, variation on the second occasion could be as much as one step on the scale above or below the point recorded on the first occasion. Longitudinal differences were therefore only regarded as real changes in vision if they exceeded this amount of change.

Results

Frequency distributions of visual acuity in the better eye are given in Table I, in men and in women, for the original examination and for the one-year and five-year follow-up.

Table I. Frequency distributions of visual acuity in the better eye at three examinations in men and women

Groups	*VA in men*			*VA in women*		
	Original	*1 year*	*5 years*	*Original*	*1 year*	*5 years*
6/6	17 (15.2)	13 (11.5)	16 (14.3)	25 (17.1)	18 (12.3)	25 (17.1)
6/9	35 (31.3)	38 (33.6)	42 (37.5)	45 (30.8)	51 (34.9)	47 (32.2)
6/12	18 (16.1)	25 (22.1)	20 (17.9)	33 (22.6)	35 (24.0)	20 (13.7)
6/18	23 (20.5)	14 (12.4)	14 (12.5)	23 (15.8)	21 (14.4)	29 (19.9)
6/24	9 (8.0)	15 (13.3)	10 (8.9)	12 (8.2)	10 (6.8)	10 (6.8)
6/36	5 (4.5)	4 (3.5)	5 (4.5)	5 (3.4)	8 (5.5)	5 (3.4)
6/60	3 (2.7)	2 (1.8)	—	—	2 (1.4)	4 (2.7)
>6/60	1 (0.9)	1 (0.9)	4 (3.6)	3 (2.1)	1 (0.7)	6 (4.1)
Blind	1 (0.9)	1 (0.9)	1 (0.9)	—	—	—
Total	112	113	112	146	146	146

Percentages in parentheses.

The steps in the scale of visual acuity were numbered from 1 to 9 for coding for the computer. Five-year differences in visual acuity were examined by subtracting the coded number for the original examination of the better eye from that for the five-year examination. The distributions of the results are given for men and for women in Table II. Differences of −1, 0 and +1 are regarded as showing no change because of the reproducibility tests described above. Values of +2 or more indicate worsening of visual acuity during the five years. By these criteria, 13 of 112 men (11.6%) and 21 of 146 women (14.4%) showed worsening of visual acuity. The sex difference is not significant.

Table II. Five-year differences in coded values of visual acuity of the better eye in men and in women

VA		*Five-year difference in coded values*	
		Men	*Women*
Improved	−4	3 (2.7)	2 (1.4)
	−3	5 (4.5)	4 (2.7)
	−2	9 (8.0)	8 (5.5)
No change	−1	15 (13.4)	28 (19.2)
	0	44 (39.3)	49 (33.6)
	1	33 (20.5)	34 (23.3)
Poorer	2	12 (10.7)	12 (8.2)
	3		5 (3.4)
	4	1 (0.9)	
	5		3 (2.1)
	6		
	7		1 (0.8)
Total		112*	146†

Percentages in parentheses.
* VA not measured in one.
† VA not measured in two.

In the same period apparent improvement has occurred in 15.2% of men and 9.6% of women. Corresponding figures after one year show worsening in 5.3% of men and 7.5% of women and improvement in 9.7% of men and 6.8% of women.

The subjects of each sex were grouped by age into those aged less than 70 years and those of 70 years and over at entry to the study. Worsening of visual acuity during five years occurred in 5 of 70 (7.1%) younger men and 8 of 42 (19%) older men. The corresponding figures for women were 5 of 90 (5.6%) and 16 of 56 (28.6%).

Linear regressions were calculated in men and in women of the five-year differences in visual acuity on age at entry. The coefficients of regression were 0.070 (s.e. 0.023) in 112 men and 0.094 (s.e. 0.022) in 146 women. These coefficients were significant in men at the 1% level and in women at the 0.1% level thus showing increasing visual impairment over five years with increasing age at entry.

Table III compares five-year change in visual acuity with the subject's assessment of what happened to vision. One man who claimed to see better had improvement recorded. Otherwise the incidence of change in visual acuity was not strikingly different whether the subjects reported no change or worsening.

In men and in women in whom no change in measured visual acuity occurred, there was no significant difference in the proportions with and without subjective worsening of vision. When the table was collapsed into a 2×2 form, in men and in women, with visual acuity 'worse' and 'not worse' tabulated against the subject's estimate of vision as 'worse' and 'not worse', the χ^2 test revealed no significant difference in the proportions.

The prevalence of cataract at the three examinations is given for each sex and for each eye in Table IV. None of the percentage increases at the one-year examination is significant. All the percentage increases from the first to the five-year examination are

Table III. Five-year differences in visual acuity in the better eye compared with subject's assessment of change in eyesight during the five years

Subject's assessment of vision	*Visual acuity*			*No.*
	Improved	*No change*	*Worse*	
Men				
No change	9	52	6	67
Better	1	2	0	3
Worse	7	27	7	41
	17 (15.3)	81 (73.0)	13 (11.7)	111* (100)
Women				
No change	8	65	8	81
Better	0	2	0	2
Worse	6	43	11	60
	14 (9.8)	110 (76.9)	19 (13.3)	143† (100)

Column totals as percentages in parentheses.
* VA not measured in one; no questions in one.
† VA not measured in two; no questions in three.

Table IV. The prevalence of cataract or aphakia in a five-year longitudinal study of older men and women

Sex	*Eye*	*No. of 5-year survivors*	*Cataract present at examination*		
			Original	*1 year*	*5 years*
Men	R	113	16 (14.2)	22 (19.5)	41* (36.3)
	L	113	16* (14.2)	27 (23.9)	45† (39.8)
Women	R	148	21* (14.2)	30 (20.3)	65* (43.9)
	L	148	24 (16.2)	37 (25.0)	68* (45.9)

Percentages in parentheses.
* One cataract removed.
† Two cataracts removed.

significant ($P<0.01$). None of the six differences in prevalence between right and left eyes is significant. The table shows that in men and in women the prevalence of cataract has risen from around 15% at the first examination to between 36 and 46% at the five-year examination. There are no significant sex differences in the table.

When age is considered the prevalence of cataract in the right eye in men aged less than 70 years at entry to the study rises from 4 of 71 (5.6%) at the first examination to 15 of 71 (21.1%) at the five-year examination. Corresponding figures for men of 70 years and over at entry are 12 of 42 (28.6%) and 26 of 42 (61.9%). The five-year increase in older men is significantly greater ($P<0.05$). In younger women the increase is from 7 of 91 (7.7%) to 31 of 91 (34.1%) compared with 14 of 57 (24.6%) to 34 of 57 (59.6%) in older women. The greater percentage increase in older women is not significant. The present study therefore shows almost a three-fold increase in the prevalence of cataract in five years. In older men, but not in older women, the increase in prevalence is significantly greater than in younger subjects. At the first examination 77 cataracts were recorded in men and women. Thirty-one subjects had cataract in both eyes and 15 in one eye only. After five years 219 cataracts were recorded, 87 subjects having these in both eyes and 45 in one eye only.

The relationship between the prevalence and incidence of cataract and five-year changes in visual acuity in the right eye is shown in Table V. The incidence of worsening in visual acuity was similar if cataract was found on either occasion of examination. If men and women are combined, 25 of 105 persons (23.8%) in whom cataract was present on either occasion had worsening of VA compared with 16 of 153 persons (10.5%) in whom cataract was absent on both occasions. The increased incidence of visual deterioration associated with cataract was significant ($P<0.01$). The difference in incidence of worsening of visual acuity between Table III and Table V is because Table III relates to the better eye and Table V to the right eye.

Table V. Changes in visual acuity in five years compared with the prevalence and incidence of cataract in older people (right eye)

Sex	*Cataract*		*5 year change in VA*			*Total*
	First exam.	*5-year exam.*	*Better*	*No change*	*Poorer*	
Men	Absent	Present	3 (12)	15 (60)	7 (28)	25
	Present	Present	2* (12.5)	11 (68.8)	3 (18.8)	16
	Absent	Absent	14 (19.7)	51 (71.8)	6 (8.5)	71†
Women	Absent	Present	4 (9.1)	30 (68.2)	10 (22.7)	44
	Present	Present	1 (5)	14* (70)	5 (25)	20†
	Absent	Absent	12 (14.6)	60 (73.2)	10 (12.2)	82†

Percentages in parentheses.
* Cataract removed in one subject.
† VA not measured in one subject.

Table VI gives the numbers in the right eye in each step of the scale of visual acuity, for men and women combined, of those with and without cataract. The proportion with cataract had risen from 14.2% at the first examination to 40.2% five years later. The table was collapsed into a 2×2 table, for each of the examinations, in which groups with and without cataract were tabulated against those with vision 6/12 or better and worse than 6/12. At the original examination 36.8% of 223 persons without cataract and 75.7% of 37 persons with cataract had visual acuity poorer than 6/12. For the five-year examination the corresponding figures were 35.5% of 155 and 66.3% of 104. Hence the prevalence of poorer vision in each group remains approximately the same but the actual number associated with cataract has more than doubled.

Discussion

A review of the literature by Weale (1975) shows that visual acuity declines after age 45 years. The material reviewed was from cross-sectional studies and the first examination of the present Edinburgh study was in agreement (Milne & Williamson 1972). The

Table VI. The association between cataract and visual acuity, older men and women combined for the right eye

VA	*First examination*		*5-year examination*	
	Cataract absent	*Cataract present*	*Cataract absent*	*Cataract present*
6/6	33	2	19	1
6/9	57	2	60	26*
6/12	51	5	21	8
6/18	28	11	30	22
6/24	25	4	13	13
6/36	18	4	8	8
6/60	6	2	1	8*
>6/60	5	5*	3	17
Blind	—	2	—	1
Totals	223†	37 (14.2%)	155†	104 (40.2%)†

* One cataract in this group removed.
† VA not measured in one subject.

present paper, based on a five-year follow-up, confirms the decline but shows that it is not a uniform phenomenon.

Five per cent of the men and 8% of the women showed worsening of visual acuity in one year. The proportions rose over the next four years to 12% and 13% respectively. Improvement in visual acuity was recorded in 15% of the men and 10% of the women during the five years. The remainder showed no change. Indeed of the survivors of both sexes who were re-examined after five years, 87% showed no worsening of visual acuity. The decline in visual acuity increased significantly with increasing age at entry to the study. Stone & Shannon (1978) also reported an age gradient.

Allen (1975) defined cataract as any opacity of the crystalline lens. This was the definition used in the present study (Milne & Williamson 1972). Although Allen found that relatively few of those fitting the definition had visual impairment, the first examination of the present study showed that 26% of the sample had cataract as defined and 18% of the sample had cataract and visual acuity poorer than 6/12 (Milne & Williamson 1972).

McWilliam (1978), in a survey of 2611 persons of 65 years and over in East Kilbride in Scotland, found 321 with visual impairment (distance vision poorer than 6/12 or reading vision poorer than N8). Seventy-six of these had cataract which gives a figure of 3% compared with 18% in the present study. This study in East Kilbride was describing a service to the elderly, seeking visual impairment rather than searching for cataract as defined by Allen.

Five-year follow-up in the present study showed an almost three-fold increase in cataract. The incidence of decline in visual acuity over the five years was similar if cataract was present on one or both occasions, amounting to 24.3% of the sample. In those without cataract the figure was 10.5%. This makes cataract an important association with decline of visual acuity in the elderly.

McWilliam (1978) reported cataract as the commonest cause of visual impairment in his study. In Egypt, Said et al (1971) regarded cataract as first among the causes of blindness in cities. Akazawa et al. (1976) followed 581 eyes with senile cataract for one to eight years and found decreased vision in 56.6%. They found the decrease slightly more rapid in men than in women. Such a difference did not emerge in the present study. Improvement in visual acuity occurred during one to eight years in 13.4% of the eyes with cataract studied by Akazawa et al. compared with 9% of subjects with cataract over five years in the present study. No change was recorded by Akazawa et al. in 30% compared with 67% of those with cataract in the present study.

Stone & Shannon (1978) in their survey of middle-aged persons in general practice found that replies to the question 'Do you have difficulty in seeing distant objects?' were poor as identifiers of visual impairment. In the present study the question 'Has your eyesight changed since you were last here?' was not satisfactory in identifying change in visual acuity.

Very few of the total number of subjects underwent operations to remove cataract during the five years. Two cataracts were removed from right eyes and three from left eyes (Table IV).

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PURE TONE AUDIOMETRY IN OLDER PEOPLE

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Abstract

Hearing loss measured by pure-tone audiometry is described for the better ear, using the median with 95% confidence limits, in seven sound frequencies in a random sample of older people (215 men and 272 women). Both sexes showed increases in hearing loss in each frequency with increasing age. Hearing loss was greater in women at frequencies of 1000 c.p.s. or less and in men at frequencies of 2000 c.p.s. and above. The difference in hearing loss between higher and lower frequencies was greater in men than in women and greater in older compared with younger persons.

Introduction

Although many cross-sectional studies of hearing loss in the elderly have been published, so far as the authors are aware, longitudinal measurements of such loss have not been reported. This paper describes hearing loss recorded in the first examination of a longitudinal study of ageing persons which has been carried out in Edinburgh since 1968. A second record of hearing loss was obtained one year after the first and the third record, 5 years after the first examination, was completed in 1974. It should be possible in a subsequent paper to compare cross-sectional data of age differences in hearing loss with age changes occuring in the same sample after one and five years.

Subjects and Methods

In 1968 there were 91 doctors in 50 general practices with surgery addresses in a defined area of Edinburgh, composed of 10 city wards. The National Health Service Lists of these doctors contained a total of 27,000 persons born in 1905 or earlier. From this total a simple random sample was examined of 215 men and 272 women aged 62-90 years. Full details of sampling with a comparison of respondents and non-respondents have been given elsewhere (Milne, Maule and Williamson 1971).

Hearing loss was measured in the men and women in this sample with a Madsen TBN 60 portable transistorised audiometer with thresholds calibrated to British Standards. The instrument was regularly calibrated and serviced by the Royal National Institute for the Deaf. Examinations were made in a double glazed quiet room in which the ambient sound level measured with a sound level meter (Type 2205, microphone type 4117, Bruel and Kjaer, Copenhagen) was 35 dB using weighting network A.

The method of measuring hearing loss was as follows. The frequency of 1000 c.p.s. in the right ear was used to demonstrate the technique to the subject, who was asked to signal by tapping each time the sound was heard during progression from audible to inaudible pulses of sound. Recording began after this at a frequency of 250 c.p.s. in the right ear. Hearing loss was recorded first in the right and then in the left ear at frequencies of 250, 500, 1000, 2000, 4000, 6000 and 8000 c.p.s. Only one attempt was made to measure hearing loss at each frequency unless something noisy interrupted the examination in any frequency in which case the measurement in that frequency was repeated. Masking was used if a difference of 40 db was found between the two ears for air conduction, if conductive deafness was present and when hearing loss by bone conduction was measured. All measurements were made by one observer (J.S.M.). Measurements were made for 213 men and 265 women. In the remaining nine persons intellectual impairment made the examination impossible.

Reliability

This was estimated by measuring hearing loss on two occasions separated by a week in six men and six women aged 65 years or more taken at random from a general practice list. Measurements were repeated on each occasion three times. Results recorded for the better ear in each person were examined by the analysis of variance. The results showed that there was no significant variation between occasions and that the limits of variation on one occasion were no greater than ±4.5 dB. For example, at 2000 c.p.s. the error variance was 5.2 which gives a standard error of 2.28. Since the audiometer measures hearing loss in steps of 5 db, and if it is assumed that the distributions of the measurement are Gaussian, the reliability is ±5 dB for different readings in the same subject by the same observer.

Results

All data are from the better ear in each subject. The distributions of hearing loss found, in common with those reported in the literature, were positively skewed. In the higher frequencies, as would be expected in an elderly population, many subjects were unable to hear the signal even at its maximum. These two findings render the mean a poor measurement of central tendency in these data. Instead median values with non-parametric confidence limits (MacKinnon, 1964) have been used to describe the results. This allowed the inclusion of data from the subjects who did not hear the signal.

The median values of hearing loss in the better ear with 95% limits are presented for men and for women in tables 1 and 2. The results for the frequencies of 1000 c.p.s. and 6000 c.p.s. are shown graphically in figures 1 and 2. The data show age effects and sex differences. Both tables show marked increases in hearing loss in each frequency with increasing age, the sole exception being the loss for bone conduction at 1000 c.p.s. in men. Not every age group shows a statistically significant increase in hearing loss when compared with the age group immediately preceding. However the hearing loss in persons of 80 years and over is significantly greater than that in persons of 62-64 years in all frequencies in both sexes except in men at 500 c.p.s. by air conduction and 1000 c.p.s. by bone conduction. For the most part increases in hearing loss with increasing age in table 1 are more obvious in men in the higher frequencies of 2000 c.p.s. and above. The increases with age in women (table 2) are obvious in all frequencies.

The age effects in each frequency in men and in women were further examined by linear regression on age of the median hearing losses in the five age groups (table 3). The table shows a significant cross-sectional loss with age for all frequencies in women. In men the loss with age is significant except for the three lower frequencies by air conduction and for 1000

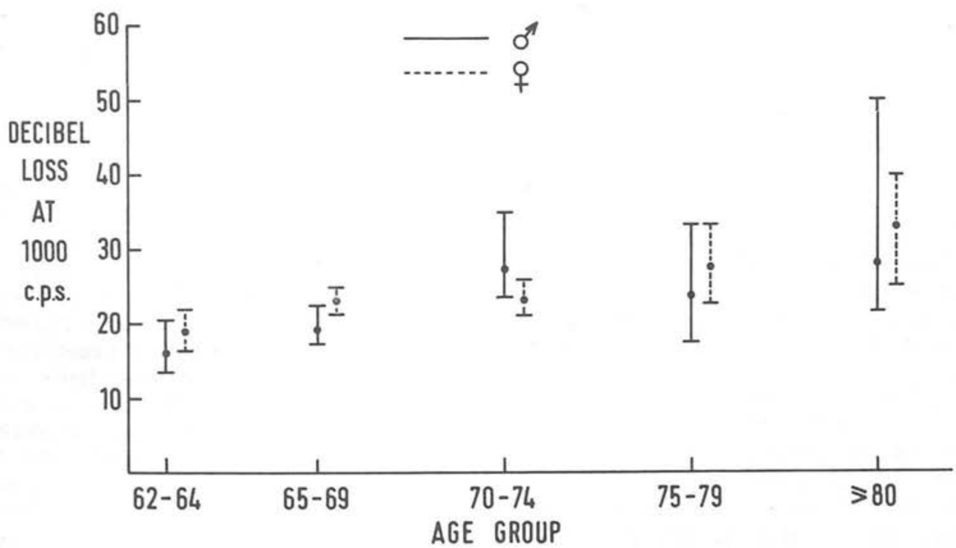

Fig. 1. Median hearing losses at 1000 c.p.s. with 95% confidence limits in five age groups of older men and women.

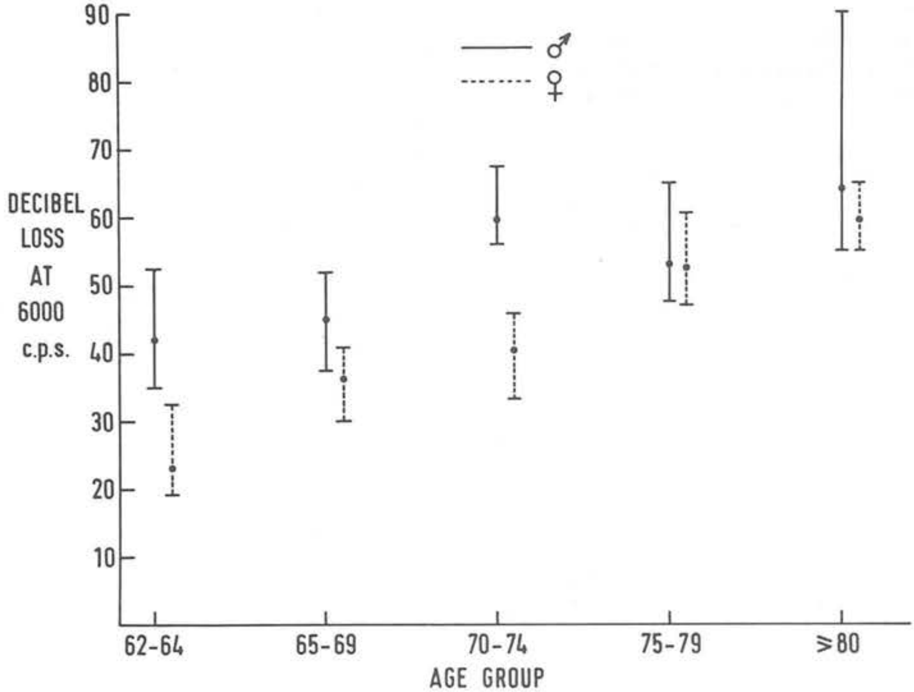

Fig. 2. Median hearing losses at 6000 c.p.s. with 95% confidence limits in five age groups of older men and women.

c.p.s. by bone conduction. These results confirm the impression gained from inspecting the tables.

Sex differences were first studied using the non-parametric confidence limits in tables 1 and 2. At frequencies of 250, 500 and 1000 c.p.s. the only significant differences found were greater hearing losses by air conduction in women compared with men at 250 and 500 c.p.s. in age groups 62-64 and 65-69. In the frequencies of 2000 c.p.s. and above, hearing losses by air conduction were significantly greater in men compared with women in eight of the twenty differences examined in the tables. Four of the eight differences were in the 70-74 age group. In the same age group hearing loss by bone conduction was significantly greater at 4000 c.p.s. in men compared with women.

The sex differences were further examined by the non-parametric Wilcoxon two sample test. This test confirmed all the significant sex differences implied by the confidence limits. In addition this method found seven other differences not detected by the confidence limits. Four of these were in the two older age groups where significantly greater hearing loss appeared in women at frequencies of 250 and 500 c.p.s. The remaining three showed significantly greater loss by air conduction in men aged 65-69 at the frequency of 6000 c.p.s. and in the two younger groups of men at 8000 c.p.s. The Wilcoxon tests also demonstrated significantly greater loss by bone conduction in two age groups of women at 1000 c.p.s. and in two age groups of men at 4000 c.p.s.

In summary, hearing loss by air conduction was significantly greater in women compared with men in eight of the fifteen groups at frequencies of 1000 c.p.s. and below and significantly greater in men compared with women in eleven of the twenty groups at frequencies of 2000 c.p.s. and above (table 1).

Possible sex differences in the rate of hearing loss with age, as estimated from cross-sectional data were examined by studying the coefficients of regression in table 3 and their standard errors. With the exception of 1000 c.p.s. by bone conduction, in which the rate of loss was greater in women than in men, the coefficients of regression for each sound frequency did not differ significantly in men and women. Hence the data in the present study have not shown any overall sex differences in the rate of hearing loss.

Finally hearing loss was considered for air

Table 1. Median values of decibel loss in older men. (The central figure in each cell is the median, the upper and lower figures being the 95% confidence limits).

c.p.s.	*Age Group*				
	62-64	*65-69*	*70-74*	*75-79*	*≥80*
250 (AIR)	16.00 17.75 19.50 F1 0	22.12 23.75 25.71 F1 0	25.91 28.86 33.33 0	21.25 24.69 33.33 F1 0	21.67 29.17 45.00 F5 0
500 (AIR)	14.09 17.08 20.00 F1 0	20.75 22.88 25.00 F1 0	25.00 30.42 34.38 0	20.83 25.42 30.00 F1 0	16.67 28.13 40.00 F5 0
1000 (AIR)	13.75 17.05 20.71 0	17.39 19.35 22.50 0	23.57 27.25 35.00 0	17.50 23.75 33.33 0	21.67 28.13 50.00 0
2000 (AIR)	10.00 14.69 22.14 0	14.12 17.50 22.14 0	23.13 28.50 38.33 M1 0	22.50 29.17 38.75 0	25.00 41.25 58.33 0
4000 (AIR)	32.50 38.75 48.75 M1 0	33.75 45.00 52.50 M1 1	56.11 59.72 65.00 M1 1	45.83 51.50 65.00 1	62.50 82.50 90.00 M1 3
6000 (AIR)	35.00 42.08 52.50 M1 1	37.50 45.00 52.00 M1 2	56.11 59.72 67.50 M1 3	47.50 53.13 65.00 2	55.00 64.17 90.00 5
8000 (AIR)	37.50 51.88 62.50 M5 2	43.75 56.25 63.75 M5 6	60.00 65.42 80.00 M1 6	65.00 70.68 73.64 3	65.00 82.50 89.44 9
1000 (BONE)	12.50 17.00 22.50 0	13.13 16.15 19.62 F1 1	17.86 22.92 30.00 0	13.00 19.50 28.33 F5 1	15.00 20.63 40.00 2
4000 (BONE)	22.86 27.50 33.75 M1 9	23.64 28.75 36.25 18	36.67 41.67 50.38 M1 13	32.50 40.63 48.75 16	46.25 49.06 51.88 M5 16
N* Total 213	46	75	38	34	20

* Total N at 250 c.p.s. and 500 c.p.s. is 187.

WILCOXON TESTS (bottom left corner in each cell).
F1 = median loss significantly greater in women at 1% level.
F5 = ,, ,, ,, ,, ,, ,, ,, 5% ,,
M1 = ,, ,, ,, ,, ,, men ,, 1% ,,
M5 = ,, ,, ,, ,, ,, ,, ,, 5% ,,
Figures in bottom right corner of each cell are numbers in whom maximum signal was not heard.

Table 2. Median values of decibel loss in older women. (The central figure in each cell is the median, the upper and lower figures being the 95% confidence limits).

c.p.s.	*Age Group*				
	62-64	*65-69*	*70-74*	*75-79*	*≥80*
250 (AIR)	23.33 26.25 29.50 0	26.80 28.70 30.94 0	26.79 29.29 33.13 0	28.33 34.00 38.75 0	32.50 40.00 45.00 0
500 (AIR)	22.50 24.82 29.29 0	27.33 30.30 32.20 0	26.82 30.00 35.00 0	28.13 34.00 39.29 0	33.33 40.71 44.29 0
1000 (AIR)	16.54 19.04 22.00 0	21.43 23.13 24.82 0	21.11 23.19 25.83 0	22.78 27.50 33.33 0	25.00 33.13 40.00 0
2000 (AIR)	10.71 15.36 23.00 0	17.38 19.64 23.33 0	15.77 18.65 22.86 0	23.13 28.33 37.00 0	28.75 36.88 46.00 0
4000 (AIR)	16.67 21.76 30.00 0	26.25 30.21 33.33 0	26.88 34.17 45.00 0	41.00 50.91 54.09 1	46.67 55.83 60.83 0
6000 (AIR)	19.29 23.06 32.50 0	30.00 36.25 41.00 0	33.33 40.50 46.00 0	47.14 52.50 60.56 1	55.00 59.58 65.00 0
8000 (AIR)	24.00 33.75 45.00 1	40.00 45.28 52.00 3	50.00 54.69 59.38 1	64.00 66.00 69.50 3	66.00 71.50 77.00 1
1000 (BONE)	12.50 16.46 19.17 0	17.81 21.07 24.64 0	17.50 22.00 26.25 1	21.67 28.21 34.00 2	28.00 32.86 40.00 0
4000 (BONE)	12.50 17.08 23.00 1	22.08 26.50 32.14 9	22.27 26.67 35.00 12	35.00 39.64 50.00 14	38.33 44.17 51.50 10
N* Total 265	42	94	56	43	30

* Total N at 250 c.p.s. and 500 c.p.s. is 223.

Figures in the bottom right corner of each cell are numbers in whom maximum signal was not heard.

Table 3. **Linear regression of median hearing loss in five age groups in older men and women.**

Frequency c.p.s.	Men			Women		
	Regression Coefficient	*Standard Error*	*Significance Level*	*Regression Coefficient*	*Standard Error*	*Significance Level*
AIR						
250	0.48	0.20	>10%	0.66	0.12	<5%
500	0.49	0.25	>10%	0.72	0.13	<5%
1000	0.51	0.17	<6%	0.67	0.10	<5%
2000	1.30	0.20	<1%	1.03	0.23	<2%
4000	1.88	0.60	<5%	1.78	0.21	<1%
6000	1.04	0.33	<5%	1.79	0.14	<1%
8000	1.51	0.14	<1%	1.93	0.20	<1%
BONE						
1000	0.21	0.16	>10%	0.80	0.08	<1%
4000	1.10	0.22	<5%	1.35	0.19	<1%

conduction within each age group of each sex as the sound frequency increased. The results based on median values of hearing loss are shown for seven sound frequencies in the five age groups of men and of women in figure 3. The figure considered along with tables 1 and 2 shows, as expected, that hearing loss was greater in women compared with men of all age groups in the lower frequencies and greater in men compared with women in the higher frequencies. Figure 3 in conjunction with tables 1 and 2 also shows that the difference in hearing loss between lower and higher frequencies was greater in men than in women and greater in older compared with younger persons of both sexes.

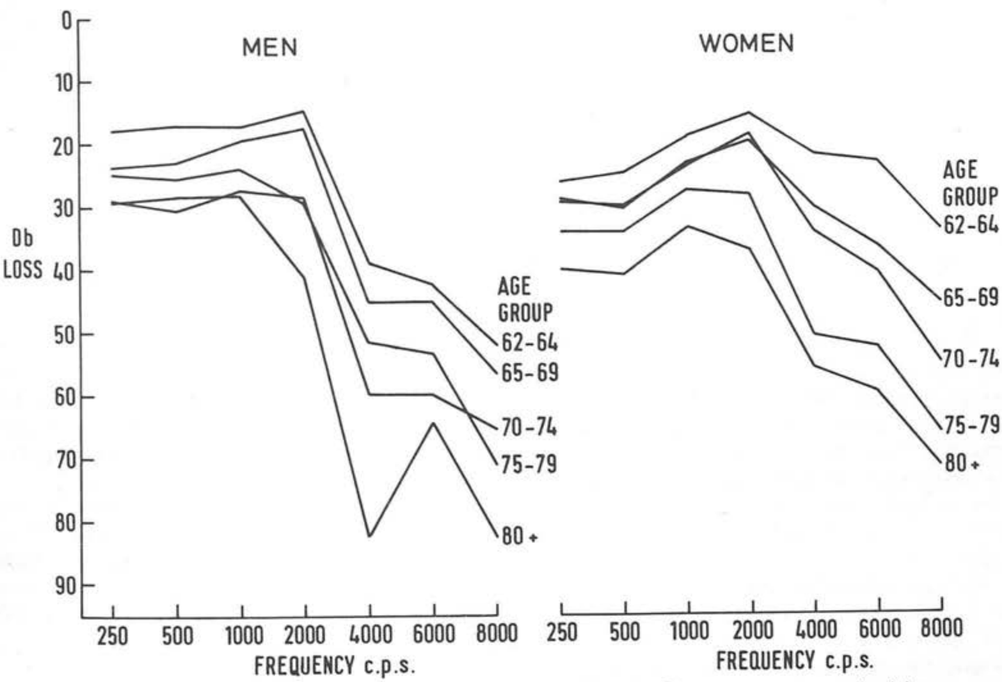

Fig. 3. Median hearing losses for seven sound frequencies in five age groups of older men and women.

In tables 1 and 2 inspection of the confidence limits of median hearing loss within each age and sex group in ascending order of magnitude of sound frequency from 250 c.p.s. upwards shows, with one exception of women aged 62-64 years, that the first significant drop in hearing loss was between the frequencies 2000 and 4000 c.p.s. Figure 3 shows graphically this large difference in hearing loss between these frequencies.

Discussion

The skew distributions of hearing loss in the present and other studies make the median a more appropriate measure of central tendency than the mean (Glorig and Nixon 1960, Corso 1963). Difficulty in using the mean is increased by the high proportion of older people who do not hear the maximum sound produced by the audiometer in the higher frequencies (Bunch 1929). For example in one study 60% of men over 65 years and 60% of women over 75 years could not hear the loudest sound at the frequency of 8000 c.p.s. (Sataloff and Menduke 1957). Miller and Ort (1965) made an estimate of hearing loss, when no sound was heard, to allow calculation of the mean. Although the median hearing loss has been reported in various studies (Hinchcliffe 1959, Glorig *et al.,* 1957, Glorig and Roberts 1965) comparisons were difficult between groups. This difficulty was met in the present study by using non-parametric confidence limits (MacKinnon 1964).

Audiometric studies collect large amounts of data. In the present study results have been given for the better ear only, which reduces the quantity of data described. Results for the better ear have been reported by other workers (Sataloff and Menduke 1957, Klotz and Kilbane 1962, Glorig and Roberts 1965). This is justified because presbyacusis largely affects both ears equally (Miller and Ort 1965, Klotz and Kilbane 1962, Sataloff and Menduke 1957). No significant difference in hearing loss was detected between right and left ears in the present sample. This means that part of the sample hear better with the right ear while the remainder hear better with the left ear. Hence in a descriptive study the better ear gives results more representative of hearing loss in every person than either right or left ear presented singly.

The ambient noise level in the present study was 35 db A. This does not differ greatly from that accepted by some other workers. In Manchester, audiological clinics accept 30 db A as a suitable sound level but would allow a level not exceeding 40 db A provided the hearing loss is 10 db or more (John 1973). Most subjects in the present study have at least that degree of loss. Some studies with special testing booths report lower ambient noise (Glorig *et al.,* 1957) but the U.S. National Health Survey accepted noise inside the booths varying from 15 db to 42 db, depending on the sound frequency, and quoted allowable maximum sound from 42 dB to 62 dB depending on the frequency (Glorig and Roberts 1965). Farrimond (1961) suggested ambient noise should not exceed 40 dB.

The present study used a descending approach to the threshold of hearing (Medicine Today 1968). Although Glorig and Nixon (1960) remark that 'in the field audiometric techniques are almost as numerous as the persons who do audiometry', a combination of ascending and descending approaches is most generally used. The method in the present study was used because older people find audiometric examination tiring and the descending approach takes the shortest time. In addition, audiometry formed part of a two hour examination and it was difficult to allow more time for it. The descending approach results in a lower threshold of hearing than a mixed ascending-descending method (Price 1971) and it could be argued that the lowest obtainable threshold is the measure of the best hearing of the subject. The present study was designed as a longitudinal one to be carried out by one observer. Provided the technique is reproducible and does not change, the actual method employed should not effect longitudinal changes.

Reliability in the present study is similar to that described by others (Ciocco 1932). Delany (1971) reports a replication variance at frequencies of 1000 to 2000 c.p.s. of 3 dB^2 which does not differ greatly from 5.2 dB^2 in the present study. Dickson (1971) mentions diurnal variation of up to 10 dB in some subjects.

The present authors studied a random sample of the elderly population. Some other workers have used random samples (Hinchcliffe 1959, Glorig and Roberts 1956) but many others have used self selected populations or occupants of residential homes.

Some studies exclude 'abnormal' subjects. These may be persons exposed to more than minimum noise levels (Corso 1963, Hinchcliffe 1959, Goetzinger *et al.,* 1961) or persons with middle ear disease (Klotz and Kilbane 1962, Pestalozza and Shore 1955, Goetzinger *et al.,* 1961) or those with an air-bone gap (Klotz and Kilbane 1962). The work of Glorig and Nixon (1961) would be against excluding persons with conductive loss since these workers regard high frequency conductive loss as characteristic of presbyacusis. The present study eliminated only persons with intellectual impairment who could not understand the test. Many subjects in the present study had been exposed to high levels of noise at work and in war. Damage to hearing from noise reaches a maximum in 10 years, provided the subject is not thereafter exposed to a greater level of noise (Glorig and Davis 1961). Hence in elderly subjects as in the present study, longitudinal changes in hearing loss presumably reflect age rather than noise effects.

The age effects, which are reported in this paper, were increasing hearing loss in each sound frequency with increasing age, the age loss being greater in the higher frequencies. These effects are common to many studies (Miller and Ort 1965, Klotz and Kilbane 1962, Hinchcliffe 1959, Ciocco 1932, Mounier-Kuhn and Morgan 1966, Goetzinger *et al.,* 1961, Hollingsworth and Ishii 1960, Glorig *et al.,* 1957, Bunch 1929). The rate of loss did not change as age increased. Some authors think little additional hearing is lost after 65 years (Sataloff and Menduke 1957). Others disagree (Klotz and Kilbane 1962, Glorig *et al.,* 1957, Hinchcliffe 1959, Goetzinger *et al.,* 1961). The present study would also disagree but the data are crossectional and only longitudinal study will resolve the disagreement.

Sex differences found in the present study and many others were that at or below the sound frequency of 1000 c.p.s. hearing loss in women exceeds that in men (Miller and Ort 1965, Corso 1963, Goetzinger *et al.,* 1961, Hollingsworth and Ishii 1960) and that at or above the sound frequency of 2000 c.p.s. hearing loss in men exceeded that in women (Miller and Ort 1965, Klotz and Kilbane 1962, Corso 1963, Hinchcliffe 1959, Ciocco 1932, Goetzinger *et al.,* 1961, Hollingsworth and Ishii 1960, Glorig *et al.,* 1957). The lesser age loss in women compared with men may be from lesser exposure to noise during life (Richards 1971, Glorig and Nixon 1960).

The frequencies reported in the present study have been used by other workers (Miller and Ort 1965, Klotz and Kilbane 1962). The present authors are uncertain of the value of the data for sound frequencies of 250 and 500 c.p.s. These data were collected from smaller numbers than those in other frequencies and ambient noise interferes with the examination. The observer in the present study has a strong clinical impression that most older people with hearing loss of less than 30 dB at 1000 c.p.s. are able to hear well when talking to one person.

Absolute comparisons with other studies are difficult but, making allowance for the difference between American and British Standards, data in the present study agree with the World Fair data at 500 and 1000 c.p.s. In frequencies of 2000 c.p.s. and more, hearing loss is greater in World Fair subjects of corresponding age groups.

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HEARING LOSS RELATED TO SOME SIGNS AND SYMPTOMS IN OLDER PEOPLE

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Abstract

Hearing loss measured by pure tone audiometry was compared, for two sound frequencies in the better ear, with subjective deafness in a random sample of older people (215 men, 272 women). Although median values with 95% confidence limits showed significantly greater hearing loss in the groups with subjective deafness, the definition of deafness as hearing loss greater than 30 dB at 1,000 c.p.s. revealed a substantial proportion who complained of deafness with hearing loss of 30 dB or less and a smaller proportion, unaware of deafness, with hearing loss greater than 30 dB. Subjective deafness alone is therefore not an adequate screening test. Tinnitus, vertigo and abnormalities of the ear drum were found to be associated with deafness in the elderly while wax and nasal catarrh were not. None of these symptoms or signs showed age effects on prevalence except subjective deafness which increased with increasing age.

Introduction

A number of signs and symptoms are regarded by clinicians as being associated with hearing loss. In this paper such association is examined using data extracted from a comprehensive survey of a sample of the elderly population.

This survey is a longitudinal study of ageing persons which has been carried on in Edinburgh since 1968. Its purposes were firstly to assess physical and mental health in a random sample of the elderly population and secondly to determine the range of certain measurements in older people. Changes in health and measurements were to be estimated at subsequent examinations. The first examination, made in 1968-9, comprised the recording, at an interview when the author used a semi-structured questionnaire, of past medical history and of past and present symptoms of physical health.

After the interview, full clinical examination was carried out. Special examinations or measurements made included anthropometry, testing of visual acuity, audiometry and otoscopy, respiratory function tests, electrocardiography, radiography, estimate of heart size, estimates of bone mass, haematology and biochemistry. Subsequent examinations made after 1 year (1969-70) and after 5 years (1973-4) repeated some of the questions, the clinical examination and the special tests. Mental health was studied at each examination by a psychiatrist who interviewed each subject using a flexible questionnaire.

The findings from pure-tone audiometry in the first examination have already been reported (Milne and Lauder, 1975). In the present paper the data used were also from the first examination.

Subjects and Methods

The random sample examined in the study was obtained as follows. In 1968 there were 91 doctors in 50 general practices with surgery addresses in a defined area of Edinburgh, composed of 10 city wards. The National Health Service Lists of these doctors contained a total of 27,000 persons born in 1905 or earlier. From this total a simple random sample was examined of 215 men and 272 women aged 62-90 years. Full details of sampling with a comparison of respondents and non-respondents have been given elsewhere (Milne, Maule and Williamson, 1971).

The questions, the answers to which are analysed in this paper, sought information about vertigo (defined as a feeling of rotation or disturbed balance), tinnitus (defined as noise or ringing in the ears) and winter nasal catarrh (defined as in the M.R.C. questionnaire of 1969 on respiratory symptoms as having a stuffy nose or catarrh at the back of the nose for at least three months of each year in the winter). There was also a question about subjective deafness to allow the subject to give an opinion about his or her hearing. The actual questions asked are given in the appendix.

The possession of a hearing aid was noted as was the presence of wax and abnormalities of the ear drum.

The purpose of that part of the total study described in the present paper was to define the prevalences of the above signs and symptoms in the sample and to relate them to the audiometric findings.

Hearing loss was measured with a Madsen TBN 60 portable transistorised audiometer with a threshold calibrated to British standards. The instrument was regularly calibrated and serviced by the Royal National Institute for the Deaf. Examinations were made in a double glazed quiet room in which the ambient sound level measured with a sound level meter was 35 dB using weighting network A.

The method of measuring hearing loss was as follows. The frequency of 1,000 c.p.s. in the right ear was used to demonstrate the technique to the subject, who was asked to signal by tapping each time the sound was heard during progression from audible to inaudible pulses of sound. Recording began after this at a frequency of 250 c.p.s. in the right ear. Hearing loss was recorded in the right and then in the left ear at frequencies of 250, 500, 1,000, 2,000, 4,000, 6,000, and 8,000 c.p.s. These data have been reported in detail elsewhere (Milne and Lauder, 1957). In the present paper two representative frequencies have been used, namely 1,000 c.p.s. and 4,000 c.p.s., in the better ear where symptoms are concerned and in the right or left ear where data related to signs are reported.

Only one attempt was made to measure hearing loss in each frequency unless something noisy interrupted the examination in any frequency, in which case that measurement was repeated. Masking was used when appropriate. Reliability, which was reported in more detail elsewhere (Milne and Lauder, 1975), was $\pm$ 5 dB for different readings in the same subject by the same observer.

The measurements were made by the author in 213 men and 265 women. In nine persons intellectual impairment made the audiometric examination impossible, although three of these subjects were able to answer questions.

Results

The prevalence of the symptoms vertigo, tinnitus, winter nasal catarrh and subjective deafness was recorded as 'yes' or 'no' for each symptom. For some of the symptoms, namely vertigo and tinnitus in men, the prevalence seemed to increase with increasing age, but this age effect reached statistical significance only for subjective deafness.

Hence in table 1 symptom prevalence, except of subjective deafness, is reported for men and for women without division into age groups. Although the prevalence of vertigo seems greater in women (25%) than in men (20%) while tinnitus is commoner in men (19%) than in women (15%), none of these proportions differs significantly between the sexes. Winter nasal catarrh is present in a significantly greater proportion of men (20%) than of women (11% $p < 0.05$).

The prevalence of subjective deafness is given in table 2 for 3 age groups of men and of women. The increase as age increases in the proportion of men who are aware of deafness is from 42% to 55% while in women the corresponding increase is from 29% to 53%. The age effect was examined using the age groupings in each sex (62-64, 65-69, 70-74, 75-79, > 80) in which the data are stored in the computer. For each sex in each age group the percentage prevalence of subjective deafness was determined. Linear regressions of these prevalences on age were calculated for men and for women. The regression coefficients were significant at the 1% level in men and at the 5% level in women (table 3), thus demonstrating an increase, as age increased, in the proportion of subjects admitting deafness. The proportions of

Table 1. Prevalence of various symptoms in older men and women. (Percentages in brackets)

	*Men**		*Women†*	
Symptom	*Symptom Present*	*Symptom Absent*	*Symptom Present*	*Symptom Absent*
Vertigo	43 (20.2)	170 (79.8)	68 (25.4)	200 (74.6)
Tinnitus	41 (19.2)	172 (80.8)	41 (15.3)	227 (84.7)
Winter Nasal Catarrh	42 (19.7)	171 (80.3)	30 (11.2)	238 (88.8)
Hearing Aid	11 (5.1)	203 (94.9)	17 (6.3)	253 (93.7)

* 2 missing values. † 4 missing values.

Table 2. Subjective deafness in three age groups of older men and women. (Percentages in brackets)

Sex	62-69 years Deaf	62-69 years Not Deaf	70-79 years Deaf	70-79 years Not Deaf	80-90 years Deaf	80-90 years Not Deaf	Total
Men*	51	70	36	36	11	9	213
	(42)	(58)	(50)	(50)	(55)	(45)	
Women†	40	96	36	64	17	15	268
	(29)	(71)	(36)	(64)	(53)	(47)	

* 2 missing values † 4 missing values.

Table 3. Linear regressions of the prevalence of subjective deafness on age in five age groups in older men and women.

Sex	Regression Coefficient	Standard Error	Significance Level
Men	0.673	0.110	<1%
Women	1.016	0.229	<5%

all men (46%) and all women (35%) who are aware of deafness differ significantly ($p < 0.05$).

No age effects were present in respect of wax in the ears or of abnormalities of the ear drum. Data about wax and the drums are hence reported without division into age groups. Table 4 shows wax was found in one or both ears in 49% of men and 38% of women in the sample. These proportions do not differ significantly. Recorded abnormalities of ear drums are given in table 5. The reason for the drum being 'not seen', in about one-third of all subjects, was usually wax. It was not practical in the study as performed to remove wax from the ears.

Possible associations amongst the recorded symptoms and signs were examined for all combinations of the symptoms and signs described above. In men a significant association ($p < 0.01$) was present between tinnitus and subjective deafness since 27 of the 98 deaf men and 14 of 155 men not aware of deafness had tinnitus. In women there was a similar association ($p < 0.01$) the numbers with tinnitus being 27 of 93 deaf women and 14 of 175 women not aware of deafness. In women only, subjective deafness was significantly associated with vertigo ($p < 0.01$). In both sexes subjective deafness was significantly associated with abnormality of the ear drum.

The association between hearing loss and symptoms and signs is displayed in table 6 for men and for women in respect of the better ear using frequencies of 1,000 c.p.s. and 4,000

Table 4. Prevalence of wax in the ears of older people. (Percentages in brackets)

Sex	None	Wax Right ear only	Wax Left ear only	Wax Both ears
Men*	117	27	17	53
	(54.7)	(12.6)	(7.9)	(24.8)
Women†	168	22	25	55
	(62.2)	(8.2)	(9.3)	(20.4)

* 1 missing value. † 2 missing values.

Table 5. The state of the ear drums in older people. (Percentages in brackets)

Sex	Right drum Normal	Right drum perforation	Right drum Scar	Right drum Not seen	Left drum Normal	Left drum perforation	Left drum Scar	Left drum Not seen
Men*	122	10	3	79	127	15	2	70
	(57.0)	(4.7)	(1.4)	(36.9)	(59.3)	(7.0)	(0.9)	(32.7)
Women†	176	12	5	77	167	15	8	80
	(65.2)	(4.4)	(1.9)	(28.5)	(61.9)	(5.6)	(3.0)	(29.6)

* 1 missing value. † 2 missing values.

Table 6. Median values of decibel loss in older men and women in those with and without various symptoms and signs. (The central figure in each cell is the median, the upper and lower figures being the 95% confidence limits.)

Symptom or Sign	*MEN* 1000 c.p.s.	*MEN* 4000 c.p.s.	*N*	*WOMEN* 1000 c.p.s.	*WOMEN* 4000 c.p.s.	*N*
Vertigo present	23.50 27.86 32.86	51.67 61.25 70.00	43	26.67 28.69 32.14	39.00 50.50 57.22	68
Vertigo absent	23.97 26.16 28.57	49.00 54.42 60.00	170	26.96 28.33 29.71	33.33 36.75 40.56	197
Tinnitus present	22.50 32.00 50.00	53.00 62.50 80.00	41	28.13 36.67 46.25	40.00 56.11 60.00	41
Tinnitus absent	24.00 25.86 27.97	48.64 53.75 59.55	172	26.72 27.93 29.14	34.17 39.31 41.67	224
Winter nasal catarrh present	23.18 26.56 31.67	46.00 52.50 62.00	42	27.00 31.56 35.00	31.00 37.50 50.00	30
Winter nasal catarrh absent	24.24 26.48 28.89	51.79 56.67 61.92	171	26.94 28.13 29.33	35.45 39.09 45.67	235
Wax present (right ear)	25.83 29.79 35.56	52.50 62.08 71.00	80	28.89 31.50 34.33	31.25 36.14 40.00	74
Wax absent (right ear)	27.00 29.00 32.31	54.09 60.00 65.00	133	30.45 32.58 34.70	42.00 47.67 53.50	191
Abnormal right drum	38.33 53.33 85.00	70.00 90.00 116.67	13	27.50 47.50 73.33	45.00 71.25 87.50	16
Normal right drum*	26.00 27.83 29.67	52.73 58.00 62.69	121	29.87 31.88 33.91	39.71 46.07 51.11	175

* Drum not seen omitted.

c.p.s. Subjective deafness is excluded from the table. For wax and ear drum abnormalities findings are given for the right ear only. Results for the left ear do not differ significantly from those for the right. Distributions of hearing loss are skew and the median is used as the best measure of central tendency (Milne and Lauder, 1975) with non-parametric confidence limits (McKinnon, 1964).

The table shows significantly smaller median values in men for 'normal right drum' compared with 'abnormal right drum' at 1,000 c.p.s. and 4,000 c.p.s. This difference is not found in women, possibly because the small number with abnormal drums makes the confidence limits larger. For none of the other symptoms or signs in the table is hearing loss significantly greater in those with, than in those without, the symptom or sign. The finding that in women at 4,000 c.p.s. hearing loss is significantly greater when wax is absent from the right ear is not found in the left ear. The figures for hearing loss, with and without tinnitus, suggest that a difference might emerge if a larger sample were used.

The results for men and for women with and without subjective deafness are given in age groups less than 70 years and 70 years and over for the same sound frequencies in table 7. In all groups the median hearing loss is signifi-

Table 7. Median values of decibel loss in older men and women with and without subjective deafness. (The central figure in each cell is the median, the upper and lower figures being the 95% confidence limits.)

Age and subject's estimate of hearing	*MEN* 1000 c.p.s.	4000 c.p.s.	N	*WOMEN* 1000 c.p.s	4000 c.p.s.	N
62-69 years	26.00	54.00		30.00	46.67	
Deaf	29.50	63.00	51	38.50	54.50	40
	33.00	67.50		43.13	60.00	
Not deaf	19.57	32.92		23.40	25.95	
	21.30	38.50	70	25.39	28.45	96
	23.00	48.11		27.03	31.67	
⩾70 years	34.38	66.25		36.88	55.45	
Deaf	43.33	76.25	47	41.43	61.43	51
	52.86	82.50		46.43	66.00	
Not deaf	23.13	50.00		25.83	33.33	
	26.54	56.25	45	27.81	41.88	78
	29.23	64.00		29.79	48.89	

cantly smaller in those persons without subjective deafness.

Table 8 gives in the same age groups and sound frequencies in men and in women a division of subjects into those with hearing loss of 30 dB or less and more than 30 dB in respect of the presence or otherwise of subjective deafness. The percentage figures in brackets in the table show that in those who claim to be unaware of deafness the proportion with hearing loss greater than 30 dB at 1,000 c.p.s. varies from 2.9% in the younger men to 19.2% in the older women. Conversely of those who claim to be deaf the proportion with hearing loss of 30 dB or less at 1,000 c.p.s. varies from 72.5% and 42.5% respectively in younger men and women to 38.3% and 31.4% respectively in older men and women. At 4,000 c.p.s. the proportions of those not subjectively deaf with hearing loss greater than 30 dB are larger and the proportions of the deaf with hearing loss of 30 dB or less are smaller. Similar data are given in table 9 in respect of hearing loss of 30 dB or less and more than 30 dB in persons with and without tinnitus, vertigo and wax in the ears. At 4,000 c.p.s., but not at 1,000 c.p.s., a significantly greater proportion of men ($p < 0.01$) and of women ($p < 0.05$) who complain of vertigo have hearing loss greater than 30 dB compared with those without vertigo. Tinnitus is similarly associated with a greater proportion of persons with hearing loss greater than 30 dB. This

Table 8. Numbers of older men and women with hearing loss ⩽30dB and >30dB and with or without subjective deafness. (Percentages in brackets)

Age and subject's estimate of hearing	*MEN* 1000 c.p.s. dB loss ⩽30	dB loss >30	4000 c.p.s. dB loss ⩽30	dB loss >30	*WOMEN* 1000 c.p.s. dB loss ⩽30	dB loss >30	4000 c.p.s. dB loss ⩽30	dB loss >30
62-69 years	37	14	7	44	17	23	8	32
Deaf	(72.5)	(27.5)	(13.7)	(86.3)	(42.5)	(57.5)	(20.0)	(80.0)
Not deaf	68	2	32	38	88	8	67	29
	(97.1)	(2.9)	(45.7)	(54.3)	(91.7)	(8.3)	(69.8)	(30.2)
⩾70 years	18	29	2	45	16	35	6	45
Deaf	(38.3)	(61.7)	(4.3)	(95.7)	(31.4)	(68.6)	(11.8)	(88.2)
Not deaf	41	4	5	40	63	15	33	45
	(91.1)	(8.9)	(11.1)	(88.9)	(80.8)	(19.2)	(42.3)	(57.7)

Table 9. Older men and women with hearing loss of ≤30dB and >30dB, with or without various symptoms or signs (percentages).

		MEN $N = 213$					WOMEN $N = 265$			
		dB loss 1000 c.p.s.		*dB loss 4000 c.p.s.*			*dB loss 1000 c.p.s.*		*dB loss 4000 c.p.s.*	
Symptom/ Sign	*N*	*≤30*	*>30*	*≤30*	*>30*	*N*	*≤30*	*>30*	*≤30*	*>30*
VERTIGO										
Present	43	74.4	25.6	9.3	90.7	68	69.1	30.9	32.4	67.6
		NS		**			NS		*	
Absent	170	77.6	22.4	24.7	75.3	197	69.5	30.5	46.7	53.3
TINNITUS										
Present	41	58.5	41.5	4.9	95.1	41	46.3	53.7	31.7	68.3
		**		**			**		NS	
Absent	172	81.4	18.6	25.6	74.4	224	73.7	26.3	45.1	54.9
WINTER CATARRH										
Present	42	78.6	21.4	19.0	81.0	30	70.0	30.0	46.7	53.3
		NS		NS			NS		NS	
Absent	171	76.6	23.4	22.2	77.8	235	69.4	30.6	42.6	57.4
WAX RIGHT										
Present	80	61.3	38.7	20.0	80.0	74	64.9	35.1	47.3	52.7
		NS		NS			NS		*	
Absent	133	64.7	35.3	16.5	83.5	191	58.6	41.4	32.5	67.5
WAX LEFT										
Present	70	64.3	35.7	12.9	87.1	78	64.1	35.9	34.6	65.4
		NS		NS			NS		NS	
Absent	143	65.0	35.0	14.0	86.0	187	57.2	42.8	28.3	71.7

NS = not significant * $p<0.05$ ** $p<0.01$
Significance tests compare results, for the appropriate sex and sound frequency, in those with and without a symptom or sign

association is significant ($p < 0.01$) in men at 1,000 c.p.s. and 4,000 c.p.s. and in women at 1,000 c.p.s. only.

Discussion

Difficulty in hearing recognised by the subject is known to increase with increasing age (Harris, 1962; Wilkins, 1949; Sheldon, 1948; U.S. National Health Survey, 1968). Sheldon (1948) reported deafness in 27.5% of men and 28.6% of women of 65 years and over. Corresponding figures given by Harris (1962) are 35% of men and 30% of women. Figures in the present study are higher at 46% of men and 35% of women of 62 years and over.

The percentages of deaf persons reported in different age groups vary widely in different surveys. Wilkins (1949) found 12% of men and women aged 65-74 with 28% of men and 25% of women aged 75 years and over complaining of deafness. Figures given by Sheldon (1948) rose from 14% of men and 18% of women aged 65-69 to 60% of men and 68% of women aged 80 years or more. Harris (1962) reported a rise from 24% at 65-69 years to 49% at 85 years and over. The present study found figures higher than other surveys in the seventh decade (42% of men, 29% of women) rising to 55% of men and 53% of women in the ninth decade (table 2). Apart from variation in confidence limits resulting from different sample sizes in the various surveys, differences in prevalence may depend on the actual questions used to obtain information. It is known that apparently minor changes in the wording of a question may affect the prevalence obtained (Rose and Blackburn, 1968).

The accuracy of assessment by elderly subjects of their own hearing is of interest because of the difficulty of using audiometry as a screening examination in the whole elderly population. It would be easy for health visitors carrying out periodic checks on the health of the elderly to ask about deafness. If such a simple question were sufficient to identify the majority of deaf old people, the size of the problem confronting the therapeutic audiological services could be gauged.

Glorig (1957, 1971) showed in the Wisconsin State Fair Hearing Survey that persons, admittedly younger than in the present study, who labelled their hearing as good had hearing loss less than 30 dB in the 500-2,000 c.p.s. range. He found that in no case did the subject describe hearing as other than good with hearing loss of this degree. Those with greater losses in this range described their hearing as fair or bad.

In the present study the distinction was less clear-cut. The two age groups of men who claimed to be deaf contained 72.5% and 38.3% with losses of 30 dB or less at 1,000 c.p.s. the corresponding figure in women being 42.5% and 31.4% (table 7). If audiometry is accepted as a good test for deafness, this means specificity of the question about deafness is poor. Sensitivity is better since of those who claimed to have good hearing in the two age groups of men 2.9% and 8.9% had hearing losses greater than 30 dB at 1,000 c.p.s. The corresponding figures in women were 8.3% and 19.2%. The latter high figure in women of 70 years and over may be associated with the known greater prevalence of intellectual impairment in women of this age (Kay, Beamish and Roth, 1964).

The results in the present survey suggest that while a question about deafness would miss a relatively small number of deaf people, except in women of 70 years and over in whom the number missed would be larger, it would wrongly classify as deaf a large number of people probably without disability from hearing loss. This is a practical difficulty in the discovery of the elderly deaf which might not be suspected from the statistically satisfactory distinction in table 7 between hearing losses in persons aware of and persons not aware of deafness. Klotz and Kilbane (1962) summarise the facts succinctly by stating 'There is a much greater tendency to complain of hearing loss when none can be demonstrated than to deny one that clearly exists'.

The work of Atherley and Noble (1971) suggests that assessment of hearing difficulty in the elderly is complex and may require, in addition to audiometry information about hearing speech, acuity for non-speech sounds, localisation, the emotional response to deafness, distortion of speech, tinnitus and the subjects' own assessment of hearing. If this is so the prospect of a simple screening test to discover older people disabled by deafness seems remote.

Estimates of the prevalence of vertigo vary widely. Sheldon (1948) gave prevalences in persons of 65 years and over of 39% in men and 57% in women. He also found rises in prevalence as age increased with a fall in the oldest men. Hobson and Pemberton (1955) reported frequent or continuous vertigo in 13.1% of men over 65 years and 30.3% of women over 60 years. Hinchcliffe (1961) found vertigo at one time or another in 29% of men and women aged 65-74 years. The U.S. National Health Survey (1968) using the slightly different concept of 'dizziness' reported this in 35-48% of men and 48-52% of women of 65 years and over with a fall in prevalence in the older members of both sexes. Some authors (Hobson and Pemberton, 1955; Sheldon, 1948; U.S. National Health Survey, 1968) have associated vertigo with an increased likelihood of deafness.

Although the prevalence is once again different (men 20%, women 25%) in the present study, the sex difference is in the same direction as those reported above and there is a statistically significant relationship with deafness at 4,000 c.p.s. No significant age effect was found for vertigo in this study.

The prevalence of tinnitus also varies widely in different surveys. Hobson and Pemberton (1955) reported 37.5% of men over 65 years and 38.5% of women over 60 years as having this symptom. Hinchcliffe (1961) gave 37% as the prevalence in both sexes aged 65-74 years while the U.S. National Health Survey (1968) found tinnitus in from 41-45% of men and women of 65 years and over. Sheldon (1948) reported tinnitus in 17.8% of persons of 65 years and over, a figure similar to those in the present study of 19% in men and 15% in women.

The association of tinnitus with deafness is mentioned by several authors (Hobson and Pemberton, 1955; Klotz and Kilbane, 1962; U.S. National Health Survey, 1968). The present study confirms this association both in respect of hearing loss (table 9) and of a significant association with subjective deafness in both sexes. A significant association between tinnitus and vertigo in women only (Hobson and Pemberton, 1955) was not found in the present study. The statement that tinnitus is experienced by many people with normal hearing (Hempstock and Atherley, 1971) is supported by the present study (table 9).

Wax was found in one or both ears in 45% of men and 38% of women in the present study. Glorig *et al.* (1957) reported 34% of men and 21% of women over the age of 60 years with some degree of wax. Hinchcliffe (1962) found one or both meatuses occluded with wax in 23% of men and 13% of women in his sample whose age range was 18-74 years. The prevalence in the present study is high compared with the others but the sex difference is in the same direction.

The presence of wax in the present study was not associated with any increase in hearing loss (table 6, table 9). The anomalous finding in women at 4,000 c.p.s. of a significantly greater proportion without wax having more than 30 dB of hearing loss was not present in the left year.

The present study reported between 4.4 and 7.0% of perforated ear drums in men and women while scarring of the drum varied between 0.9 and 3.0%. The proportion of drums not seen on examination varied between 28.5 and 36.9%. The U.S. National Health Survey (1968) revealed in men and women of 65 years and over from 8.0 to 14.9% of abnormalities of the ear on otoscopy with the proportion of drums not seen varying from 16.4 to 20.9%. In that study the prevalence of scars was greater and of perforations less than in the present study. The U.S. study and the present study found an association between impaired hearing (subjective or measured) and abnormality of the drum. On the other hand Glorig (1957) did not think abnormalities of the drum were reliable indicators of hearing loss.

Hearing aids were possessed by 5.1% of men and 6.3% of women in the present study. These are similar to the figure in the Lewisham survey which was 6.2% of all persons interviewed. (Harris, 1962).

APPENDIX

Questions used at Interview

Vertigo

1. Do you suffer from faintness or lightheadedness or unsteadiness or giddiness?
2. (If yes to 1.) In an attack do you have any feeling of going round?
3. (If yes to 1.) Is your balance ever affected?

Replies of yes to 1 and 2 or 3 were coded as 'vertigo present'.

Tinnitus

Do you suffer from ringing or noise in your ears?

Winter Nasal Catarrh

1. Do you usually have a stuffy nose or catarrh at the back of your nose in the winter?
2. Do you have this on most days for as much as three months each year?

Replies of yes to 1 and 2 were coded as 'winter catarrh present'.

Subjective Deafness

1. Do you suffer from deafness?
2. Are you hard of hearing?

Replies of yes to 1 or 2 were coded as 'subjective deafness present'.

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THE AIR-BONE GAP IN OLDER PEOPLE

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Abstract

The air-bone gap was computed in an audiometric study of hearing loss in a random sample of older people (215 men and 272 women) using sound frequencies of 1,000 c.p.s. and 4,000 c.p.s. and omitting persons with abnormal ear drums. The prevalence of a gap larger than 10 dB was greater in both sexes for the higher sound frequency. There was no age effect on the air-bone gap in the sample but the gap increased significantly as hearing loss increased. Mean values of the gaps were significantly greater than zero in both sexes for both frequencies and significantly larger in men than in women at 4,000 c.p.s. In both sexes means were significantly larger at 4,000 c.p.s. than at 1,000 c.p.s. The many missing values in the study were mainly due to failure to hear the loudest signal available for bone conduction.

Introduction

The existence of the air-borne gap described as occurring in older people by Glorig and Davis in 1961 has not been generally accepted. Indeed some workers have produced evidence to show that the gap does not exist (Sataloff, Vassalo and Menduke, 1965). The present paper describes data about the air-bone gap from a study of older people in Edinburgh.

This project is a longitudinal study of older people which has been carried on in Edinburgh since 1968. Although the subjects in the study have now been examined on three occasions the present paper is based on the initial, and hence cross-sectional, examination.

The aims of the study were to assess physical and mental health in a random sample of the elderly population and to determine the range of certain measurements in older people. At the first examination, made in 1968-9, the author interviewed each subject and used a semi-structured questionnaire to record past medical history and past and present symptoms of physical health. After the interview a full clinical examination was made. This included some special measurements and examinations among which were pure tone audiometry and otoscopy. The findings from the pure-tone audiometry have already been reported (Milne and Lauder, 1975).

Subjects and Methods

The random sample examined was obtained as follows. In 1968 there were 91 doctors in 50 general practices with surgery addresses in a defined area of Edinburgh, composed of 10 city wards. The National Health Service lists of these doctors contained a total of 27,000 persons born in 1905 or earlier. From this total a simple random sample was examined of 487 persons divided into 215 men and 272 women aged 62-90 years. Details of sampling with a comparison of respondents and non-respondents have been given elsewhere (Milne, Maule and Williamson, 1971).

Hearing loss was measured in the men and women in this sample with a Madsen TBN 60 portable transistorised audiometer with thresholds calibrated to British Standards. The instrument was regularly calibrated and serviced by the Royal National Institute for the Deaf. Examinations were made in a double glazed quiet room in which the ambient sound level, measured with a sound meter, was 35 dB using weighting network A.

The method for measuring hearing loss was as follows. The frequency of 1,000 c.p.s. in the right ear was used to demonstrate the technique to the subject, who was asked to signify by tapping each time the sound was heard during progression from audible to inaudible pulses of sound. Recording began after this in the right and then the left ear. Seven sound frequencies in each ear were used to record hearing loss by air conduction. Hearing loss by bone conduction was measured in each ear at 1,000 c.p.s. and 4,000 c.p.s. with the vibrator over the corresponding mastoid process. Hence in the present paper hearing loss at these frequencies only was used to compute the air-bone gap by subtracting the loss for bone conduction from that for air conduction.

Only one attempt was made to measure hearing loss at each frequency unless something noisy interrupted the examination in any frequency in which case measurement in that frequency was repeated. Masking was used if a difference of 40 dB was found between the two ears for air conduction and when hearing loss by bone conduction was measured. All measurements were made by the author.

Replies to questions to discover those suffering from vertigo, tinnitus, winter nasal catarrh and deafness have been used in the present paper as has the prevalence of wax in the ears. The prevalence of these symptoms and signs, their relationship to pure-tone audiometry and the questions used have been fully described elsewhere (Milne, 1976).

Data were collected from 213 men and 265 women. In the remaining nine persons intellectual impairment made the examination impossible.

Reliability was found to be ±5 dB for readings on different occasions in the same subject by the same observer. The method of testing this has been described elsewhere (Milne and Lauder, 1975). The possibility was considered that at 4,000 c.p.s. radiated sound from the bone conductor might have affected the results. It was also possible at 4,000 c.p.s. that faulty calibration was responsible for the apparent air-bone gap.

Subjects wore earphones during the measurement of hearing loss by bone conduction, since masking was supplied through the earphones. This would tend to reduce radiation from the bone conductor.

To test faulty calibration, the tests as described above, were performed on 13 young adults all less than 30 years of age and all with apparently normal hearing. In 8 of these subjects hearing loss was the same by air and bone conduction. In four the gap was −10 dB and in one −15 dB. This means that in no younger subject was an air-bone gap present of the type described in the older people. It is therefore assumed that the gap in the older people did not result from faulty calibration.

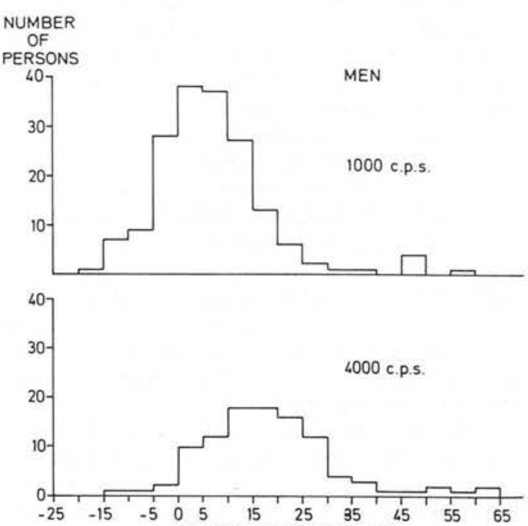

Fig. 1. Distributions of the air-bone gap at 1,000 c.p.s. and 4,000 c.p.s. in older men.

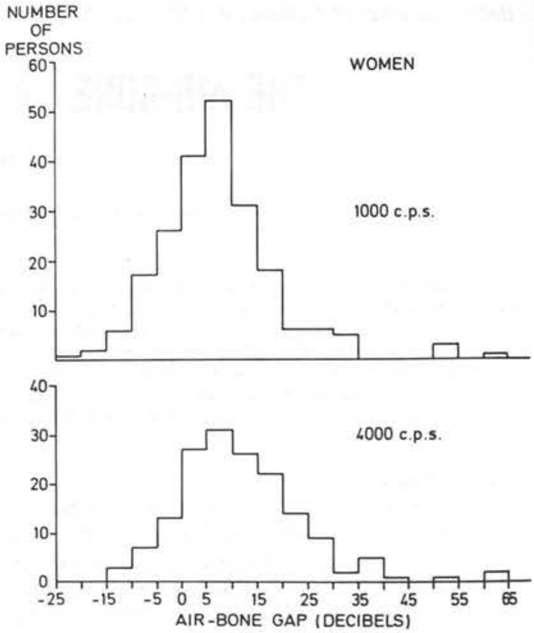

Fig. 2. Distributions of the air-bone gap at 1,000 c.p.s. and 4,000 c.p.s. in older women.

Results

Any person found to have an abnormality of either ear drum, i.e. scar or perforation, was excluded from the analysis because preliminary calculations showed, as expected, large air-bone gaps in these subjects.

Distributions of the air-bone gap are displayed in figures 1 and 2 for men and for women. Since the reproducibility of hearing loss measured by audiometry is ±5 dB an air-bone gap is definitely present only when it exceeds 10 dB in size. Using this criterion, the distributions show that 16% of men and 18% of women had an air-bone gap greater than 10 dB at 1,000 c.p.s. while 58% of men and 34% of women had such a gap at 4,000 c.p.s. The sex difference at 4,000 c.p.s. is significant at the 1% level. Conversely less than 5% of the sample at 1,000 c.p.s. and less than 2% of the sample at 4,000 c.p.s. had the gap reversed, i.e. hearing loss by bone conduction was greater than that by air conduction.

The effect of age on the air-bone gap was

Table 1. Linear regressions of air-bone gaps on age in older men and women for both ears and two sound frequencies

SEX and AGE RANGE	c.p.s.	RIGHT EAR REGR. COEFF.	SE	r	MISSING VALUES	N	LEFT EAR REGR. COEFF.	SE	r	MISSING VALUES	N
MEN 62-90	1,000	0.27	0.14	0.15	40	175	0.25	0.14	0.14	38	177
	4,000	0.25	0.27	0.09	111	104	0.36	0.26	0.14	112	103
WOMEN 62-90	1,000	−0.18	0.13	0.10	57	215	−0.20	0.12	0.11	60	212
	4,000	0.34	0.19	0.14	107	165	0.29	0.19	0.12	114	158

Table 2. Mean values with related statistics of the air-bone gaps at 1,000 c.p.s. and 4,000 c.p.s. in both ears in older men and women

SEX and AGE RANGE	c.p.s.	RIGHT EAR MEAN	SD	SE	MISSING VALUES	N	LEFT EAR MEAN	SD	SE	MISSING VALUES	N
MEN 62-90	1,000	4.37	11.67	0.88	40	175	4.80	11.85	0.89	38	177
	4,000	16.15	13.73	1.35	111	104	16.75	14.10	1.39	112	103
WOMEN 62-90	1,000	4.72	11.95	0.82	57	215	3.63	11.03	0.76	60	212
	4,000	9.58	13.43	1.05	107	165	8.54	14.49	1.15	114	158

investigated by the linear regressions of the gaps on age in men and in women at 1,000 c.p.s. and 4,000 c.p.s. (table 1). The table shows that none of the lines had a significant slope.

Missing values in the table amount to 97 for the right ear and 98 for the left ear at 1,000 c.p.s., while at 4,000 c.p.s. the corresponding figures are 218 and 226, each from a total sample of 487. The loudest signals available from the audiometer for bone conduction were 60 dB at 1,000 c.p.s. and 50 dB at 4,000 c.p.s. Of the missing values given above 12 on the right and 10 on the left at 1,000 c.p.s., with 131 on the right and 138 on the left at 4,000 c.p.s. were from subjects who were unable to hear the loudest signal used for bone conduction. The remaining missing values were from subjects with intellectual impairment, subjects with one or both ear drums abnormal and a few subjects where the signal was heard by bone conduction but not by air conduction.

Mean values for the air-bone gap in both ears in men and in women are given in table 2 with standard deviations, standard errors, numbers of missing values and numbers of subjects from whom statistics were derived.

Study of the table revealed:

1. Student's 't' test showed that all the mean values differed significantly from zero ($p < 0.01$).

2. There was no difference between mean values for right and left ears in groups which corresponded with respect to sex and sound frequency.

3. There was no significant difference between mean values for men and women at 1,000 c.p.s. but mean values for men were significantly larger than those for women at 4,000 c.p.s.

4. Mean values for the air-bone gap were significantly larger at 4,000 c.p.s. than at 1,000 c.p.s. in men ($p < 0.01$) and women ($p < 0.05$).

The effect of hearing loss on the size of the air-bone gap in corresponding sound frequencies was examined by the linear regression of the gap on hearing loss by air conduction in men and in women in both ears at 1,000 c.p.s. and 4,000 c.p.s. Results are given in table 3. The slope of the lines was found to be significant in all groups ($p < 0.01$). The addition of age to the regression as an independent variable did not improve the fit of the lines.

Table 3. Linear regressions of air-bone gaps on hearing loss by air conduction in older men and women for both ears and two sound frequencies

		RIGHT EAR					LEFT EAR				
SEX and AGE RANGE	*c.p.s.*	*REGR. COEFF.*	*SE*	*r*	*MISSING VALUES*	*N*	*REGR. COEFF.*	*SE*	*r*	*MISSING VALUES*	N
MEN											
62-90	1,000	0.46	0.05	0.61	40	175	0.45	0.05	0.59	38	177
	4,000	0.59	0.05	0.77	111	104	0.65	0.05	0.77	112	103
WOMEN											
62-90	1,000	0.50	0.05	0.53	57	215	0.43	0.05	0.52	60	212
	4,000	0.58	0.05	0.70	107	165	0.61	0.05	0.74	114	158

Mean values of the air-bone gap were calculated in men and women at 1,000 c.p.s. and 4,000 c.p.s. in each ear in those with and without vertigo, tinnitus, winter nasal catarrh or wax in the ears. The presence or absence of these variables did not affect the size of the air-bone gap in any group.

The admission of deafness on questioning is known to increase in prevalence as age increases in both sexes (Milne, 1976). Mean values of the air-bone gap were therefore calculated in men and in women, aged less than seventy and seventy years and over, in those who did and did not admit subjective deafness. These values with 95% confidence limits are given for the right ear in figures 3 and 4. In every group the mean value was larger in those aware of deafness but the difference reached significance only in men of 70 years and over at 1,000 c.p.s.

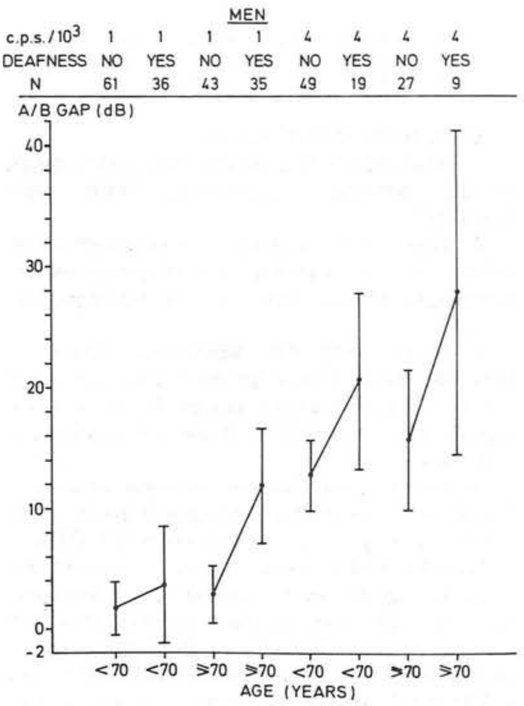

Fig. 3. Mean values of the air-bone gap with 95% confidence limits at 1,000 c.p.s. and 4,000 c.p.s. in two age groups of older men separated into the deaf and those not aware of deafness.

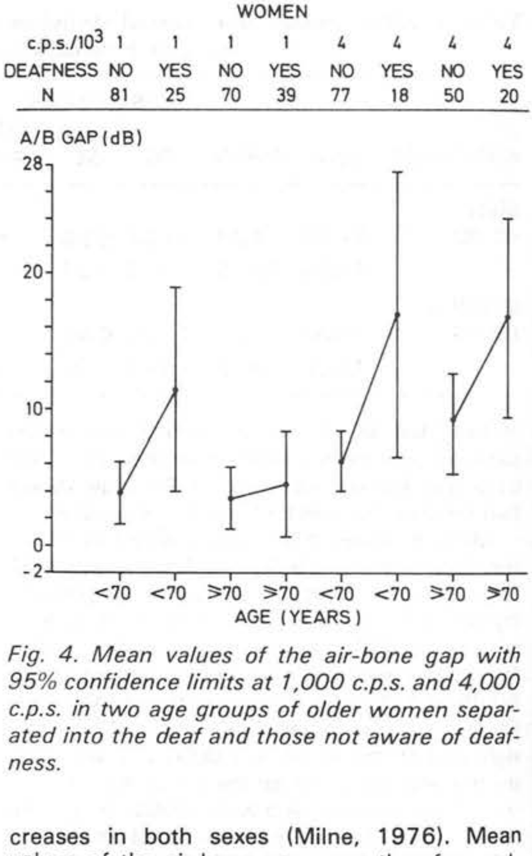

Fig. 4. Mean values of the air-bone gap with 95% confidence limits at 1,000 c.p.s. and 4,000 c.p.s. in two age groups of older women separated into the deaf and those not aware of deafness.

Discussion

The air-bone gap was described by Glorig and Davis in 1961 as beginning in middle age and increasing with increasing age, especially in the higher sound frequencies. These authors identified four major age effects on hearing loss which were (1) central presbycusis (2) classical sensori-neural presbycusis (3) middle ear conductive presbycusis and (4) inner ear presbycusis. The latter two factors would be characterised by high-tone conductive deafness and hence by an air-bone gap.

Some authors have begged the question by studying 'normal' hearing in older people after defining presbycusis as showing approximately equal loss by air and bone conduction (Pestalozza and Shore, 1955, Harbert, Young and Menduke, 1966) thus excluding persons with conductive deafness. Miller and Ort (1965) followed the advice of Glorig by including all types of hearing loss in their study of the elderly. They reported an air-bone gap but concluded that this was usually accompanied by positive signs on otological examination or by a history of otosclerosis. Nixon, Glorig and High (1962) on the other hand regarded the conductive part of hearing loss in the elderly as probably caused by degenerative change in the ear drum, the ossicular chain and the small muscles in the ear.

One group of workers made a special study of the air-bone gap in which attention was paid to possible air conduction from the bone vibrator (Sataloff, Vassalo and Menduke, 1965). These authors concluded the air-bone gap did not exist and found no conductive component in the hearing loss of the elderly. Willeford (1971) in a clear summary of work on the air-bone gap concluded that the consensus was that no conductive deficit was present in older people.

The present study appears to demonstrate an airbone gap in older people with greater prevalence and larger gaps with higher sound frequency. Larger gaps at higher frequencies agree with the speculative explanation by Nixon, *et al.* (1962) that conductive loss in the elderly is caused by loss of mechanical integrity in the joints of the ossicular chain, which results in dissipation of vibratory energy at these joints. This would affect high rather than low frequencies because of the middle ear losing some of the properties necessary to transmit high frequency sounds at low intensity levels.

The work of Glorig and Davis described the conductive change in presbycusis as beginning in middle life and increasing as age increases. The present study with its youngest subjects in the seventh decade had no age effects. The coefficients of regression on age (table 1) were positive at 4,000 c.p.s. but did not reach statistical significance. Nixon, *et al.* (1962) regarded the age increase in the gap reported by them as being due to the shift for air conduction being greater than the shift for bone conduction as a function of ageing.

The size of the gap reported by Glorig and Davis was larger than in the present study since it approached 40 dB in 79 year old men. Rosen (1966) studying the Mabaan in the Sudan, a tribe whose ageing seems slowed in comparison with Western Europeans, and men in experimental studies of ischaemic heart disease in Finland concluded that the air-bone gap was reduced in size where the ageing process went on more slowly. This hypothesis would presuppose wide variation in the size of the gap in different communities. The prevalence of a gap greater than 10 dB when averaging results for three central frequencies (500, 1,000 and 2,000 c.p.s.) reported by Miller and Ort (1965) was 22%. This figure is similar to 16% of men and 18% of women with gaps greater than 10 dB at 1,000 c.p.s. in the present study.

In the present study the size of the air-bone gap increases in any frequency as hearing loss in that frequency increases. This is compatible with the findings of Rosen (1966) that the Mabaan with smaller hearing loss than that found in older people in Edinburgh have smaller air-bone gaps. The sex effect in the present study in which women, at 4,000 c.p.s., have a mean air-bone gap significantly smaller than that in men does not seem to have been described elsewhere. This is in keeping with the smaller hearing losses in higher frequencies in the present sample in women compared with men (Milne and Lauder, 1975). Miller and Ort (1965) examined women in their study but did not separate their results from those of men.

The bone vibrator in the present study was placed on the appropriate mastoid process. Sataloff, *et al.* (1965) showed that bone conduction was similar whether the vibrator was on the brow or on the mastoid.

Acknowledgements

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A LONGITUDINAL STUDY OF HEARING LOSS IN OLDER PEOPLE

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Abstract

Audiometric data and subjects' opinions about change in their hearing have been collected from 113 men and 148 women who were those members of a random sample of older people examined on three occasions in a longitudinal study of persons aged 62-90 years at entry to the study. Increases in hearing loss were small after one year but greater after 5 years especially at higher sound frequencies. Some subjects showed increased loss at all frequencies measured. Linear regressions were used to show that, at 4,000 c.p.s. the greater the hearing loss at the original examination, the smaller would be the change over five years. The regressions, using data from frequencies of 1,000 c.p.s. and 4,000 c.p.s. showed age effects, i.e. increased loss over five years as age at entry increased, only in men at 1,000 c.p.s. Subjects who thought their hearing had deteriorated had greater, but not significant, increases in mean hearing loss than those who did not so complain. This finding may reflect the lack of correspondence between audiometry and understanding of speech.

Introduction

A longitudinal study of ageing persons has been carried on in Edinburgh since 1968. Its purposes were firstly to assess physical and mental health in a random sample of the elderly population and secondly to determine the range of certain measurements in older people. Changes in health and measurements were to be estimated at subsequent examinations.

The first examination, made in 1968-9, comprised the recording, at an interview when the author used a semi-structured questionnaire, of past medical history and of past and present symptoms of physical health. After the interview, full clinical examination was carried out. Special examinations or measurements made included anthropometry, testing of visual acuity, audiometry and otoscopy, respiratory function tests, electrocardiography, radiography, estimate of heart size, estimates of bone mass, haematology and biochemistry. Subsequent examinations made after one year (1969-70) and after five years (1973-4) repeated some of the questions, the clinical examination and the special tests.

The findings from pure-tone audiometry in the first examination have already been reported (Milne and Lauder, 1975). The present paper reports audiometric data from the examinations made after one and five years and relates these to the subjects' assessment of changes in hearing.

Subjects and Methods

The original group examined in the study consisted of 215 men and 272 women aged 62-90 years who formed a simple random sample of the 27,000 older persons living in north Edinburgh in 1968. Full details of sampling have been given elsewhere (Milne, Maule and Williamson, 1971). For the examination made five years later, 113 men and 148 women were available. Death had occurred in 78 men and 60 women leaving 24 men and 64 women who survived for five years after the original examination but were not re-examined for various reasons. The follow-up of the members of the original sample has been fully described elsewhere (Milne and Chopin, 1975). The data reported in the present paper are from the 113 men and 148 women who were examined on three occasions. At the examinations after one and five years, the subjects were asked 'has your hearing changed since you were last here?' and if so whether it was better or worse.

Hearing loss was measured on each of the three occasions with the same Madsen TBN 60 portable transistorised audiometer with a threshold calibrated to British standards. The instrument was regularly calibrated and serviced by the Royal National Institute for the Deaf. Examinations were all made by the author in a quiet room in which the ambient sound level measured with a sound level meter was 35 dB using weighting network A.

The method of measuring hearing loss was as follows. The frequency of 1,000 c.p.s. in the right ear was used to demonstrate the technique to the subject who was asked to signal by tapping each time the sound was heard during progression from audible to inaudible pulses of sound. Recording began after this at a frequency of 250 c.p.s. in the right ear. Hearing loss was recorded in the right and then in the

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left ear at frequencies of 250, 500, 1,000, 2,000, 4,000, 6,000 and 8,000 c.p.s.

Only one attempt was made to measure hearing loss in each frequency unless something noisy interrupted the examination in any frequency, in which case that measurement was repeated. Masking was used when appropriate. Reliability, which was reported in more detail elsewhere (Milne and Lauder, 1975) was ±5 dB for readings on different occasions in the same subject by the same observer.

In the present paper the audiometric data are presented for all 7 frequencies measured in the better ear. Where audiometric data are related to the subjects' assessment of hearing change, frequencies of 1,000 c.p.s. and 4,000 c.p.s. in the better ear have been used in the comparisons.

Results

The distribution of hearing loss is known to be skew and the median is therefore a better measure of central tendency than the mean. Table 1 presents median values for hearing loss,

Table 1. Median values of hearing loss in two age groups of men and women on three occasions of measurement

SEX AGE AT ENTRY	*SOUND FREQUENCY (c.p.s.)*	*MEDIANS*			*N*
		AT ORIGINAL EXAMINATION	*AFTER 1 YEAR*	*AFTER 5 YEARS*	
MEN 62-69	250	26.3	25.4	26.4	66
	500	25.7	25.0	27.7	66
	1,000	21.4	22.3	25.9	71
	2,000	20.0	19.8	25.3	71
	4,000	46.7	44.3	51.9	71
	6,000	44.4	46.0	55.9	71
	8,000	57.9	56.0	65.7	71
MEN 70-90	250	28.1	26.5	30.5	34
	500	26.7	27.5	32.5	34
	1,000	26.8	25.8	34.2	42
	2,000	28.8	27.0	36.7	42
	4,000	58.5	57.5	65.4	42
	6,000	57.5	61.3	67.5	42
	8,000	70.0	71.9	77.5	42
WOMEN 62-69	250	30.1	30.9	31.5	77
	500	30.3	30.8	30.7	77
	1,000	24.0	24.6	27.1	91
	2,000	20.9	20.3	24.1	91
	4,000	27.1	26.8	35.4	91
	6,000	29.3	30.8	41.0	91
	8,000	42.8	45.0	54.3	91
WOMEN 70-90	250	33.0	34.1	35.3	46
	500	34.2	35.0	35.0	46
	1,000	26.3	27.4	30.4	57
	2,000	25.6	24.4	28.9	57
	4,000	44.3	46.7	53.2	57
	6,000	47.9	52.3	59.7	57
	8,000	62.8	65.0	70.6	57

for seven frequencies in the better ear, in those subjects whose hearing was examined on the three occasions. These occasions were the original examination and further examinations after one and five years. The subjects have been divided into men and women below 70 years of age and 70 years and above on entry to the study.

The table suggests little difference in hearing loss after one year. Five year differences between median values suggest increasing hearing loss as sound frequency increases.

Differencies in hearing loss were further examined by subtracting, in each subject, the hearing loss at the original examination from the losses found after one and five years. This was done for the better ear at the same seven sound frequencies in the same age groups of men and women. Distributions of these differences, at 1,000 c.p.s. and 4,000 c.p.s. are displayed for men and women in figures 1 and 2. Mean values of the differences, at all seven sound frequencies, with standard errors are given in table 2. Student's 't' was used to test whether the mean differences differed from zero. The table suggests that mean five-year differences increase as sound frequencies increase in men and in women below 70 years of age. The effect is less obvious in subjects of 70 years and older. The 't' test shows that 24 of 28 five year mean differences in the table are significantly greater than zero. For the one year mean difference only 5 of the 28 differences are significantly greater than zero. Since the reproducibility of the technique is ±5 dB in subjects tested on two occasions by the same observer a difference to be significant should really be greater than +5 dB. None of the one year differences in the table are as large as this. The last column in table 2 shows that testing 5 year differences in this way reduces the number of differences significantly greater than +5 dB to 7 of the 28 in the table. All but one of these differences are at sound frequencies of 6,000 c.p.s. and 8,000 c.p.s.

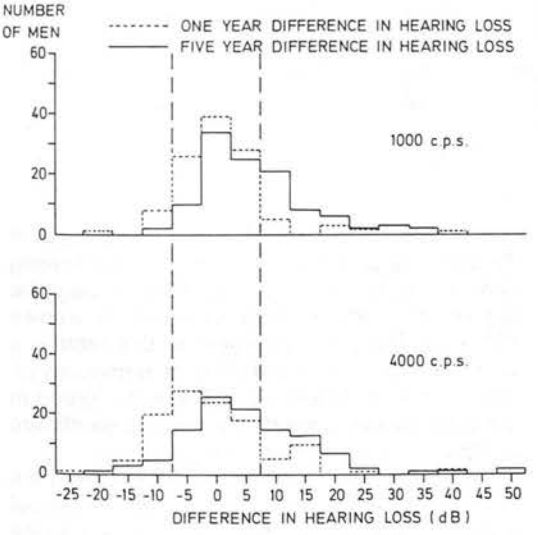

Fig. 1. Distributions of differences in hearing loss after 1 year and after 5 years at 1,000 c.p.s. and 4,000 c.p.s. in men.

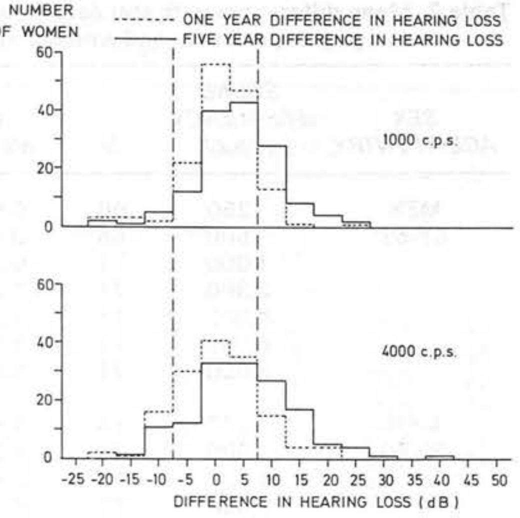

Fig. 2. Distributions of differences in hearing loss after 1 year and after 5 years at 1,000 c.p.s. and 4,000 c.p.s. in women.

Percentages of subjects with one or five year differences greater than +5 dB are presented in tables 3 and 4 in the same age groups of men and women. The tables also show the percentages of subjects with differences between −5 dB and +5 dB (i.e. no difference when observer variation is considered) and the percentages with apparent improvement (i.e. differences of less than −5 dB). The tables show a larger proportion of subjects with differences greater than 5 dB after five years compared with one year. They also show larger proportions of differences greater than 5 dB in higher frequencies compared with lower. There is no consistent significant sex difference.

In both sexes the tables suggest an increasing proportion of subjects in the older group with five year differences greater than +5 dB. These age-related increases are not present at every frequency and only a few reach statistical significance.

The effects of age and of the original hearing loss were examined by calculating the linear

Table 2. Mean differences with standard errors (SE) in hearing loss, after one and five years in two age groups of men and women, in seven sound frequencies in the better ear

SEX AGE AT ENTRY	*SOUND FREQUENCY (c.p.s.)*	*N*	*ONE YEAR DIFFERENCE MEAN*	*SE*	*FIVE YEAR DIFERENCE MEAN*	*SE*	*DIFF. FROM +5*
MEN 62-69	250	66	−0.61	0.84	0.53	0.90	
	500	66	−0.46	0.83	3.11**	0.96	
	1,000	71	−0.21	0.95	4.86**	0.97	
	2,000	71	−1.27	0.78	5.21**	0.99	
	4,000	71	−2.25	0.99	5.00**	1.39	
	6,000	71	3.31**	1.12	12.11**	1.38	**
	8,000	71	1.20	1.09	13.87**	1.64	**
MEN 70-90	250	34	3.53	1.85	4.71*	1.85	
	500	34	2.50	1.50	6.77**	1.66	
	1,000	42	2.62	1.03	8.81**	1.55	*
	2,000	42	−0.24	1.26	4.76**	1.59	
	4,000	42	1.79	1.62	7.02**	2.12	
	6,000	42	3.33	1.83	10.36**	2.12	*
	8,000	42	1.67	1.44	3.93*	1.89	
WOMEN 62-69	250	77	1.23	0.69	1.23	0.71	
	500	77	0.71	0.63	0.91	0.78	
	1,000	91	1.48*	0.62	3.79**	0.73	
	2,000	91	0.17	0.61	3.85**	0.80	
	4,000	91	0.33	0.71	5.33**	0.91	
	6,000	91	2.75**	0.95	9.01**	1.03	**
	8,000	91	3.08**	0.90	10.11**	1.06	**
WOMEN 70-90	250	46	0.76	1.08	1.86	1.47	
	500	46	0.76	0.95	3.14*	1.42	
	1,000	57	0.61	0.90	4.35**	1.13	
	2,000	57	0.09	0.96	3.89**	1.17	
	4,000	57	1.23	1.12	5.46**	1.38	
	6,000	57	4.65**	1.26	11.67**	1.60	**
	8,000	57	2.54	1.32	8.52**	1.82	

* $p < 0.05$ ** $p < 0.01$

regressions of the one year and five year differences in hearing loss separately on age and on original hearing loss using representative sound frequencies of 1,000 c.p.s. and 4,000 c.p.s. The regression coefficients with their standard errors are given for one year and five year differences respectively in tables 5 and 6.

None of the coefficients of regression for one year differences is significant except in women at 4,000 c.p.s. in respect of the regression of the one year difference on hearing loss at the original (first) examination (table 5). This coefficient is negative showing decrease in the one year difference as the original hearing loss increases.

Regression of the five-year difference in decibel loss at 4,000 c.p.s. on original hearing loss similarly produces significant negative regression coefficients in men and in women (table 6). The only age effect in this table is a significant positive coefficient of regression on age in men at 1,000 c.p.s. The same group in the table shows a significant positive coefficient of regression on the original hearing loss.

The most striking finding emerging from the regressions is that at 4,000 c.p.s. as the decibel loss in the original examination increased, so the five-year difference between readings decreased.

Subjects were questioned at the original

Table 3. Distributions of differences in hearing loss in one year and in five years in two age groups of older men—percentages

AGE GROUP (AT ENTRY)	SOUND FREQUENCY (c.p.s.)	ONE YEAR DIFFERENCE			FIVE YEAR DIFFERENCE			N
		< −5 dB	−5 dB to +5 dB	> +5 dB	< −5 dB	−5 dB to +5 dB	> +5 dB	
62-69	250	12.1	80.3	7.6	13.6	71.2	15.2	66
	500	12.1	80.3	7.6	3.0	78.8	18.2	66
	1,000	11.3	81.7	7.0	1.4	69.0	29.6	71
	2,000	15.5	80.3	4.2	4.2	59.2	36.6	71
	4,000	28.2	60.6	11.3	11.3	53.5	35.2	71
	6,000	7.0	66.2	26.8	1.4	33.8	64.8	71
	8,000	14.1	67.6	18.3	4.2	29.6	66.2	71
70-90	250	14.7	55.9	29.4	8.8	58.8	32.4	34
	500	2.9	76.5	20.6	—	58.8	41.2	34
	1,000	2.4	83.3	14.3	2.4	47.6	50.0	42
	2,000	11.9	78.6	9.5	9.5	61.9	28.6	42
	4,000	14.3	64.3	21.4	2.4	59.5	38.1	42
	6,000	23.8	42.9	33.3	7.1	31.0	61.9	42
	8,000	11.9	66.7	21.4	14.3	54.8	31.0	42

Table 4. Distributions of differences in hearing loss in one year and in five years in two age groups of older women—percentages

AGE GROUP (AT ENTRY)	SOUND FREQUENCY (c.p.s.)	ONE YEAR DIFFERENCE			FIVE YEAR DIFFERENCE			N
		< −5 dB	−5 dB to +5 dB	> +5 dB	< −5 dB	−5 dB to +5 dB	> +5 dB	
62-69	250	10.4	74.0	15.6	6.5	77.9	15.6	77
	500	6.5	81.8	11.7	9.1	77.9	13.0	77
	1,000	2.2	89.0	8.8	5.5	69.2	25.3	91
	2,000	8.8	83.5	7.7	4.4	65.9	29.7	91
	4,000	11.0	76.9	12.1	5.5	56.0	38.5	91
	6,000	12.1	59.3	28.6	3.3	40.7	56.0	91
	8,000	9.9	63.7	26.4	3.3	40.7	56.0	91
70-90	250	10.9	76.1	13.0	14.0	62.8	23.3	46
	500	10.9	80.4	8.7	9.3	65.1	25.6	46
	1,000	10.5	77.2	12.3	5.6	59.3	35.2	57
	2,000	12.3	75.4	12.3	5.6	63.0	31.5	57
	4,000	15.8	63.2	21.1	13.0	64.8	22.2	57
	6,000	10.5	54.4	35.1	3.7	33.3	63.0	57
	8,000	12.3	52.6	35.1	11.1	40.7	48.1	57

Table 5. Regressions of one year differences in hearing loss (at 1,000 c.p.s. and 4,000 c.p.s) on age and original hearing loss in older men and women

SEX / *AGE AT ENTRY*	*SOUND FREQUENCY (c.p.s.)*	*INDEP. VARIABLE*	*REGR. COEFF.*	*SE*	*N*
MEN 62-90	1,000	AGE	0.20	0.12	113
	1,000	HEARING LOSS	–0.05	0.05	113
	4,000	AGE	0.27	0.15	113
	4,000	HEARING	–0.08	0.04	113
WOMEN 62-90	1,000	AGE	–0.13	0.09	148
	1,000	HEARING LOSS	–0.04	0.05	148
	4,000	AGE	–0.07	0.10	148
	4,000	HEARING LOSS	–0.12**	0.03	148

** $p < 0.01$

Table 6. Regressions of five year differences in hearing loss (at 1,000 c.p.s. and 4,000 c.p.s.) on age and original hearing loss in older men and women

SEX / *AGE AT ENTRY*	*SOUND FREQUENCY (c.p.s.)*	*INDEP. VARIABLE*	*REGR. COEFF.*	*SE*	*N*
MEN 62-90	1,000	AGE	0.32*	0.16	113
	1,000	HEARING LOSS	0.12*	0.06	113
	4,000	AGE	0.15	0.20	113
	4,000	HEARING LOSS	–0.15**	0.05	113
WOMEN 62-90	1,000	AGE	0.05	0.11	145
	1,000	HEARING LOSS	0.09	0.06	145
	4,000	AGE	0.05	0.14	145
	4,000	HEARING LOSS	–0.10*	0.04	145

* < 0.05 ** $p < 0.01$

examination about their own assessment of their hearing ('Do you suffer from deafness?' 'Are you hard of hearing?') and at the five-year examination about change in their hearing ('Has your hearing changed since you were last here?' If yes 'In what way?'). Forty-seven percent of 112 men and thirty-one percent of 144 women at the five-year examination thought their hearing had worsened. Table 7 shows the relationship between subject's assessment of their hearing at the original examination and their assessment of change over 5 years. In men and in women a significantly greater proportion ($P < 0.01$) of those who claimed to be deaf originally thought their hearing had worsened over 5 years compared with those not claiming deafness at the first examination. There are no age effects in these assessments. Figure 3 shows in men and in women mean differences (with 95% confidence limits) in hearing loss after 5 years at 1,000 c.p.s. and 4,000 c.p.s. in those who thought their hearing had not changed and in those who said it was worse. The mean differences are larger in those who said their hearing had worsened but the differences are not statistically significant. Comparisons were also made between mean 5 year differences in those who said they were deaf at the original examination and in those who claimed their hearing was normal, using frequencies of 1,000 c.p.s. and 4,000 c.p.s. in the better ear in men and in women. No differences emerged between corresponding groups. Hearing loss was also examined, using data from the original examination, in those who died and in those who survived for 5 years in men and in women using all seven sound frequencies in the better ear. Comparisons were made using medians with non-parametric 95% confidence limits. No significant difference emerged between the dead and the survivors.

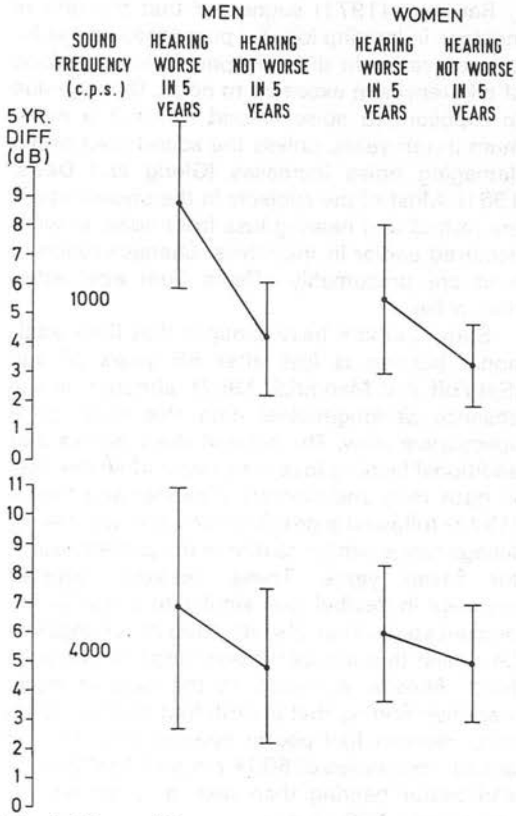

Fig. 3. Mean differences in hearing loss at 1,000 c.p.s. and 4,000 c.p.s. after 5 years, with 95% confidence limits, in men and in women with and without subjective worsening of hearing.

Discussion

The present study used a descending approach only to the end point when carrying out audiometry. The reasons for this were first that it is easy to tire old people with audiometry and secondly that in an examination lasting two hours the time available for audiometry was limited (Milne and Lauder, 1975). The same instrument and the same observer were used in all examinations. It is assumed that this constancy of technique ensured that the differences in hearing loss found were due to true changes in the subjects examined.

Table 7. Comparison of subjects' assessment of hearing loss at the original examination with their assessment of change in hearing after 5 years

SEX	*DEAF ORIGINALLY NO CHANGE IN 5 YEARS*	*NOT DEAF ORIGINALLY NO CHANGE IN 5 YEARS*	*DEAF ORIGINALLY HEARING WORSE IN 5 YEARS*	*NOT DEAF ORIGINALLY HEARING WORSE IN 5 YEARS*	*N*
MEN	21	38	35	18	112
WOMEN	22	78	20	24	144

Bergman (1971) suggested that the rate of increase in hearing loss for pure tones as age increases varies in different populations because of differences in exposure to noise. Damage due to exposure to noise is said to reach a maximum in ten years, unless the sound level of the damaging noise increases (Glorig and Davis, 1961). Most of the subjects in the present study are retired and hearing loss from noise at work occurred earlier in their lives. Changes reported here are presumably effects from age rather than noise.

Some authors have thought that little additional hearing is lost after 65 years of age (Sataloff and Menduke, 1957), although in the absence of longitudinal data this must be a speculative view. The present study shows that additional hearing loss does occur after this age, in both men and women. Eisdorfer and Wilkie (1972) followed a group of men and women, of an age range similar to that in the present study, for seven years. These workers reported changes in decibel loss similar to those in the present study. They also reported the changes to be similar throughout the age range of their subjects. Another similarity to the present study was their finding that in both first and follow-up tests women had poorer hearing than men at sound frequencies of 500 c.p.s. and 1,000 c.p.s., and better hearing than men at a sound frequency of 4,000 c.p.s.

In the present study true changes over 5 years (i.e. greater than 5 dB) were found mainly in the higher sound frequencies when mean values were examined. When proportions of subjects with change in hearing loss of 5 dB or more were calculated, some subjects had worsening of their hearing at all sound frequencies used.

The negative coefficient of regression of the five year change in hearing loss on the hearing loss at the first examination at the sound frequency of 4,000 c.p.s. means that where the hearing loss is already severe, five year changes are smaller. It may be that a point is reached where further loss simply does not occur. In the first examination hearing losses at 4,000 c.p.s. were large compared with those at 1,000 c.p.s. in both groups of men and in older women (table 1).

The study suggests that those who claimed to have become more deaf during the five years had larger changes in decibel loss than those who regarded their hearing as unchanged (figure 3) but the differences between these two groups did not reach statistical significance. The lack of correspondence between subjects' assessment of change in hearing and measurement of the change by pure tone audiometry accords with the known disproportionate loss in speech understanding over and above what can be accounted for by the loss in threshold sensitivity (Berkowitz and Hochberg, 1971, Jerger, 1973).

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LONGITUDINAL STUDIES OF BODY WEIGHT AND SKINFOLD THICKNESS IN OLDER PEOPLE

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ABSTRACT

Bodyweight and skinfold thickness were measured at the start of a longitudinal study of a random sample of older people in Edinburgh (215 men and 272 women, 62-90 years) and again after 1 and 5 years (113 men and 148 women). In the first examination mean weight, corrected for height, fell with age only in the oldest group of women but not in men while most mean skinfold thicknesses (transformed logarithmically) fell with increasing age. Survival for 5 years, in men only, was associated with greater mean weight and skinfolds compared with values in those who had died.

Longitudinal changes in corrected weight showed significant falls after 1 and 5 years in men and after 5 years in older women. With skinfold thickness, longitudinal changes showed significant mean increases after 1 and 5 years in the supra-iliac fold in men while women showed significant mean falls in subscapular folds after 5 years.

There were significant correlations in both sexes between weight and skinfold, and between changes in weight and changes in skinfold, but even the best correlation left 40% of the variance of weight unexplained by skinfold thickness. The relationship was closest in thinner persons of both sexes.

INTRODUCTION

The percentage of body mass occupied by fat is a measurement of undoubted value to clinicians. Methods used by physiologists to estimate this such as under-water weighing or the K^{40} count are not easily applied in medical practice, especially in the elderly. The most easily measured variables related to body fat are body weight and skinfold thickness.

The present paper reports longitudinal data about changes in body weight and skinfold thickness over 5 years from a study of a random sample of older people begun in Edinburgh in 1968. This study, which included examinations by a physician, a psychiatrist and a dietician was designed to record changes in physical and mental health and in normal measurements over a period of time in older people. Body weight and skinfold thickness were included among these measurements.

SUBJECTS AND METHODS

The subjects studied were 215 men and 272 women aged 62-90 years who in 1968 formed a simple random sample of the population of 27,000 people of that age range living in ten city wards in north Edinburgh. The method of sampling with a comparison of respondents and non-respondents has been described elsewhere (1). The subjects were examined during 1968-9 and one (1969-70) and five (1973-4) years later. At the five year review it was possible to re-examine 113 men and 148 women. Only these persons are included in the description of longitudinal data. Seventy-eight men and 60 women had died during the five years leaving 24 men and 64 women who for various reasons were not re-examined. Follow-up of the sample has been described in detail elsewhere (2).

Body weight was measured with a lever balance to the last complete 100 g. Women wore a gown weighing 250 g. while men wore underpants weighing up to 500 g. Height was measured to the last complete millimetre with a Harpenden stadiometer. Skinfold thickness was measured with a Harpenden skinfold caliper, to the nearest tenth of a millimetre, on the left side of the body, the sites being biceps, triceps, subscapular and supra-iliac. The readings were transformed into logarithms using the equation described by Edwards et al (3), and are reported in these units. The caliper was used as described by Tanner (4), the appropriate fold being held by the finger and thumb of the left hand during the measurement and the reading taken immediately the pointer stopped moving after releasing the spring of the caliper.

RELIABILITY

Reliability was studied by measuring the same 12 subjects on two occasions. A reliability coefficient was calculated, using the analysis of variance, by dividing the variance for persons by the sum of the variances due to persons, occasions and error. Variance due to error was the residual mean square after removing variances due to persons and occasions. Coefficients for the author's variance determined in this way before and after the survey are given in table I.

TABLE I

Reliability studies of one and two observers measuring skinfold thickness.

Observers	Skinfold	Reliability Coefficient	
		Before Survey	After Survey
One	Biceps	0.95	0.97
	Triceps	0.99	0.96
	Subscapular	0.97	0.97
	Supra-iliac	0.98	0.93
Two	Triceps	0.95	-
	Subscapular	0.90	-

An inter-observer study was made when the author and an experienced observer measured another 12 subjects on one occasion in such a way that one observer did not see the other at work. The coefficients, which were calculated with variance due to observers substituted for variance due to occasions, are in table I.

The contributions to the total variance made by persons and occasions were examined with the F test. For all variables in intra- and inter-observer studies in table I, the ratio of mean square for persons to mean square for error was significant at the 1% level. The corresponding ratio for occasions (or observers) was significant for none of the variables. The principal contributor to the variance was therefore persons and the observations can be accepted as reproducible.

RESULTS

Body weight at the first examination. The frequency distributions of body weight were sufficiently near Gaussian in the sample to use parametric statistics. Mean values with standard deviations of body weight, in three age groups of men and of women, from the first examination are given in table II.

TABLE II

Body weight as recorded and corrected for height: mean values with standard deviations in three age groups of older men and women.

Sex	Body weight			Body weight corrected for height		
Age group	Mean	SD	N	Mean	SD	N
Men						
62-69	69.18	12.06	121	68.90	10.88	121
70-79	66.90	12.04	71	68.02	10.07	71
⩾80	66.46	13.18	19	68.36	10.75	19
Women						
62-69	62.39	12.64	135	62.15	11.97	135
70-79	62.33	12.32	99	63.31	11.92	96
⩾80	53.82	11.45	30	57.50	10.64	25

The left of the table is from body weight as recorded. On the right weight has been corrected for height according to the equation

$$W_c = W - b(H - \bar{H})$$

where W_c is the corrected weight, W is recorded weight, b the coefficient of regression of weight on height, H is recorded height and $\bar{H}$ the mean height. The mean heights were calculated from all three examinations combined, being 1675 mm in men and 1550 mm in women.

The apparent fall with age on the left of the table disappeared in men with correction for height, but a significant fall remained after correction in the oldest women ($p < 0.05$).

Body weight at the three examinations. Mean values with standard deviations of body weight, corrected for height, are given in table III from all three examinations of the 113 men and 148 women studied at the five year examination.

Groupings of age at entry as <70 and ⩾70 years were used because after five years there were few survivors of those who were in the ninth decade or more at the beginning. Weight was corrected to the mean heights given above using regression coefficients calculated

TABLE III

Body weight, corrected for height, at three consecutive examinations in older men and women.

Sex Age at entry	Original exam. Mean	SD	N	One year exam. Mean	SD	N	Five year exam. Mean	SD	N
Men									
<70	69.18	9.84	71	68.70	9.78	71	68.45	11.11	71
⩾70	72.70	9.29	42	72.07	9.25	42	70.72	9.20	41
Women									
<70	61.78	10.63	90	62.03	10.92	89	61.27	10.86	89
⩾70	62.27	11.20	54	61.99	10.71	56	59.47	10.77	54

for each examination separately. Mean values of weight are larger in older men at each examination and smaller in older women at two of three examinations, but none of the differences is significant. The mean values fell in each age/sex group in the table over the five years.

When linear regressions of weight on age were calculated in each sex for each examination, none of the lines had a significant slope in women. In men the three regression coefficients were positive, those for the original and one year examinations being significant ($p < 0.05$).

Mortality effects of body weight. After five years the original subjects were separated into survivors (137 men, 212 women) and those who had died (78 men, 60 women). Comparison of mean weights from the original examination in survivors and in those who had died, with the 't' test, showed that only in men, body weight was significantly greater in survivors. Possible effects of age and "death" on this difference were examined by regression techniques. Stepwise multiple regressions were calculated with body weight as the dependent variable; independent variables were age and "death", the latter being dichotomous with death coded 'O' and survival '1'. The regressions in men showed that body weight was significantly related to "death" rather than age (5). Coefficients of correlation with weight were 0.04 for age, 0.29 for "death" and 0.29 for age and "death". This association of death with lower mean body weight may account for the greater mean body weight of older surviving men at each examination (table III).

Longitudinal changes in body weight. Changes in body weight with time were examined by subtracting, in each subject, the weight corrected for height at the one year or five year examinations from

from that at the original examination. Distributions of the differences were Gaussian.

Linear regressions of the one year and five year differences on age at entry were calculated for men and for women. Of the four coefficients of regression only that for the five year difference in women was significant (regression coefficient 0.19, SE 0.07, N 141, $p < 0.05$). Mean values of the other groups are therefore reported without subdivision for age. At one year they are for men 0.728 Kg SE 0.282 N 113 and for women -0.006 Kg SE 0.216 N 143. The value in men differs significantly from zero ($p < 0.01$) showing a fall in weight after one year. At five years the mean fall in men was 1.141 Kg SE 0.391 N112 and $p < 0.01$. Five year mean differences in women showed a fall in both age groups being 0.478 Kg SE 0.390 N 89 in women less than 70 years at entry and 2.581 Kg SE 0.858 N 52 in women of 70 years and over. Only the latter differs significantly from zero ($p < 0.01$). Changes in women over five years were therefore larger as age at entry to the study increased.

Skinfold thickness at first examination. Frequency distributions of the four skinfolds in millimetres were positively skewed. Distributions more nearly Gaussian were obtained by logarithmic transformation as advised by Edwards et al (3). Linear regressions of the transformed variables on height produced regression lines without significant slope, showing the transformed skinfolds to be independent of height.

Mean values with standard deviations of the transformed skinfolds measured at the first examination are given in table IV in three age groups of men and of women. In women the mean values decreased with increasing age but in men, in three of the four skinfolds, although the mean values decreased from the seventh to the eighth decade, they rose again in the ninth. The decreases in women are significant for biceps, triceps and subscapular folds ($p < 0.01$) but the variations in men are not.

TABLE IV
Mean values with standard deviations of four skinfold thicknesses (logarithmically transformed) in three age groups of older men and women. Values in parentheses are in millimetres.

Sex Age group	Biceps Mean	SD	N	Triceps Mean	SD	N	Subscapular Mean	SD	N	Supra-iliac Mean	SD	N
Men												
62-69	134.2 (4.0)	32.2	119	183.6 (8.7)	23.8	121	210.4 (14.5)	24.6	121	190.5 (9.9)	29.1	121
70-79	129.4 (3.8)	32.4	70	178.9 (7.9)	23.3	73	205.1 (13.0)	25.7	73	183.9 (8.7)	31.4	73
⩾80	128.1 (3.7)	36.4	19	183.7 (8.7)	18.4	20	207.9 (13.7)	22.2	19	188.4 (9.4)	34.7	19
Women												
62-69	178.5 (7.9)	25.8	135	227.1 (20.5)	15.0	135	228.8 (21.1)	23.1	135	200.3 (11.8)	28.2	135
70.79	167.9 (6.6)	25.9	99	222.8 (18.6)	18.5	99	224.7 (19.4)	21.9	100	199.2 (11.6)	26.3	100
⩾80	154.4 (5.3)	28.7	31	208.1 (13.8)	22.2	31	206.6 (13.3)	31.3	32	192.6 (10.4)	30.8	32

Principal components analysis. The relative contribution of each of the four skinfolds in the original examination to the total variance was examined by principal components analysis. The loadings which emerged showed that, in both sexes, the contribution of biceps and triceps folds to the total variance was negligible. Longitudinal data have therefore been reported in respect of subscapular and suprailiac skinfolds only.

Skinfold thickness at the three examinations. Mean values with standard deviations of the two skinfolds are given in table V from all three examinations of the 113 men and 148 women, who were studied at the five year examination, in age groups of less than 70 years and 70 years and over at entry to the study. In four of the six entries for men in table V the mean value in the older men was greater than that in the younger men. In all six entries for women, the mean values in the older women were less than those in the younger women. Mean values in the table rose during the five years in men except for the subscapular fold in older men. In women mean values remained relatively constant over five years for both skinfolds in younger women and fell over this period in older women.

Mortality effects of skinfold thickness. Mean values were calculated of transformed subscapular and suprailiac skinfolds, using data from the first examination, in men and in women who survived the five years or who died during that time. As with body weight, only in men, the mean of either skinfold was significantly greater in survivors compared with those who had died. The regression technique described above showed that, for both skinfolds, the effect was related to "death", rather than age. For the subscapular fold correlation coefficients were with age 0.04, with "death" 0.27 and with age and "death" 0.27. Corresponding figures for the suprailiac skinfold were 0.18, 0.29 and 0.30. Death in the sample was therefore associated with lower mean skinfold thickness in men.

TABLE V.
Means and standard deviations of two skinfold thicknesses (logarithmically transformed) at three consecutive examinations in older men and women. Values in parentheses are in millimetres.

Skinfold	Men						Women					
Time of	<70			⩾70			<70			⩾70		
examination	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Subscapular (original)	213.2 (15.3)	22.0	71	215.4 (15.9)	22.1	42	231.6 (22.2)	20.6	90	223.9 (19.0)	23.2	57
Subscapular (1 year)	214.0 (15.6)	22.7	71	217.3 (16.6)	22.7	42	232.3 (22.7)	21.1	90	225.1 (19.5)	23.0	57
Subscapular (5 years)	215.0 (15.9)	23.7	71	214.9 (15.8)	19.3	42	230.5 (21.8)	21.3	89	218.7 (17.2)	25.3	56
Suprailiac (original)	193.6 (10.5)	23.8	71	195.4 (10.7)	25.8	42	203.1 (12.5)	26.4	90	201.2 (12.0)	26.6	57
Suprailiac (1 year)	199.2 (11.5)	23.0	71	201.5 (12.1)	25.0	42	203.0 (12.4)	23.4	90	199.3 (11.5)	28.6	57
Suprailiac (5 years)	202.1 (12.2)	24.4	70	200.3 (11.8)	23.9	42	203.9 (12.7)	25.2	89	192.6 (10.3)	28.2	56

Longitudinal changes in skinfold thickness. These were studied by subtracting, in each subject, un-transformed values recorded at one year and at five years from the value recorded at the first examination. The untransformed values in millimetres were used because the effect of subtracting the log transformations is such that significant differences all transform back to the same value in millimetres while significant differences recorded in millimetres are not of the same value. The distributions of differences in millimetres were approximately Gaussian. Mean values with standard errors of one and five year differences of subscapular and suprailiac skinfolds for men and for women are given in table VI.

The negative values for suprailiac mean differences in men show significant increases over one and five years. In women there is a significant decrease in the subscapular skinfold over five years. Other values in the table do not differ significantly from zero.

Age effects on the differences were examined by the linear regression of each difference on age at entry in men and in women. Of the eight

TABLE VI

Changes in skinfold thickness, in millimetres, after one and five years in older men and women.

Sex Time of examination	Skinfold difference in mm Subscapular Mean	 SD	 N	 Suprailiac Mean	 SD	 N
All men						
1 year	-0.49	0.34	113	-1.23***	0.29	113
5 years	-0.28	0.37	113	-1.78***	0.38	113
All women						
1 year	-0.45	0.36	147	0.41	0.45	147
5 years	0.96*	0.44	145	0.73	0.51	145

*$p<0.05$ *** $p<0.001$

regression coefficients calculated, those for the five year difference in subscapular skinfold on age in men and for the five year difference in suprailiac skinfold on age in women were positive and significant. Mean values of these two variables were examined in two age groups as above. The mean five year differences in the subscapular skinfold in both age groups of men and in the suprailiac skinfold in women less than 70 years at entry did not differ significantly from zero. In women of 70 years and over at entry the mean suprailiac difference was 1.99 mm with SE 0.59 N 56 and $p<0.01$, showing a significant fall in suprailiac skinfold thickness in older women over five years.

<u>Relationship of body weight to skinfold thickness.</u> This relationship was investigated for the first examination by the linear regression of body weight corrected for height on subscapular and suprailiac skinfolds

TABLE VII

Linear regressions of body weight and five year change in body weight (both corrected for height) on skinfold thickness (log. trans.) and five year change in skinfold (millimetres) in older men and women.

Sex	Dependent Variable	Independent Variable	Regr. Coeff.	SE	r	N
Men	Weight	Subscap fold (log trans)	0.35	0.02	0.78	206
	Weight	Suprailiac fold (log trans)	0.26	0.02	0.71	206
Women	Weight	Subscap fold (log trans)	0.35	0.02	0.67	254
	Weight	Suprailiac fold (log trans)	0.28	0.02	0.65	254
Men	Wt change	Subscap change (mm)	0.24	0.02	0.72	111
	Wt change	Suprailiac change (mm)	0.15	0.02	0.66	111
Women	Wt change	Suprailiac change (mm)	0.22	0.03	0.54	139
	Wt change	Suprailiac change (mm)	0.08	0.02	0.32	139

transformed by logarithms. The calculations were made separately for each skinfold in each sex and are displayed in table VII.

Changes in body weight over five years were related to corresponding changes in skinfold thickness by the linear regression of the former on the latter. Differences were obtained by subtracting the five year reading from the original reading. Skinfold thicknesses in millimetres were used. Details of the regressions are also in table VII.

All the relationships in the table are highly significant ($p < 0.001$) and appear stronger in men than in women. Even the closest relationship leaves 40% of the variance of the dependent variable "unexplained".

TABLE VIII

Body weight, corrected for height, tabulated against skinfold thickness in older men and women

Wt corrected for Ht (Kg)	Skinfold thickness (log. transf) 120-	140-	160-	180-	200-	220-	240-	260	Totals
Men									
30-	-	-	-	-	-	-	-	-	-
40-	2	1	2	1	-	-	-	-	6
50-	-	2	17	13	2	1	-	-	35
60-	-	-	5	21	40	11	1	-	78
70-	-	-	-	3	25	28	7	-	63
80-	-	-	-	-	4	12	6	1	23
90-	-	-	-	-	-	1	4	-	5
100	-	2	1	-	-	-	-	-	3
Totals	2	5	25	38	71	53	18	1	213
Women									
30-	1	2	-	-	-	-	-	-	3
40-	1	1	5	12	8	3	-	-	30
50-	-	-	1	11	34	31	10	-	87
60-	-	-	-	1	11	30	40	1	83
70-	-	-	-	-	-	15	15	1	31
80-	-	-	-	-	1	2	8	3	14
90-	-	-	-	-	1	1	2	2	6
100	-	1	2	3	3	2	2	-	13
Totals	2	4	8	27	58	84	77	7	267

Frequency distributions of body weight corrected for height are plotted against distributions of subscapular skinfold thickness in table VIII.

This table shows, especially in women, that while low body weight and thin skinfolds correspond well, increasing skinfold thickness is associated with a broadening of the distribution of body weight.

Prediction of total body fat. A recent study in Glasgow used body density measured by underwater weighing and skinfold thickness measured in the same subjects to predict body density from skinfolds (6). The percentage fat in body weight was then calculated using the equation of Siri (7). In table IX are given percentages of body weight as fat for different values of the sum of subscapular and suprailiac skinfolds in men (aged 62-72 years) and women (aged 62-68 years) in the sample whose ages allowed the use of the Glasgow prediction equations.

TABLE IX

Percentage of body weight as fat in older men and women (from the equations of Durnin and Womersley, reference no 6).

Sum of Subscapular and Suprailiac skinfolds (mm)	Percentage fat in body weight Men (62-72 years)	Women (62-68 years)
10	6.2	16.9
20	14.8	25.4
30	20.0	30.6
40	23.8	34.3
50	26.8	37.2
60	29.2	39.6
70	31.3	41.7
80	33.2	43.5
90	34.8	45.1

DISCUSSION

Cross-sectional studies in various countries over many years have shown body weight in the elderly decreasing as age increased in men (8, 9, 10, 11, 12, 13, 14, 15, 16) and in women (8, 10, 12, 13, 15). The cause has been suggested as an age related loss of lean body mass with loss of the obese by death (14). There was a similar fall with age in cross-sectional data from the present study but when weight was corrected for height the decrease disappeared in men and remained only in the oldest women (table II). Anderson and Cowan (17) found no significant contribution from age added to a multiple regression to predict weight from height and chest girth in the elderly.

Many studies show a cross-sectional weight difference associated with social class (18, 19, 20, 21, 22, 23, 24, 25) but Kemsley et al (23) thought weight corrected for height did not show a social class difference. May and Beric Wright (26) studied businessmen from social classes I and II in 1959. The weights of these men corrected for height are similar to those from the present study which contained relatively few from these social classes.

Secular increase in weight has been reported in various occupational groups (8, 15, 24, 27, 28, 29, 30). This trend is not affected by correction for height since the figures of Kemsley obtained in 1943 (31) are significantly smaller than those of the present study made 25 years later.

Damon (32) thought that cross-sectional studies were falsified by secular trend and commented that the cross-sectional fall in weight in persons over 50 years is not found in longitudinal data. Parizkova and Eiselt (33) who followed up men in the seventh and eight decades for 8-10 years, found weight relatively constant over that time. These workers examined differences between means rather than mean differences. In the present study mean differences in weight corrected for height showed significant falls in men over one and five years and in women over five years.

The first examination in the present study showed a fall in mean values of four skinfolds as age increased in women. In three of the four skinfolds in men, the mean values fell from the seventh to the eighth decade but rose again in the ninth decade. Longitudinal data once again revealed the potential error in interpreting cross-sectional studies, since in men the subscapular skinfolds did not change significantly in any age group in one or five years while the suprailiac skinfold showed mean increases for all age groups over this period. In women both skinfolds showed decreases over the five years. Parizkova and Eiselt (33) in their longitudinal study of men in the seventh and eighth decades reported relative constancy of body fat calculated from skinfolds over 8-10 years. Once again they examined differences in means rather than mean differences compared with zero, but there is a small decrease in mean values in three of four groups in their tables.

Many studies have reported thicker skinfolds in women compared with men (34, 35, 36, 37, 38, 39, 40). With these the present study agrees (table IV).

The lower mean weight in men who died, compared with that in survivors, in the present study (5) has also been reported in an American study (41). Master et al (14) found that the association of death with overweight in younger groups also applied to the elderly. They felt that death of the obese contributed to age-related decline in weight. In the present study surviving men had greater mean skinfold thickness, as well as greater weight, than those who died. Comstock et al (42), measuring subcutaneous fat from chest radiographs, described an association between mortality from cardiovascular causes and thicker fat layers, but mentioned that this was not found in men older than 55 years. Parizkova and Eiselt (33) reported greater mean weights in older men who died from cardiovascular causes than in survivors. Such men who died in the present study had smaller mean weights than survivors (5).

Individual differences in weight at a given height have been regarded as mainly due to variation in fat (43). Tanner thought that changes in body fat over a period would be reflected by changes in weight, although body fat could not be inferred from weight (4). Durnin and Rahaman found that skinfold thickness had a higher correlation with body density, and hence with body fat, than other anthropometric variables (44). Womersley et al showed reasonable agreement among measurements of skinfold thickness, underwater weighing, total body water and the potassium-40 count in estimating total body fat (45). Skinfold thickness therefore seems to be a useful simple estimator of body fat.

Keys et al showed that weight corrected for height had a high correlation with measurements of body fat (46). However Florey demonstrated that while corrected weight and subscapular skinfold correlated well in thin people, there was a wide range of skinfold values in heavier people (47). Seltzer et al succinctly reported greater variance of skinfold thickness as relative weight increases, i.e. correction of weight for height is not sufficient to control for variance of body build (48). Indeed Parnell condemned weight corrected for height as an estimator of fat on the commonsense grounds that post mortem examination revealed bone, muscle and viscera as well as fat (49).

In the present study the best correlation between corrected weight and skinfold thickness left 40% of the variance of weight "unexplained". The imperfect correlation was also shown in men in the present study by the fact that longitudinal mean weight loss was accompanied by a mean increase in thickness of suprailiac skinfolds. The comparison of subscapular skinfold and corrected weight in table VIII is similar to that of Florey (47).

Differences in body density between younger and older people are not reflected by skinfold thickness (43, 50, 51, 52, 53) possibly because fat in internal depots increases as age increases (44).

Prediction of total body fat from skinfold thickness therefore needs data from a population of the age group to which the results will be applied, preferably in the same area. Durnin and Womersley showed skinfold thickness to be a good predictor of body density, and hence of total body fat, in Glasgow (6). In the absence of similar equations based on an elderly population in Edinburgh, their data were used to calculate total body fat in the present study.

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A LONGITUDINAL STUDY OF HEIGHT IN OLDER PEOPLE

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S U M M A R Y

Height and sitting height were measured in a simple random sample of 215 men and 272 women aged 63-90 years in Edinburgh. These variables were re-measured 5 years later in 113 men and 148 women. At the first examination mean values of height showed a cross-sectional decline in men and women, significant in women only, although the decline in sitting height was significant in both sexes.

The 5 year longitudinal measurement showed significant decreases in height and sitting height in both sexes, with significant increase in the size of the change, as age at entry to the study increased, in height in both sexes and in sitting height in men only.

Predictions of five year changes in height and sitting height based on the linear regression of these variables on age at the first examination over-estimated the changes, mainly because of secular increase.

INTRODUCTION

Height is well-recognised as a variable in which interpretations of age change from cross-sectional data are deceptive (Miall, Ashcroft, Lovell and Moore 1967). There are many cross-sectional and a few longitudinal studies of height. The present paper reports changes in height over five years from a study of a random sample of older people begun in Edinburgh in 1968. This study, which included examinations by a physician, a psychiatrist and a dietician, was designed to record changes in physical and mental health and in normal measurements, over a period of time, in older people. Standing height and its subdivisions were included among these measurements.

SUBJECTS AND METHODS

The people studied were 215 men and 272 women aged 62-90 years who, in 1968, formed a simple random sample of the 27,000 persons in that age range living in ten city wards in north Edinburgh. The method of sampling, with a comparison of respondents and non-respondents, has been described elsewhere (Milne, Maule and Williamson 1971). The subjects were examined during 1968-69 and again five years later (1973-74). At the five year review it was possible to re-examine 113 men and 148 women. Seventy-eight men and 60 women had died leaving 24 men and 64 women surviving who for various reasons were not re-examined. Follow-up of the sample has been described in detail elsewhere (Milne and Chopin 1975). Data from the persons re-examined at the five year review have been used in the longitudinal aspects of the present paper.

Standing height was measured with a Harpenden stadiometer. Subjects stood without shoes on the plinth in front of the column with heels, sacrum and the spine between the scapulae touching the column. Heads were put in the Frankfurt plane i.e. a line joining the tragus to the infra-orbital margin was parallel to the ground. Height was read, to the last complete millimeter from the counter of the stadiometer.

Sitting height was measured with subjects sitting on a stool which straddled the plinth of the stadiometer. Sacrum and thoracic spine were in contact with the column, the head being in the Frankfurt plane. Subischial height was calculated in each subject by subtracting sitting from standing height.

RELIABILITY

This was studied by measuring the same 12 subjects on two occasions. A reliability coefficient was calculated, using the analysis of variance, by dividing the variance for persons by the sum of the variance due to persons, occasions and error. Variance due to error was the residual mean square after removing variance due to persons and occasions. The coefficients for standing height and sitting height were 0.99 and 0.97 respectively before the survey began and 0.99 and 0.99 respectively after the survey ended.

Contributions to the total variance by persons and occasions were examined with the F test. For both variables the ratio of mean square for persons to mean square for error was significant at the 1% level. The corresponding ratio for occasions was not significant.

Since the principal contributor to the total variance was persons, the observations can be accepted as reproducible.

RESULTS

1. Height and its subdivisions at the first examination

The distributions of these variables were approximately Gaussian. Mean values with standard deviations of height, sitting height and subischial height at the first examination in five age-groups of older men and women are given in table 1. Height and sitting height show decreasing mean values in both sexes as age increases. Mean values of subischial height show little age effect in women and increase with increasing age in men.

Linear regressions of the three variables on age in men and in women are given in table 2. The decline of height with increasing age is significant in women only. There is a significant decline in sitting height with increasing age in both sexes. The lines for subischial height have no significant slope in either sex.

2. Changes in height and its subdivisions over five years

The change during five years in each of the three variables was examined by subtracting, in each subject, the five year reading from the original reading. Mean values, with standard errors, of the resulting differences, in age groups of less than 70 years and 70 years and over at entry to the study, are given in table 3. Two age groupings only were used because the number of subjects had fallen, especially among those aged 80 years and over at entry to the study. Positive mean values signify a decrease during the five

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TABLE 1. Mean values with standard deviations (SD) of height, sitting height and subischial height from the first examination in a study of older men and women.

SEX	HEIGHT (mm)			SITTING HEIGHT (mm)			SUBISCHIAL HEIGHT (mm)		
AGE GROUP	MEAN	SD	N	MEAN	SD	N	MEAN	SD	N
Men									
62-64	1685.3	69.1	46	898.3	33.4	46	786.9	46.5	46
65-69	1674.3	65.4	75	889.2	36.1	74	786.4	44.4	74
70-74	1666.4	65.9	37	875.3	40.1	37	791.1	40.7	37
75-79	1665.9	76.0	33	873.4	39.6	33	792.5	44.3	33
⩾80	1652.0	81.8	19	855.5	38.2	19	796.5	54.4	19
Women									
62-64	1571.8	66.3	42	835.9	36.3	42	735.9	40.5	42
65-69	1546.0	69.0	93	819.1	35.8	92	727.5	45.9	92
70-74	1542.5	54.5	54	814.7	28.3	54	728.6	45.5	53
75-79	1522.8	54.4	42	794.0	33.3	42	728.8	39.8	42
⩾80	1519.3	71.8	26	788.7	42.3	24	729.7	46.9	24

Table 2 Linear regressions on age of height, sitting height and subischial height from the first examination of older men and women.

SEX	DEPENDENT VARIABLE	REGR. COEFF.	SE (regr.coeff)	R	N
Men	Height	-1.419	0.745	0.13	210
	Sitting height	-1.844***	0.399	0.31	209
	Subischial height	0.380	0.483	0.05	209
Women	Height	-2.475***	0.639	0.24	257
	Sitting height	-2.389***	0.362	0.38	254
	Subischial height	-0.234	0.459	0.03	253

*** $p < 0.001$

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Table 3. Mean values (mm) and standard errors (SE) of five year changes in height, sitting height and subischial height in older men and women.

AGE AT ENTRY	FIVE YEAR CHANGES IN : HEIGHT			SITTING HEIGHT			SUBISCHIAL HEIGHT		
SEX	MEAN	SE	N	MEAN	SE	N	MEAN	SE	N
Men									
<70	5.52***	1.07	71	2.79	1.53	71	2.73*	1.05	71
≥ 70	11.71***	1.81	41	10.10**	3.30	42	3.20	3.06	41
Women									
<70	9.53***	1.03	89	4.38***	1.26	88	5.00***	1.16	88
≥ 70	14.64***	2.41	52	7.96*	3.74	53	6.15	3.53	52

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

years. The decrease in height is significant in the table in all four groups. For sitting height the decrease is significant except in the younger men. In respect of subischial height the decrease is significant in the younger groups of both sexes.

Linear regressions on age of the five year differences in each of the three variables are given in table 4. The decrease in height over five years becomes significantly larger in both sexes as age increases. This effect is present for sitting height in men only and there are no age effects in changes in subischial height.

3. Comparison of predicted with actual changes in height and sitting height

Mean values of height at the original examination (table 1) show a cross-sectional fall with age in both sexès but the linear regression of height on age is significant in women only (table 2).

Hence the use of this regression to predict height from age was possible in women only. In each woman, height predicted in this way for the time of the five year examination (i.e. for age at entry plus 5) was subtracted from recorded height for this examination. Mean values of the difference were 8.4 mm at age less than 70 years at entry and 14.5 mm at age 70 years and over. Remembering that the corresponding mean differences between recorded height at the first examination and that at the five year examination were 9.5 mm and 14.6 mm (table 3), the predicted loss is approximately double the actual loss in five years.

Since the linear regression of sitting height on age (table 2) was significant in both sexes, similar calculations were made in respect

Table 4. Linear regressions on age at entry of five year changes in height, sitting height and subischial height in older men and women.

DEPENDENT	MEN				WOMEN			
VARIABLE	REGR. COEFF.	SE	R	N	REGR. COEFF.	SE	R	N
HEIGHT	0.78***	0.16	0.42	112	0.51**	0.20	0.21	141
SITTING HEIGHT	1.04***	0.26	0.36	113	0.13	0.29	0.04	141
SUBISCH. HEIGHT	F LEVEL INSUFFICIENT FOR COMPUTATION				0.38	0.27	0.12	140

** $p<0.01$ *** $P<0.001$

of sitting height in both sexes. Apart from men less than 70 years at entry, in whom predicted and actual decreases over five years were almost equal, predicted decrease exceeded actual decrease sixfold in older men and by factors of 3.7 and 2.6 in younger and older women respectively.

DISCUSSION

The present study demonstrates the difference between actual loss in height as age increases shown by longitudinal measurement of the same subjects and the apparently greater loss with increasing age evident in cross-sectional studies. The age related fall in height in cross-sectional studies is a combination of actual loss with age, secular increase in height, the migration from an area of taller subjects (Miall et al 1967) and possibly increased mortality in taller people. Actual loss was measured in the present study and there was no association between height and mortality (Milne and Lauder 1978). No information about migration is available.

The excess of predicted over actual loss in height over five years is probably mainly due to secular increase in height in younger subjects. Secular increase has been clearly demonstrated by Scandinavian military records from 1741 onwards (Bøe et al 1957) although interpretation is complicated by the varying age at which maximum height may have been reached. Tanner, having corrected for this late maturing effect, used western European data to calculate that, from 1850 to the mid-twentieth century, secular increase was about one centimetre per decade (Tanner 1962, 1964). The present group of subjects may have experienced a larger secular increase than this and the data certainly point to the main cause of cross-sectional decline in height as secular trend rather than actual loss in individuals. Various other studies support the concept of secular increase (e.g. Damon 1965, Durnin and Weir 1952, Khosla and Lowe 1968, Parnell and Somerset 1962, Rosenbaum 1954, Society of Actuaries 1959 and the US National Health Survey 1965).

Miall et al (1967) in a longitudinal study estimated the decrease in height from 25 to 70 years to be 36 mm and 17 mm in men and 43 mm and 35 mm in women in the Rhondda and the Vale of Glamorgan respectively. They thought the difference (similar to that in the present study) between age loss and cross-sectional decrease included some effect from migration of taller subjects as well as secular increase. The greater actual loss in women reported by them was also found in the present study. A study of older men from Czechoslovakia reported mean decreases in height after 8-10 years of 10-16 mm (Pařízková and Eiselt 1971). These figures are comparable with those of the present study.

Decline in stature has been attributed to changes in the spine (flattening of discs, vertebral body collapse), thinning of weight-bearing cartilages, bent knee gait, flattened foot arches and posture related to habit or occupation (Hughes 1961, Trotter and Gleser 1951). In the older people in the present study decline in sitting height is the main factor in height loss rather than variation in leg length. The Czechoslovakian study mentioned above also shows this (Pařízková and Eiselt 1971). "Shrinkage in old age is more a matter of the vertebral column than the limbs" (Ruger and Stoessiger 1927).

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A C K N O W L E D G M E N T S

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Age effects in kyphosis and lordosis in adults

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Summary. A surveyor's flexicurve has been used to measure kyphosis and lordosis in a cross-sectional study of men and women aged 20–90 years. No age effect was found in men aged 20–59 years or in women aged 20–49 years. Linear regressions showed an increase in kyphosis with age in older men and women. Various indices were examined to test their suitability as estimates of kyphosis. Lordosis was absent in an increasingly large proportion of men and women as age rose above 60 years.

1. Introduction

A clinical impression that kyphosis increases with increasing age, especially in women, is widespread. This paper describes methods of measuring age differences in kyphosis and lordosis.

2. Subjects and methods

The persons examined, 413 men and 406 women, formed a sample obtained from two sources. The first sample of older people was obtained from the medical lists of 91 doctors in 50 general practices with surgery addresses in a defined area of Edinburgh. A total of 27 000 persons born in 1905 or earlier was available for sampling. From this total a simple random sample was drawn, of 215 men and 272 women aged 62–90 years. Full details of sampling with a comparison of respondents and non-respondents have been given elsewhere (Milne, Maule and Williamson, 1971). The second group, 198 men and 134 women aged 20–65 years, were donors providing blood at the Regional Blood Transfusion Service in Edinburgh. One of us (JSM) visited donor sessions and circulated a leaflet asking for volunteers for anthropometry. More people volunteered than could be measured in the time available. Bias was introduced by the Blood Transfusion Service policy of rejecting donors under 5 feet (1525 mm) in height or 112 lb (51 kg) in weight and by self-selection.

The curvature of the spine and of the overlying soft tissues was recorded with a surveyor's flexicurve. This instrument is a strip of lead covered with plastic, 60 cm in length, which can be bent in one plane only. Since it retains the shape into which it is bent, it can be used to copy any curved surface. The flexicurve was placed on the subject's back, with one end on the seventh cervical spine, and closely applied to the midline of the back, the subject being asked to stand as erect as possible. The level of the lumbosacral joint was marked on the flexicurve with a grease pencil, after which the instrument was laid on a piece of paper and the spinal curve copied by running a pencil along the flexicurve. The letters used in describing the curve are shown in figure 1 (2). H (not shown) represents the whole length of the curve and for convenience is called spinal length. The ends of the curve have been joined with a straight line. Perpendiculars B and D, drawn to the points on the curve farthest from the straight line, measure kyphosis and lordosis respectively. Dimension E is that part of the straight line from the cephalic end of the curve to the point where the curve crosses the straight line. Dimension G is that kyphotic part of the curve which corresponds to E. All records were made by one observer (JSM).

Reproducibility of method

Ten persons had their spinal curvature copied by the observer on two occasions. The pairs of measurements were examined by the analysis of variance. A reliability coefficient was calculated by dividing the variance for persons by the sum of the variances for persons, occasions and error. Variance due to error was the residual mean square after removing variance due to persons and occasions. Coefficients determined in this way for dimensions B and E and for the index B/E were respectively 0·78, 0·94 and 0·78. The contributions to the total variance made by persons and occasions were examined using the F test. The ratio of mean square for persons to mean square for error was significant at the 1% level for B and E, and at the 5% level for B/E. The corresponding ratio for occasions was not significant for any of the variables. Since the principal contributor to the total variance was persons, the observations may be accepted as reproducible.

3. Results

The types of curve obtained are shown in figure 1. The upper curve (1), most usually found in younger people, has well marked lumbar lordosis. The lowest curve (4), with no lordosis, was usually found in the elderly. In this curve dimension E is the length of the line joining the ends of the curve. The second curve (2) might be found at any age. A variant of this (3) has no lordosis, the lumbar part of the curve coinciding with the straight line joining the ends of the curve. This differs from curve (4) in that E is shorter than the straight line joining the ends of the curve. Curve (3) is common in older people. It is possible to find subjects with any of these curves at any age.

A. *Kyphosis*

Perpendicular B which measures kyphosis is significantly correlated with age and spinal length. Details of the relationships will emerge as the results are described. An ideal variable would not only truly measure kyphosis and reflect the effects of age upon it, but would also be independent of spinal length. In the male and female groups, the sampling distributions of spinal length for small age ranges are very similar. This means that straightforward application of regression techniques can be used to describe the behaviour of the variables, and in particular good estimates of age effects can be obtained. The effects of age and spinal length on B and on variables derived from B were estimated from linear regressions with B or the derived variable as the dependent variable and age or spinal length as

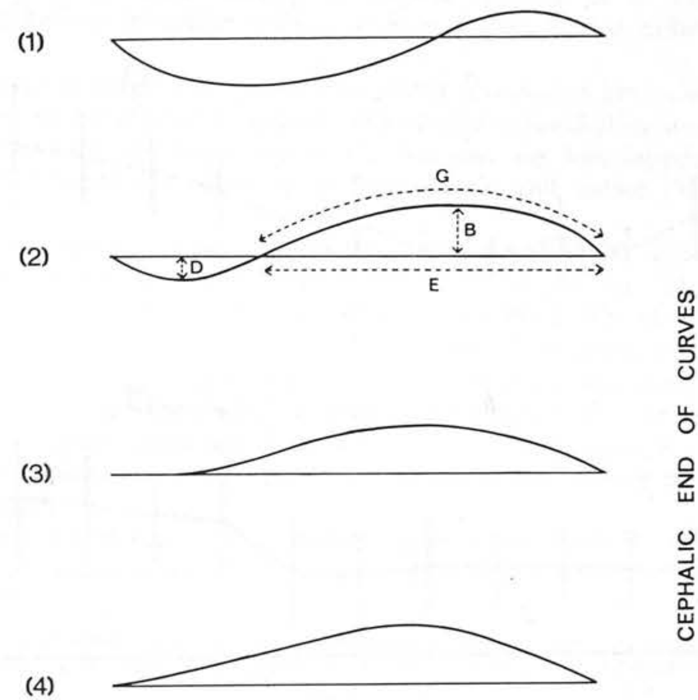

Figure 1. Types of spinal curve recorded with the flexicurve.

the independent variable. To select the index or variable derived from B closest to the ideal, the following variables were examined: B, log B, B/E, B/G, B/H and B_c. These are self-explanatory apart from B_c which is B corrected for spinal length according to an equation of the form

$$B_c = B - kH$$

where B and H are observed values and k is the linear regression coefficient for B on H (table 2). The value of the regression coefficient k, used in this equation, was computed for men aged 20–59 years and for women aged 20–49 years. B_c was then calculated for all men and all women in the sample over the age range 20–90 years, using respectively the male and female coefficients for the younger groups. The coefficients were computed from the younger groups because of the absence of detectable ageing effects on B in these age ranges (*vide infra*), which allows estimation of the effect of H on B without bias due to age.

The effect of age is shown in figure 2 which gives mean values of B with standard deviation in men and women. The means increase in value as age increases, after the age of 50 years in women and 55 years in men.

The age effect is also shown in table 1 where B and the indices derived from it are dependent variables which have been regressed on age, regression and correlation coefficients being given in the table. No age effect was found on B in men aged 20–59 years or in women aged 20–49 years. Regressions of B on age were also computed in men aged 55–90 years and in women aged 45–90 years. These regressions showed a significant increase in the value of B with increasing age (table 1). The variables derived from B were also studied in the age ranges

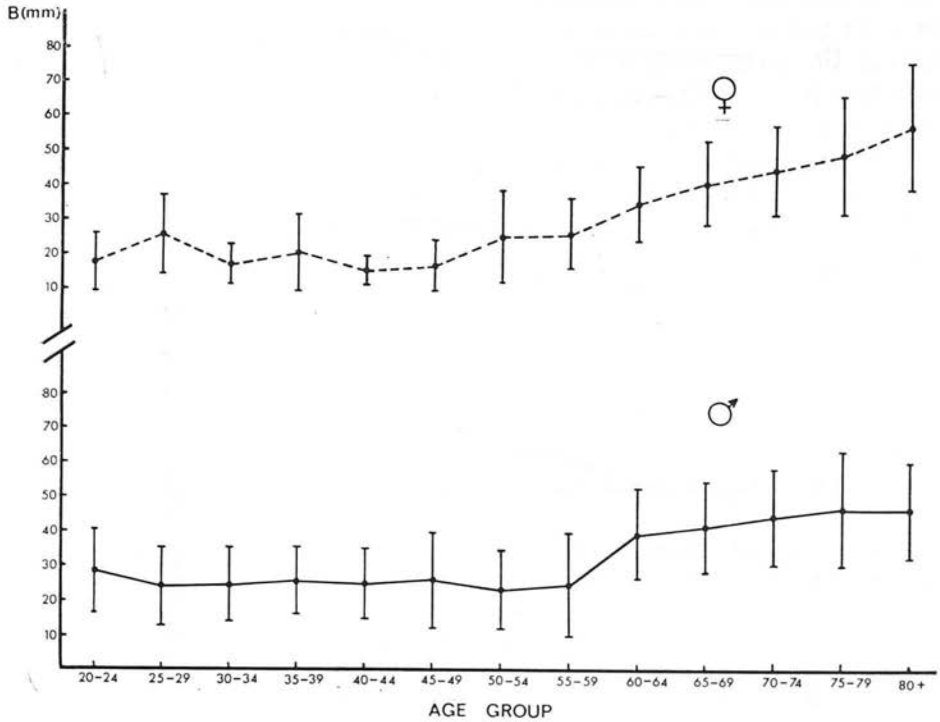

Figure 2. Variable *B*. Mean values with SD in men and women aged 20–90 years.

	Men 20–59 $N=188$		Men 55–90 $N=235$	
Index	k	r	k	r
B	−0·07	0·07	0·55*	0·27
log B	−0·002	0·10	0·01*	0·29
B/H	0·0	0·0	0·001*	0·31
B/E	0·0	0·0	0·001*	0·25
B/G	0·0	0·0	0·001*	0·25
B_c	−0·05	0·05	0·63*	0·33

	Women 20–49 $N=103$		Women 45–90 $N=307$	
Index	k	r	k	r
B	−0·16	0·15	1·0*	0·56
log B	−0·003	0·12	0·01*	0·60
B/H	0·0	0·15	0·003	0·60
B/E	0·0	0·14	0·002*	0·55
B/G	0·0	0·14	0·002*	0·56
B_c	−0·18	0·18	1·0*	0·61

Table 1. Regressions of *B* and derived indices on age.

*$P<0·05$. Levels are approximately 5% since not all distributions are normal.
k=linear regression coefficient for index on age.
r=correlation coefficient between index and age.
N=sample size.

used for B since all these variables are simple functions of B. These derived variables all behave in similar fashion to B in respect of first order age effects (table 1).

The overlap of age in these regressions covers a transition period within which the effects of age on B begin to appear. The overlap is justified by its small range relative to the total age range and by the fact that any bias introduced by the overlap will increase age effects in younger people and reduce them in older people.

Variable B and its derived indices were each regressed on spinal length in the same age groups as those used in the regressions on age. The regression coefficients and correlation coefficients are given in table 2. The clearest evidence of the dependence of the first four variables in table 2 on spinal length is found in the younger groups of men and women in whom no age effect was found which could bias the regression on spinal length (table 1). The indices least dependent on spinal length are B/E and B/G. The comparison is not straightforward in the older groups because of age effects. B_c has already been corrected for spinal length.

It was not found necessary to include higher order terms in the regressions for any of the independent variables apart from in the sample of women aged

	Men 20–59 $N=188$		Men 55–90 $N=235$	
Index	k	r	k	r
B	0·22*	0·5	0·23*	0·43
$\log B$	$0{\cdot}04\times10^{-1}$*	0·42	$0{\cdot}02\times10^{-1}$*	0·37
B/H	$0{\cdot}38\times10^{-3}$*	0·38	$0{\cdot}31\times10^{-3}$*	0·26
B/E	$0{\cdot}26\times10^{-3}$*	0·30	$0{\cdot}32\times10^{-3}$*	0·27
B/G	$0{\cdot}24\times10^{-3}$*	0·29	$0{\cdot}28\times10^{-3}$*	0·26
B_c	0·0	0·0	0·01	0·02

	Women 20–49 $N=103$		Women 45–90 $N=307$	
Index	k	r	k	r
B	0·11*	0·26	0·27*	0·44
$\log B$	$0{\cdot}02\times10^{-1}$	0·19	$0{\cdot}02\times10^{-1}$*	0·36
B/H	$0{\cdot}16\times10^{-3}$	0·15	$0{\cdot}40\times10^{-3}$*	0·27
B/E	$0{\cdot}11\times10^{-3}$	0·12	$0{\cdot}48\times10^{-3}$*	0·34
B/G	$0{\cdot}10\times10^{-3}$	0·11	$0{\cdot}41\times10^{-3}$*	0·33
B_c	0·0	0·0	0·16*	0·27

Table 2. Regressions of B and derived indices on spinal length.

*approx. 5% levels.
k=linear regression coefficient for index on spinal length.
r=correlation coefficient between index and spinal length.
N=sample size.

45–90 years. In this group there is an age spinal length interaction effect on B. To test for this type of effect, multiple regressions were made of the dependent variables on A (age), H, $A\times H$ (table 3). It can be seen that of the dependent variables only B, B/E, B_c demonstrate this effect. The regression coefficient for $A\times H$ is

Index	Regression coefficients for A (age)	H	$A \times H$	Partial F
B	$-2{\cdot}01$	$-0{\cdot}27$	$0{\cdot}8 \times 10^{-2}$	*
$\log B$	$0{\cdot}03 \times 10^{-1}$	$0{\cdot}01 \times 10^{-1}$	$0{\cdot}0$	
B_c	$-2{\cdot}0$	$-0{\cdot}38$	$0{\cdot}8 \times 10^{-2}$	
B/E	$-0{\cdot}03 \times 10^{-1}$	$-0{\cdot}04 \times 10^{-2}$	$0{\cdot}01 \times 10^{-3}$	*
B/G	$-0{\cdot}02 \times 10^{-1}$	$-0{\cdot}03 \times 10^{-2}$	$-0{\cdot}01 \times 10^{-3}$	*
B/H	$-0{\cdot}02 \times 10^{-1}$	$-0{\cdot}05 \times 10^{-2}$	$0{\cdot}01 \times 10^{-3}$	

$*P<0{\cdot}05$.

Table 3. Multiple regressions of B and derived variables on A, H and $A \times H$ in women aged 45–90 years.

positive in each case which implies that a more marked age effect is present in women with longer backs.

The effect of weight on B and the derived indices is not marked in any of the groups and it is therefore not necessary to compare the behaviour of the indices with respect to weight.

Comparison of B and derived variables

Variable B and log B behave similarly. Both exhibit greater dependence on spinal length than the other indices (table 2) and are therefore unsuitable for measuring kyphosis.

B_c, which is variable B corrected for spinal length, might be expected to be a good estimator of kyphosis. However, the coefficients of regression of B on spinal length used in computing B_c have large standard deviations, particularly in young women (table 4). This leads to an unstable estimate of the effect of spinal length. The dependence of B_c on spinal length in women aged 45–90 years

Sex and age range	Regression coefficient	S.D.
Men 20–59	0·22	0·03
Women 20–49	0·11	0·04

Table 4. Regression coefficients with standard deviations for regression of B on spinal length.

could result from this instability. Efficient estimation of the effect of spinal length would need larger samples in which the effect of age on B was absent or known. Correcting for spinal length in older people with a coefficient derived from younger persons assumes the same relationship between B and spinal length in all age groups. Secular trend altering this relationship could also explain the dependence of B_c on spinal length in older women. Another possible cause in older women is the $A \times H$ interaction effect.

The three remaining indices, B/H, B/E and B/G, are all dependent on spinal length in younger men and independent of it in younger women. B/E and B/G behave almost identically and reflect the recorded types of spinal curvature, particularly curve (3) in figure 1. The other indices, including B/H, do not allow for this type of spinal curve in which the lumbar end of the curve merges with the line joining the ends of the curve (figure 1, curve 3). For this reason B/E or B/G seems preferable to B/H. Dimensions E and G are positively correlated with spinal length (table 5). Hence, apart from the exception given above, B/E and B/G should behave similarly to B/H. This means that B/E and B/G will allow for any effect of age and secular trend on spinal length. Finally these two indices are not based, as is B_c, on parameters estimated from the sample. Of the variables studied which could be used to measure kyphosis these two seem preferable. B/E is marginally better because the measurements are easier to make, and because B/E demonstrates the $A \times H$ interaction effect in older women while B/G does not.

Sex	$r_{H \cdot E}$	$r_{H \cdot G}$
Men	0·43*	0·44*
Women	0·25*	0·28*

*P<0·01.

Table 5. Correlation coefficients between spinal length (H) and E,G in men and women.

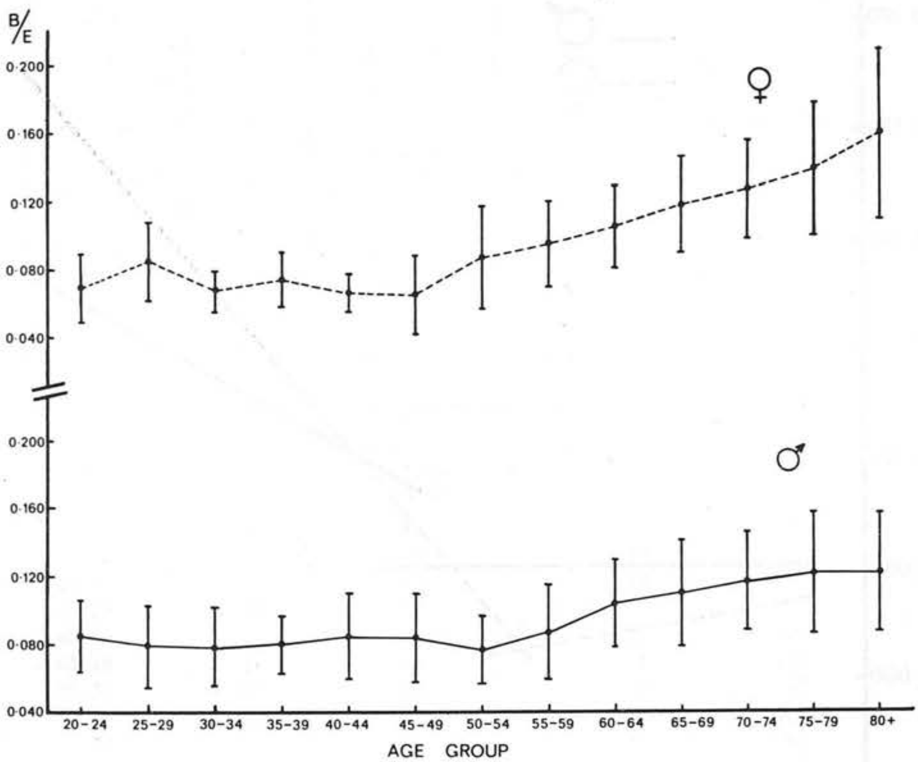

Figure 3. Derived variable B/E. Mean values with SD in men and women aged 20–90 years.

Mean values with standard deviations of B/E are given in figure 3 and show increases after 55 years in men and 45 years in women. Regression relationships of B/E with age are given more fully in table 6, and shown graphically in figure 4. These demonstrate the significant increase of B/E with age in the older groups of men and women. The increase is more marked in women than in men.

Sex and age range Men	Constant	Regr. Coeff. k	S.E. k	t	r	N	S.E. abt. Regr.
20–59	0·08	0·0	$0{\cdot}15\times10^{-3}$	0·0	0·0	188	0·02
55–90	0·03	$0{\cdot}11\times10^{-2}$	$0{\cdot}29\times10^{-3}$	3·9*	0·25	235	0·03
Women							
20–49	0·08	$0{\cdot}32\times10^{-3}$	$0{\cdot}22\times10^{-3}$	1·46	0·14	103	0·02
45–90	−0·04	$0{\cdot}02\times10^{-1}$	$0{\cdot}21\times10^{-5}$	11·24*	0·55	307	0·03

*$P<0{\cdot}05$.
r=correlation coefficient between B/E and age.
N=sample size.
t=value of t-test for $k=0$ against $k\neq0$.

Table 6. Regressions of B/E on age.

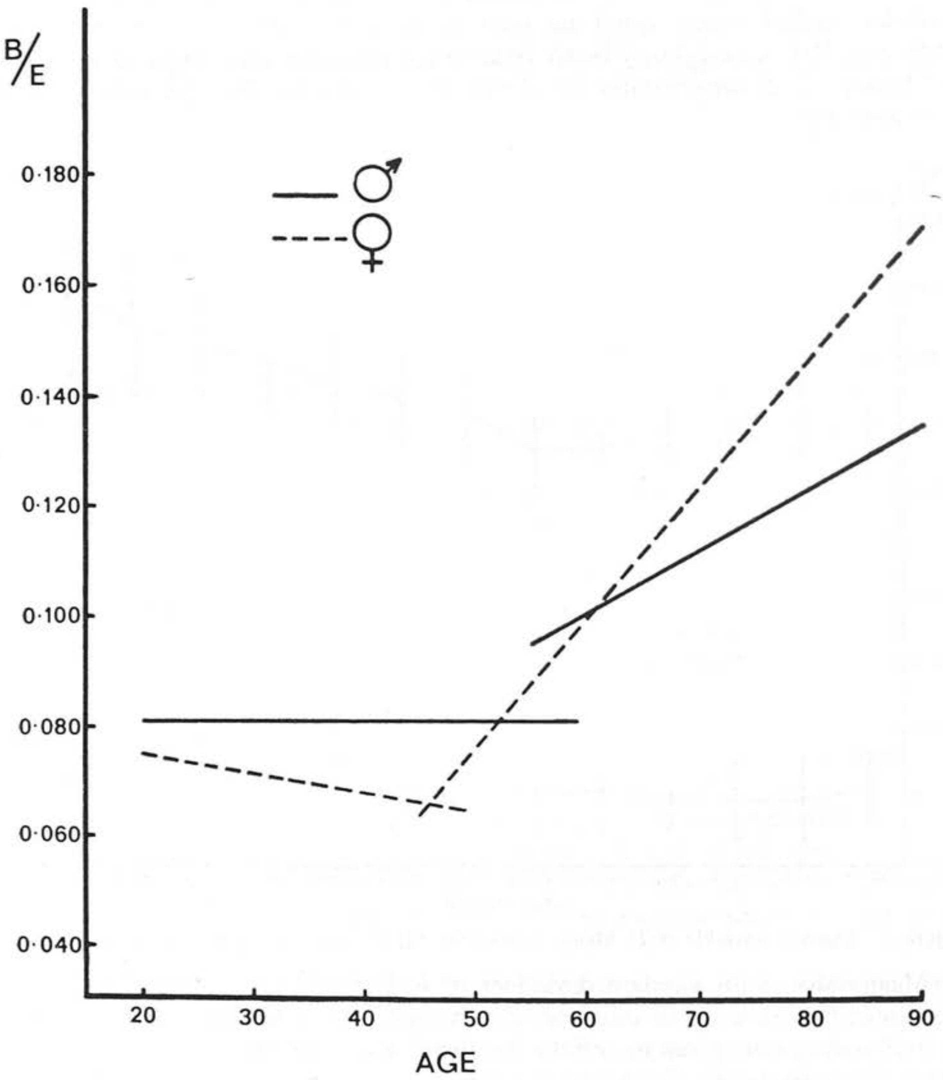

Figure 4. Regressions of B/E on age in men and women aged 20–90 years.

B. Lordosis

This is estimated by perpendicular *D* (figure 1) of which mean values with standard deviations are given in figure 5. These mean values show a steep fall in men and women over the age range 55–64 years. With increasing age, an increasing proportion of persons in the sample have values of *D* equal to zero. This is shown in table 7 which gives, in five-year age groups for men and women,

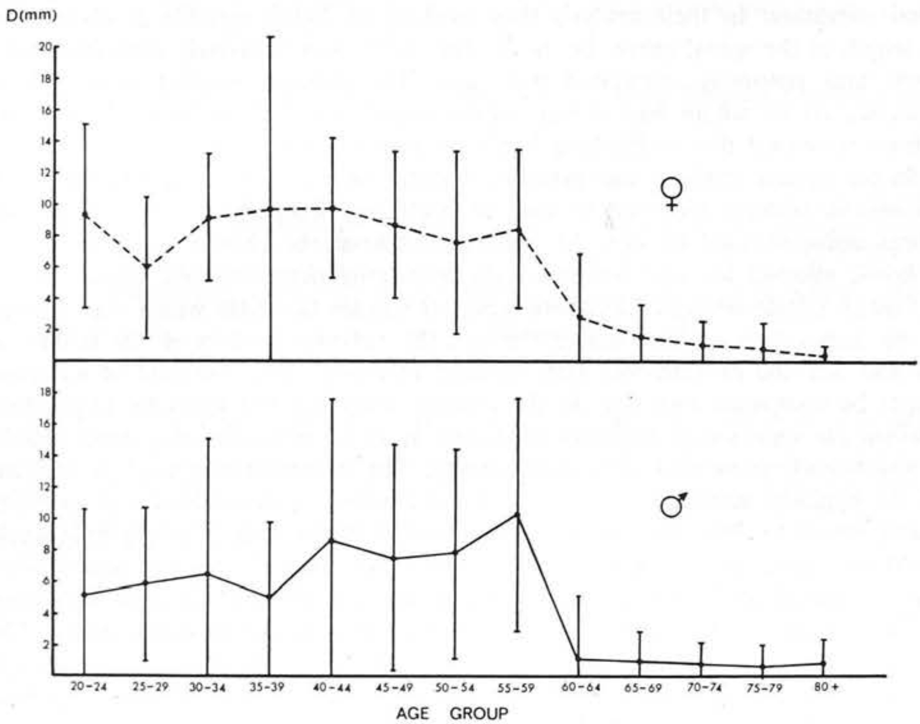

Figure 5. Variable *D*. Mean values with SD in men and women aged 20–90 years.

	Men		Women	
Age group	*N*	% with $D>0$	*N*	% with $D>0$
20–24	33	85	37	97
25–29	33	88	19	95
30–34	28	82	18	100
35–39	30	87	7	71
40–44	15	80	11	100
45–49	17	88	11	100
50–54	20	90	13	92
55–59	12	92	8	100
60–64	55	39	51	65
65–69	77	35	94	54
70–74	38	37	55	47
75–79	34	21	45	33
$\geqslant 80$	20	20	30	17

No data in 2 men and 7 women.

Table 7. Percentages of men and women in 5 year age groups in whom variable *D* exceeds zero.

the percentage in whom D is greater than zero. Up to age 60 this varies between 75 and 100%. In older people the percentage falls, reaching in the age group 80 years and over, 20% in men and 17% in women.

4. Discussion

Takahashi and Atsumi (1955) described the use of the flexicurve in copying spinal curvature. In their analysis they used as an index variable B divided by the length of the spinal curve, i.e. B/H. This index was negatively correlated with height and positively correlated with age. The subjects studied were elderly Japanese, all of whom had spinal curves resembling that in figure 1 (4). The authors attributed this to life-long habits of posture and occupation.

In the present study it was possible, because of the absence of age effects on kyphosis in younger men and women, to study the effect of spinal length on the indices uncomplicated by age. An index could hence be chosen which measured kyphosis, allowed for age and was only minimally dependent on spinal length.

Cowan (1965) described kyphosis using the kyphotic angle which was formed by the intersection of lines drawn through the anterior borders of the bodies of 2nd and 3rd and of 12th and 11th thoracic vertebrae. This estimate of kyphosis cannot be compared with that in the present study but the kyphotic angle does measure the increase of kyphosis with age. It is possible that this angle would be significantly correlated with spinal length. The measurements used in estimating the kyphotic angle are not easy to make because of the difficulty of deciding exactly where to draw the necessary lines on the X-ray film. The kyphotic angle would also need specially taken lateral chest films, since the routine lateral films used in clinical work do not clearly outline the 2nd and 3rd thoracic vertebrae.

The reasons for kyphosis increasing as age increases are probably many. The effects of occupation and of habitual posture, with loss of muscle tone as age increases, are added to such causes as spinal osteoporosis, and senile emphysema. The absence of lordosis, which is increasingly common in this cross-sectional study after 64 years of age, may result from increasing kyphosis pushing the centre of gravity of the body forwards with loss of lordosis from compensatory straightening of the lower spine. Urist, Gurvey and Fareed (1970) reported, in a study of osteoporosis in ageing women, accentuation of the dorsal posterior curve with increasing age and reversal of the anterior lumbar curve.

The flexicurve has been found satisfactory, used clinically, in following the progress of patients with spondylitis (Chalmers, J., personal communication). The present analysis would suggest the instrument could also be used in cross-sectional and longitudinal population studies.

Acknowledgments

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Zusammenfassung. Das Kurvenbiegungsmass eines Landvermessers wurde benützt um Kyphosis und Lordosis zu messen im Studium eines Querschittes von Männern und Frauen im Alter von 20 bis 90 Jahren. Es wurde gefunden, dass Alter keine Auswirkungen verursachte auf Männer im Alter von 20–59 Jahren und auf Frauen im Alter von 20–49 Jahren. Lineare Regressionen zeigten ein Ansteigen von Kyphosis mit dem Alter in älteren Männern und Frauen. Verschiedene Anzeichen wurden studiert um ihre Eignung als Kyphosis-Einschätzungen zu prüfen. Lordosis war bei Männern und Frauen nicht vorhanden in steigender grosser Proportion mit steigendem Alter über 60 Jahre.

Résumé. Un curvimètre d'enquête a été utilisé pour mesurer la cyphose et la lordose, lors d'une enquête transversale portant sur des hommes et des femmes de 20 à 90 ans. Aucune influence de l'âge n'a été décelée pour les hommes de 20 à 59 ans, et les femmes de 20 à 49 ans. Chez les hommes et les femmes plus âgés, il existe une liaison linéaire positive entre l'âge et la cyphose. Plusieurs indices ont été essayés pour évaluer la cyphose. La lordose est absente dans des fractions de plus en plus importantes des populations masculine et féminine examinées lorsque l'âge augmente au delà de 60 ans.

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The relationship of kyphosis to the shape of vertebral bodies

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Summary. An index which measures the wedge deformity of vertebral bodies in lateral chest radiographs in older people was calculated by dividing the sum of the vertical anterior heights of the lower six thoracic vertebral bodies and discs by the corresponding sum of vertical posterior heights. This index increased with increasing age in a similar manner in men and in women, in contradistinction to an index measuring kyphosis in which the age effect was greater in women. The index of wedging explained 42 per cent and 48 per cent of the variation in kyphosis in men and in women respectively. Additional effects due to age, detected in women only, added a further 4 per cent to the explained variation and may be due to ageing of soft tissues.

1. Introduction

Various authors have described methods of measuring the degree of thoracic kyphosis (Takahashi and Atsumi, 1955; Cowan, 1965; Neugebauer, 1970; Milne and Lauder, 1974). Cowan, using what he called the kyphotic angle, demonstrated the expected increase in kyphosis with increasing age.

The present authors measured kyphosis using a surveyor's flexicurve. This instrument is a strip of lead covered with plastic 60 cm in length, which can be bent in one plane only and which retains any shape into which it is bent. The flexicurve was placed on the subject's back with one end on the seventh cervical vertebra and closely applied to the mid-line of the back, the subject being asked to stand as erect as possible. The level of the lumbrosacral joint was marked on the flexicurve after which the instrument was laid on a piece of paper and the spinal curve copied by running a pencil along the flexicurve. The resulting curve is shown in figure 1, in

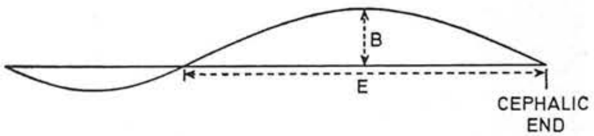

Fig. 1. Typical record of kyphosis obtained with a surveyor's flexicurve showing the dimensions used in calculating the index of kyphosis (B/E).

which the ends of the curve have been joined by a straight line. Kyphosis is measured by dimension B. This dimension varies with height and after examination of various possible indices, it was shown that the most appropriate index for describing kyphosis, with the least dependence on height is dimension B divided by dimension E (Milne and Lauder, 1974). In the present paper this is called the index of kyphosis. This index also shows the expected increase with increasing age, particularly in women.

Inspection of lateral chest radiographs in older people reveals vertebral bodies many of which are wedge-shaped, rather than rectangular as they are in younger persons. Some authors mention the association between wedging of vertebral bodies and kyphosis (Nicholas and Wilson, 1963; Rowe and Sorbie, 1963). The present paper describes a method of measuring this wedge deformity and of relating it to measurements of kyphosis.

2. Subjects and methods

The sample of older people on whom the measurements were made was obtained from the medical lists of 91 doctors in 50 general practices with surgery addresses in a defined area of Edinburgh. A total of 27 000 persons born in 1905 or earlier were available for sampling in January 1968. From this total a simple random sample was examined of 215 men and 272 women aged 62–90 years. Full details of sampling with a comparison of respondents and non-respondents have been given elsewhere (Milne, Maule and Williamson, 1971).

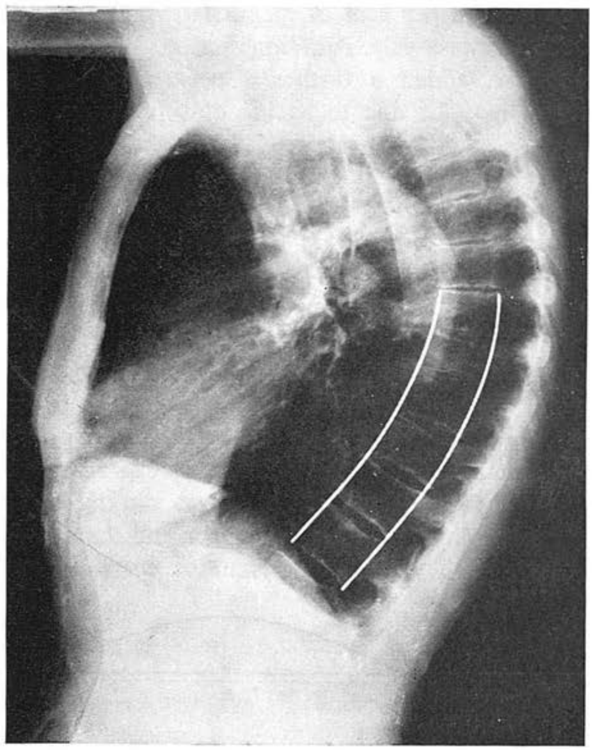

Fig. 2. Dimensions of a lateral chest radiograph to estimate index of wedging (of vertebral bodies)

Left lateral chest radiographs were taken at a tube–film distance of 183 cm with the subject standing with the upper limbs parallel to the ground. The shape of vertebral bodies was measured from the lateral chest radiograph by measuring two distances along the spine in the lower thoracic region with a "Curvimetre" map measurer. This instrument has a toothed wheel geared to a pointer on a dial so that running the wheel along a curved line records the length of the line on the dial. One revolution of the pointer is equivalent to 10 cm. A digital counter in a window in the dial sums decimetres. The dial is graduated in centimetres and millimetres. The anterior distance measured extended from the upper end of the anterior border of the seventh thoracic vertebra to the lower end of the anterior border of the twelfth thoracic vertebra. The posterior distance was measured along a line immediately anterior to the intervertebral foramina extending from the upper border of the seventh to the lower border of the twelfth thoracic vertebra, i.e. along the posterior aspect of the vertebral bodies. The lines have been drawn in white on the lateral chest radiograph in figure 2. If the posterior measurement in expressed as a percentage of the anterior, the more this index exceeds 100, the greater is the degree of wedge deformity in the six vertebrae measured.

The six vertebrae measured were chosen because in 50 lateral chest radiographs selected at random from the 447 films exposed in the study, only two were found in which fewer than six vertebrae were clearly visible. The lower seven dorsal vertebrae were clearly visible in only 18 of the 50 films.

Kyphosis was measured with a surveyor's flexicurve as described above and elsewhere (Milne and Lauder, 1974).

Reproducibility and validity of methods

The technique for estimating wedge deformity in vertebral bodies was tested by four comparisons of paired measurements. These were:

1. Using one radiograph in each person the index was calculated in ten persons on two occasions of measurement.

2. Using two radiographs in each person, exposed on separate occasions the index was calculated in ten persons for each occasion.

3. Using one radiograph in each of ten persons the index was calculated from two measurements, the first using six vertebrae as described above and the second using the greatest number of visible vertebrae (maximum nine).

4. Using one radiograph for each of ten persons the index was calculated from six vertebrae, firstly from measurement along continuous lines as in figure 2 and

Paired measurement (as numbered in text)	1st mean	2nd mean	Mean diff.	SD diff.	SE diff.	N	t
1	112·5	111·8	0·7	1·20	0·40	10	1·75
2	116·0	115·7	0·3	1·68	0·56	10	0·54
3	115·7	115·5	0·2	1·47	0·49	10	0·41
4	110·9	112·2	1·3	4·73	1·58	10	0·82

Table 1. Comparison of paired measurements used in studying the index of wedging (of vertebral bodies).

secondly by summing the anterior and posterior heights of individual vertebrae, the intervertebral disc being excluded from the measurements.

A different group of ten persons was used for each of the four comparisons. For each of the four sets of paired measurements, the mean difference was calculated (table 1). None of these mean differences differs significantly from zero. The comparisons suggest that the index is reproducible. The fourth comparison suggests that even with intervertebral discs included in the measurements the index estimates wedge deformity of vertebral bodies.

The reproducibility of the index of kyphosis has been described elsewhere (Milne and Lauder, 1974).

3. Results

Mean values with standard deviations are given for the index of kyphosis in table 2 and for the index of wedging in table 3. Both variables show age effects.

Age group Men (N=213)	Mean	SD	N
62–64	0·105	0·025	46
65–69	0·111	0·030	75
70–74	0·117	0·029	38
75–79	0·122	0·036	34
80–90	0·122	0·035	20
Women (N=265)			
62–64	0·107	0·023	42
65–69	0·118	0·028	93
70–74	0·127	0·029	55
75–79	0·139	0·039	45
80–90	0·160	0·050	30

Table 2. Mean values with standard deviations of the index of kyphosis (B/E) in men and women aged 62–90 years.

Age group Men (N=200)	Mean	SD	N
62–64	111·2	4·02	45
65–69	110·7	4·66	68
70–74	112·8	6·21	37
75–79	113·4	5·88	31
80–90	114·3	5·85	19
Women (N=247)			
62–64	110·3	4·03	40
65–69	111·8	4·59	90
70–74	113·5	4·88	53
75–79	114·5	6·75	39
80–90	114·0	5·07	25

Table 3. Mean values with standard deviations of the index of wedging (of vertebral bodies) in men and women aged 62–90.

The effects are more marked in women compared with men for the index of kyphosis but this is not so for the index of wedging where values in corresponding age groups are similar in the sexes (tables 3 and 5). The larger number of missing values in table 3 compared with table 2 reflects films unsuitable for measurement, persons unable to attend hospital who were examined at home and persons who could not stand for radiographs to be exposed.

Linear and multiple regression techniques were used, with the index of wedging and age as the independent variables, to estimate the extent to which variation in the index of kyphosis is explained by the index of wedging and other age effects. The results, presented in table 4, show that in men and in women the principal contribution to the regression is made by the index of wedging which explains 42 per cent of the variation in men and 48 per cent in women. Additional effects due to age, detected in women only, add a further 4 per cent to the variation explained by the index of wedging.

Sex	N	Dependent variable	Independent variables	Regression coefficient	SE	R	Partial F test (on inclusion of age in the regression)
Men	200	B/E	W	0·0037	0·0003	0·64	
	200	B/E	W	0·0037	0·0003	—	
			A	0·0002	0·0003	0·65	0·65
Women	247	B/E	W	0·0044	0·0003	0·69	
	247	B/E	W	0·0041	0·0003	—	
			A	0·0021	0·0003	0·72	22·2 **

$^{**}P<0{\cdot}001$.

Table 4. Regressions of index of kyphosis (B/E) on the index of wedging (W) and age (A) in men and women aged 62–90 years.

The addition of quadratic terms in respect of the index of wedging and of age to the regression did not improve the fit. Measurement error in the index of wedging did not affect the fitted curves by more than 2 per cent.

4. Discussion

Osteoporosis of the spine which is known to increase in severity with increasing age in older people is regarded as following a sequence of events which are visible in lateral radiographs of the spine. Rarefaction of bone is followed by the devel-

Sex	Regression coefficient	SE	r	N
Men	0·17**	0·06	0·21	200
Women	0·20**	0·05	0·24	247

$^{**}P<0{\cdot}01$

Table 5. Linear regressions of the index of wedging (W) on age in men and women aged 62–90 years.

opment of biconcave vertebrae. Ultimately collapse of the anterior parts of some vertebral bodies leads to wedging of these vertebrae (Dent, 1955; Rowe and Sorbie, 1963). The asymptomatic fractures which precede wedging in osteoporotic spines are reported as occurring mainly in the upper anterior parts of vertebral bodies (Gershon-Cohen, Rechtman, Schraer and Blumberg, 1953). These events have been used to describe four grades of osteoporosis, grade 3 being characterized by biconcavity and some wedge deformity while grade 4 is shown by marked wedging with collapse of several vertebral bodies (Guggenheim, Reshef, Ben-Menachem and Bernstein, 1971). These authors reported that it was rare for them to find men in grades 3 or 4 although 5 per cent of women over 60 years were so graded in their study. The index of wedging in the present study did not show this sex difference.

Doyle, Gutteridge, Joplin and Fraser (1967) were doubtful whether biconcavity of vertebral bodies indicated osteoporosis. They found that mineral analysis did not correspond well with biconcavity and regarded collapse of one or more vertebral bodies as the most reliable sign of spinal osteoporosis. A minimum prevalence could therefore be estimated with this criterion. Lateral radiographs alone may not exclude other causes of vertebral body collapse such as metastases, hyper-parathyroidism, polycythaemia vera or osteomalacia, although osteoporosis is regarded as the commonest cause (Nicholas and Wilson, 1963). The index of wedging in the present study is therefore probably measuring osteoporosis of the spine.

Some authors mention an association between the appearance of wedging in vertebral bodies and increasing kyphosis (Nicholas and Wilson, 1963; Rowe and Sorbie, 1963). In the samples examined in the present study approximately half of the variation in the index of kyphosis in men and in women was explained by age effects. In the men the index of wedging accounted for the total age effect in the index of kyphosis. Multiple regression showed that in women in the sample the index of kyphosis was affected by age, or other variables related to age, in addition to the effect attributable to the index of wedging. This additional age effect is small but definite.

Nicholas and Wilson (1963) reported height loss caused by 'postural slumping' producing increase in existing spinal curves which they regarded as common in osteoporosis of the spine. This statement is compatible with the additional age effect found in the present study in old women. One might speculate that this additional effect is produced by ageing of soft tissue with perhaps resulting loss of muscle tone leading to increased kyphosis in old women but not in old men.

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Zusammenfassung. Zur Messung der keilartigen Verformung der Wirbelkörper auf seitlichen Thorax-Röntgenaufnahmen älterer Menschen wurde ein Index aus den Summen der vorderen und hinteren Wirbel—und Bandscheibenhöhen der unteren sechs Brustwirbel gebildet. Dieser Index steigt mit dem Alter bei Männern und Frauen in vergleichbarer Weise, an wogegen ein Index der Kyphose bei Frauen stärker anstieg. Der Index der Keilverformung beschreibt 42 prozent bzw. 48 prozent der Kyphosenvariabilität bei Männern bzw. Frauen. Der zusätzliche Alterseffekt, der nur bei Frauen festgestellt wurde, erklärt weitere 4 prozent der Variabilität und kann mit Alterung der Weichteile interpretiert werden.

Résumé. Un indice qui mesure la déformation en coin des corps vertébraux sur des radiographies latérales du thorax chez le vieillard a été calculé en divisant la somme des hauteurs verticales antérieures des six corps et disques vertébraux inférieurs par la somme des hauteurs verticales postérieures correspondantes. Cet indice s'élève avec l'âge de façon semblable chez l'homme et chez la femme, contrairement à un indice mesurant la cyphose pour lequel l'effet de l'âge est plus marqué chez la femme. L'indice de déformation en coin a assumé 42 et 48 pour cent de la variation de la cyphose chez l'homme et la femme respective- ment. Des effets supplémentaires de l'âge, détectés chez la femme seulement, ont ajouté 4 pour cent de plus à la variation assurée et peuvent être dûs au vieillissement des tissus mous.

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A five-year follow-up study of bone mass in older people

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Summary. Bone mass was estimated in a simple random sample of older people from Edinburgh (215 men and 272 women aged 62–90 years), by measuring metacarpal cortical thickness and by measuring the optical density of the radius compared with that of a metal wedge on an X-ray. Information was also collected about diet, energy expenditure and anthropometric variables. The two bone mass estimations were moderately correlated (0·47 in men, 0·53 in women). Both showed decrease as age increased. Estimates of bone mass increased as body size or activity increased, but were unrelated to dietary intakes of calcium or vitamin D.

Five years later the cortical thickness was remeasured in 111 men and 141 women. Loss of bone was not uniform, and some subjects actually showed a gain. The mean loss was 0·27 mm (SD 0·41) in men and 0·28 mm (SD 0·40) in women. This loss was unrelated to body size or to intake of calcium and vitamin D.

1. Introduction

Many authors have published cross-sectional data suggesting that men and women lose bone as they grow older. A few authors (Adams, Davies and Sweetman, 1970; Garn, Rohmann and Wagner, 1967; Exton-Smith, Millard, Payne and Wheeler, 1969 a) have reported longitudinal studies of changes in bone mass. The present paper reports follow-up data about changes in bone mass over five years from a study of a random sample of older people begun in Edinburgh in 1968. This study, which included examinations by a physician, a psychiatrist and a dietitian, was designed to record changes in physical and mental health and in normal measurements over a period of time in older people. Bone mass was included among these measurements.

2. Subjects and methods

The people studied were 215 men and 272 women aged 62–90 years who in 1968 formed a simple random sample of the population of 27 000 people in that age range living in ten city wards in north Edinburgh. The method of sampling with a comparison of respondents and non-respondents has been described elsewhere (Milne, Maule and Williamson, 1971). The subjects were examined during 1968–69. Five years later, during 1973–74, it was possible to re-examine 113 men and 148 women. 78 men and 60 women had died, leaving 24 men and 64 women surviving who for various reasons were not re-examined. Follow-up of the sample has been described in detail elsewhere (Milne and Chopin, 1975).

Metacarpal cortical thickness

In both examinations metacarpal cortical thickness was measured on an X-ray of the right hand exposed at a tube-film distance of 112 cm. The measurement was made at the mid-point of the second metacarpal bone using an engineer's vernier caliper. The cortical thickness $(D-d)$ was calculated by subtracting the diameter of the medullary cavity (d) from the diameter of the bone (D). A jeweller's eye-piece made the measurement easier.

Bone mass

A densitometric estimate of bone mass was made at the first examination only using a method developed from methods described by Keane, Spiegler and Davis (1959) and modified by Meema, Harris and Porrett (1962). The forearm was X-rayed, immersed in water and lying beside a metal wedge (Schraer, 1958). Allowance was made in developing the apparatus for the need for correction for soft-tissue variation (Jackson, 1951), of ensuring even distribution of radiation over the film (Meema *et al.*, 1962; Doyle, 1965), of a sufficient exposure to keep the optical density of wedge or radius above the minimum optical density of the film (Garn, Feutz, Colbert and Wagner, 1966 b), of a long arm–film exit distance to cope with scatter (Keane *et al.*, 1959), of a standard wedge (Schraer, 1958) and of suitable film handling and processing (Doyle, 1965). The apparatus used is shown diagrammatically in figure 1.

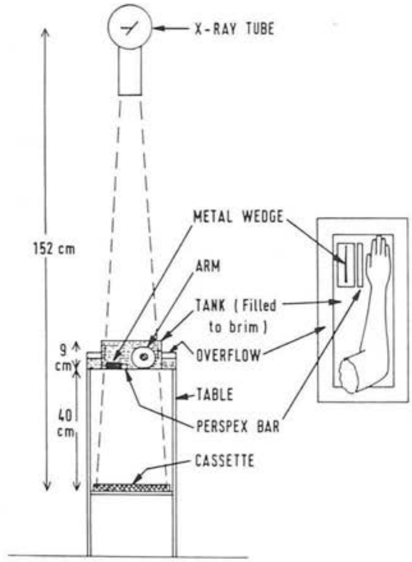

Figure 1. Apparatus for measurement of equivalent metal thickness of radius.

Two films were exposed in each subject. In each the optical density of the lower end of the radius was compared in a specially modified EEL densitometer with the optical density of the X-ray of the standard wedge. A perspex template corresponding to marks on the densitometer head was used to locate accurately the area measured in the radius. This was approximately at the centre of the expanded lower end of the bone. After allowance for X-ray magnification the mean of the two results was recorded in each subject as millimetres of equivalent metal thickness.

All skeletal measurements were made by one observer (J.S.M.).

Diet

Dietary histories covering a period of one week were obtained by one of us (M.E.L.) for 212 men and 263 women. Food tables prepared by the Ministry of Health (Disselduff, Marr and Robertson, 1968) were used to calculate the nutrient intakes. Information about energy expenditure during 24 hours was collected by the diary method (Garry, Passmore, Warnock and Durnin, 1955). Entries in the diary were checked for consistency by the observer (M.E.L.). Details of physical activity recorded in the diary were transformed into megajoules per 24 hours using the values of Durnin and Passmore (1967).

Anthropometric data

Height was measured to the last complete millimetre with a Harpenden stadiometer. Weight was measured with a lever balance to the last complete 100 g. Women wore a gown weighing 250 g while men wore underpants weighing approximately 500 g. Grip of the right hand was recorded in millimetres of mercury, as the best of three attempts, using the Arthritis and Rheumatism Council's modified sphygmomanometer cuff attached to a mercury manometer of bore one millimetre and height 600 mm. Other measurements recorded were skinfold thickness measured with a Harpenden caliper (triceps, biceps, subscapular and suprailiac sites), sitting height, span, biacromial and biiliac diameters, limb circumferences and intercondylar diameters.

The data were examined by standard statistical methods (Snedecor and Cochran, 1967).

Reproducibility

The two measurements which estimated bone mass were performed in eight persons on two separate occasions. For each variable the standard deviation of the mean difference was calculated and expressed as a percentage of the mean of all the measurements (Tanner and Weiner, 1949). The results were 7·5 for equivalent metal thickness of the radius and 6·1 for metacarpal cortical thickness. Reproducibility of the other variables was satisfactory and will be published elsewhere.

3. Results

Bone mass variables and age

This section is based on data gathered at the first examination. Frequency distributions of these bone variables were approximately Gaussian. Mean values with standard deviations of the bone mass variables are given in table 1 for three age groups of men and women. Using Student's "t" test it was shown from the tables that these mean values decline significantly with increasing age in both sexes except for cortical thickness in the oldest men. In them the mean value shows a small but not significant increase compared with the previous age group.

The tables also show that the variance of each variable is similar in the three age groups of each sex except for women of 80 years and over in respect of cortical thickness.

Mean values of each of the variables in men are significantly larger than those in women in all correspondeing age groups.

Linear regressions of cortical thickness and of equivalent metal thickness on age were calculated after examining scattergrams to find out whether the data were linear. One regression line was appropriate to describe each variable in each sex over the age range 62–90 years with the exception of cortical thickness in men. In them two overlapping age ranges, 62–79 years and 75–90 years, were required. All the lines proved to have significant negative slopes ($P<0 \cdot 01$) with the exception of that for the regression of cortical thickness on age in men aged 75–90 years in whom the coefficient of regression did not differ significantly from zero. The lines of regression of equivalent metal thickness on age were almost parallel in men and women. The same was true of metacarpal cortical thickness up to the age of 79 years.

Correlation coefficients between metacarpal thickness and equivalent metal thickness were 0·47 in 200 men ($P<0 \cdot 01$) and 0·53 in 250 women ($P<0 \cdot 01$).

Sex/age range	Metacarpal cortical thickness (cm)			Equivalent metal thickness (mm)		
	Mean	SD	N	Mean	SD	N
Men						
62–69	0·468	0·076	121	2·15	0·49	118
70–79	0·426	0·078	70	1·94	0·59	67
≥80	0·434	0·063	19	1·67	0·42	15
Women						
62–69	0·380	0·068	134	1·44	0·43	129
70–79	0·345	0·064	98	1·24	0·40	95
≥80	0·317	0·099	25	0·95	0·49	26

Table 1. Mean values of metacarpal cortical thickness and equivalent metal thickness in three age groups of older men and women.

Diet, energy expenditure, anthropometric data and bone mass

No age effects were found in respect of intakes of calcium or vitamin D, in men or in women. There was no association in this study between intakes of calcium or vitamin D and the variables estimating bone mass.

As a first step in investigating the possible relationship between bone mass and body size, a correlation matrix was constructed relating bone mass variables, anthropometric data, handgrip and energy expenditure. The matrix suggested that bone mass might vary with body size and activity.

Accordingly principal components analysis was performed using all the anthropometric data, metacarpal dimensions, handgrip and energy expenditure. Three components emerged in both men and women. The first component, apparently resulting from bulk, was best represented by weight (W) corrected for height (H) as W/H^2 in men and W/H in women. These are the appropriate ratios to correct weight for height in older people in Edinburgh (Milne, 1973). The second component, apparently associated with body length, had height as the greatest contributor. The third component, apparently physical activity, was equally well represented by handgrip or energy expenditure.

Linear regression of these variables separately on age showed significant decreases in value as age increased with the exceptions of W/H^2 and height in men and W/H in women.

The relationship between bone mass and the four variables associated with body size or activity was studied by calculating linear regressions of each of the variables estimating bone mass on each of the four variables separately. To eliminate the effect of age, the dependent and independent variables used in the regressions (apart from the three without age effects) were first corrected for age using the equation $Y_c = Y - b\,(\text{age} - \overline{\text{age}})$ where Y_c is the variable corrected for age, Y is its recorded value, b the coefficient of regression of Y on age and $\overline{\text{age}}$ the mean value of the ages of the subjects included in the regression. The results are given in table 2 which shows significant relationships between variables estimating bone mass and those representing body size or activity, with the exception of height in respect of equivalent metal thickness in women.

		Cortical thickness				Equivalent metal thickness			
Sex	Indep. variable	Regr. coeff.	SE	r	N	Regr. coeff.	SE	r	N
Men	W/H^2	$0{\cdot}40$**	$0{\cdot}14$	$0{\cdot}20$	210	$3{\cdot}77$***	$0{\cdot}95$	$0{\cdot}27$	200
	Height	$1{\cdot}7\times10^{-4}$*	8×10^{-5}	$0{\cdot}15$	210	$1{\cdot}7\times10^{-3}$***	5×10^{-4}	$0{\cdot}22$	200
	Handgrip	$2{\cdot}5\times10^{-4}$***	6×10^{-5}	$0{\cdot}30$	210	2×10^{-3}***	4×10^{-4}	$0{\cdot}31$	200
	Energy exp.	7×10^{-5}***	1×10^{-5}	$0{\cdot}32$	210	$3{\cdot}8\times10^{-4}$***	$1{\cdot}1\times10^{-4}$	$0{\cdot}25$	199
Women	W/H	$1{\cdot}97$***	$0{\cdot}55$	$0{\cdot}22$	250	$8{\cdot}87$*	$3{\cdot}61$	$0{\cdot}16$	243
	Height	$2{\cdot}3\times10^{-4}$**	7×10^{-5}	$0{\cdot}21$	253	$3{\cdot}3\times10^{-4}$	$4{\cdot}3\times10^{-4}$	$0{\cdot}05$	246
	Handgrip	8×10^{-5}***	2×10^{-5}	$0{\cdot}31$	250	$1{\cdot}55\times10^{-3}$***	$3{\cdot}9\times10^{-4}$	$0{\cdot}25$	246
	Energy exp.	$3{\cdot}5\times10^{-4}$***	6×10^{-5}	$0{\cdot}34$	253	$3{\cdot}6\times10^{-4}$*	$1{\cdot}1\times10^{-4}$	$0{\cdot}21$	243

*$P<0{\cdot}05$
**$P<0{\cdot}01$
***$P<0{\cdot}001$

Table 2. Linear regressions of variables estimating bone mass (corrected for age) on variables associated with body size or activity (corrected for age where appropriate) in men and in women aged 62–90 years.

Five-year follow-up study of bone mass variables

Five-year changes are reported for metacarpal cortical thickness only since it was not possible to repeat the densitometry.

The first comparison of interest is of measurements made at the original examination, separated after 5 years into those who survived and those who died during that period. Mean values were similar in surviving and dead subjects up to the age of 79 years. In men of 80 years and over at entry to the study the mean value in survivors ($0{\cdot}470$ cm SD $0{\cdot}071$, $N=5$) was greater than in survivors in the age group 70–79 years ($0{\cdot}428$ cm SD $0{\cdot}063$, $N=44$) but in dead men of 80 years and over the value ($0{\cdot}421$ cm SD $0{\cdot}060$ $N=14$) was less than in the preceding age group ($0{\cdot}428$ cm SD $0{\cdot}102$, $N=27$). In women the mean value in dead subjects of 80 years and over was less than that of the corresponding age group of survivors. None of these differences reaches statistical significance. Survivors in the age group described above includes all subjects originally examined who were alive five years later, whether they were re-examined or not.

The next comparisons made were of mean values of metacarpal cortical thickness in the decades 70–79 years and 80–90 years at the original examination with mean values from persons who were in these decades five years later. In the original examination mean values were larger in the older ($0{\cdot}434$ cm SD $0{\cdot}014$, $N=19$) compared with the younger men ($0{\cdot}426$ cm SD $0{\cdot}009$, $N=70$). Five years later the mean value in those men then in the 80–90 decade ($0{\cdot}386$ cm SD $0{\cdot}013$, $N=23$) was less than in men then in the 70–79 age group ($0{\cdot}425$ cm SD $0{\cdot}010$, $N=57$). The values for the

70–79 age groups were almost identical in the original examination and in that made five years later. The mean value in the four men in the 85–95 decade at the five-year examination, i.e. in men from the 80–90 decade at the original examination, was 0·430 cm.

None of the differences described is statistically significant but the follow-up study does not support the impression gained from cross-sectional data that the 80–90 decade in men would be expected to contain survivors with greater mean cortical thickness than found in younger men. In women the greater mean value in the 70–79 decade compared with the 80–90 decade at the first examination is also found five years later in the groups who have reached these decades.

Changes occurring in five years in metacarpal cortical thickness were further examined by subtracting, in each subject, the value after five years from that at the original examination. The distributions of the resulting differences in men and in women are given in figure 2. A positive value means a decrease in metacarpal thickness during the five years and vice versa. The figure shows that in 67 per cent of the men and in 70 per cent of the women there was either no difference or a decrease in cortical thickness over five years. In the remainder the study shows an increase.

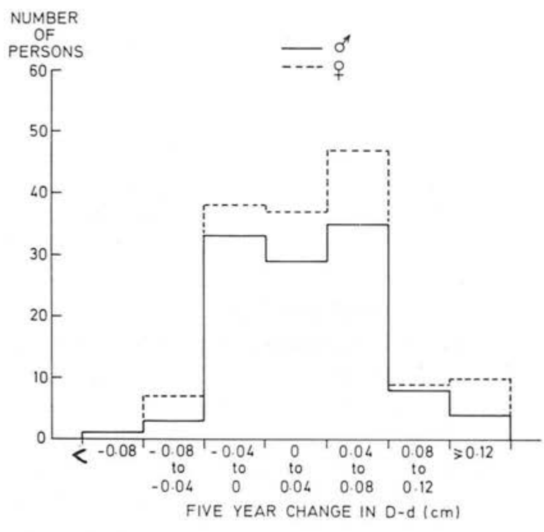

Figure 2. Distribution of five year changes in metacarpal cortical thickness in older men and women.

These data were further examined by the linear regression of the five-year differences in cortical thickness on age in men and in women. The coefficients of regression did not differ significantly from zero. The mean values of the differences are therefore reported without separation into age groups the values being 0·027 cm in men (SD 0·041, $N=111$) and 0·028 cm in women (SD 0·040, $N=141$). There was therefore no significant sex difference in loss of bone during the five years. The mean values of the differences differ significantly from zero ($P<0\cdot001$).

Regression techniques showed no relationship between five year differences in metacarpal cortical thickness and values obtained at the first examination for body size or for dietary intakes of calcium or vitamin D. There was a significant association between the five year difference in cortical thickness and the cortical thickness at the first examination ($r=0\cdot25$ in men, $0\cdot37$ in women, $P<0\cdot01$), suggesting that loss of metacarpal bone over five years was greater in subjects whose original cortical thickness was greater.

4. Discussion

Moderate correlations have been reported between densitometric and cortical thickness measurements. Anderson, Shimmins and Smith (1966) reported $r=0\cdot61$ and Garn *et al.* (1966 b) $r=0\cdot6$. Correlations in the present study in much larger samples were $r=0\cdot45$ in men and $r=0\cdot52$ in women. These latter coefficients correlate metacarpal cortical thickness with density of the radius whereas those of the other authors apply to the measurements on the same bone. Meema and Meema (1969) have offered a hypothesis in which increased porosity of cortical bone precedes a reduction in cortical thickness. This would reduce the correlation between densitometric data and cortical thickness.

Metacarpal cortical thickness has been reported in the present study rather than more complicated indices because of the work of Morgan (1973), who showed that cortical thickness was the most sensitive of the indices examined by him in the detection of persons with a diminished amount of metacarpal cortex. In assessing the amount of bone in the shaft of a metacarpal the best indices were cortical thickness and the calculated cross-sectional area of bone corrected to a standard size of bone. Since these two variables give identical information, the simpler has been used in the present paper. Virtama and Mahönen (1960) showed a good correlation between cortical thickness and mineral analysis of the same bone ($r=0\cdot71$).

It is generally agreed that metacarpal cortical thickness is reduced in older people of both sexes (Barnett and Nordin, 1961; Garn, Rohmann, Pao and Hull, 1966 a; Garn, Rohmann and Wagner, 1967; Exton-Smith, Millard, Payne and Wheeler, 1969 b; Nordin, 1971) and that at all ages men tend to have thicker cortices than women (Garn, 1963). With both of these the present study agrees. Absolute figures given by Morgan, Spiers, Pulvertaft and Fourman (1967) and Garn (1963) agree reasonably well with those in the present study.

Exton-Smith *et al.* (1969 a) found in men that the curve of bone loss flattened off over 70 years of age and rose again in the eighties. Cross-sectional data in the present study agree in that in men the mean value of cortical thickness in the decade 80–90 years is greater than that in the decade 70–79 years. Garn *et al.* (1967) reported similar figures from Guatemala but their results from Ohio and from El Salvador show smaller mean values in the older men.

Longitudinal data in the present study show that, after 5 years, men then in the decade 80–90 years have mean cortical thickness less than men in the decade 70–79 years. At the same 5 year examination the four men then in the 85–95 decade still had a mean value greater than the 70–79 or 80–90 decades.

Exton-Smith *et al.* (1969 a) interpreted the cross-sectional increase in cortical thickness in men in their eighties as suggesting the emergence of a biological élite, one of whose characteristics would be a skeleton containing more bone than average in old age. The present follow-up data do not confirm this and the high mean value in the oldest men in the present study could well be an accident of sampling. Results in this matter from the present study are not conclusive since it is based on a simple random sample. As time has passed the sample has come to contain too few of the oldest people to obtain statistically significant differences. The problem could have been better studied with a random sample suitably stratified for age.

Newton-John and Morgan (1968) and Morgan *et al.* (1967) reported that the variance of metacarpal cortical thickness in cross-sectional study remained constant at different ages. This was interpreted as meaning that all persons lose bone with ageing and that all lose much the same amount however much or little they had to start with. Adams, Davies and Sweetman (1970) and Garn *et al.* (1966 a) have shown by longitudinal study that although a majority followed the pattern of loss with age, some persons did not lose bone at all in the period of the study or even gained some. The present study agrees with these findings. It is clear therefore that bone loss with increasing age is not a uniform phenomenon.

Actual mean losses reported by Adams *et al.* were 0·47 mm in men and 0·62 mm in women in eleven years, but these did not differ significantly in the sexes. Garn *et al.* (1967) estimated the mean loss at 0·25 mm per decade. Losses in the present study would if extrapolated to a decade give figures of 0·54 mm in men and 0·56 mm in women. The sensitivity of the method was shown by Garn *et al.* (1967) in a careful study which demonstrated measurable losses of bone after one year.

The present study has shown an association between estimates of bone mass and body size or activity, especially bulk indices, hand-grip and energy expenditure. The larger the value of any of the latter three variables, the greater is the cortical thickness. Exton-Smith *et al.* (1969 a) recognized the importance of body size when they divided cortical area by the product of metacarpal diameter and metacarpal length. Chalmers and Ho (1970) suggest that the prevalence of osteoporosis has increased because fewer people now work hard physically than formerly. This is in keeping with the positive correlation in the present study between cortical thickness and energy expenditure.

There was no relationship in the present study between changes in cortical thickness and body size or activity. Adams *et al.* (1970) found no association between 11 year changes and weight or height. There was also no evidence in the present study that taller subjects lost less bone as age increased as described by Garn *et al.* (1967). The present study confirms the finding of Adams *et al.* (1970) that cortical thickness has no prognostic value in respect of mortality.

No association was demonstrable in the present study between dietary intakes of calcium or vitamin D and cortical thickness. This absence of association has been previously reported (Exton-Smith, Hodkinson and Stanton, 1966; Garn *et al.*, 1967). Indeed, Garn *et al.* showed that intake as high as 1500 mg calcium daily did not prevent the development of osteoporosis.

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Zusammenfassung. Bei einer einfachen Stichprobe älterer Menschen aus Edinburgh (215 Männer und 272 Frauen im Alter von 62 bis 90 Jahren) wurde die Knochenmasse bestimmt durch Messung der Cortexdicke der Mittelhand und der optischen Dichte des Radius im Vergleich mit einem Metallkeil auf Röntgenaufnahmen. Es wurden weiterhin Informationen gesammelt über Ernährung, Energieverbrauch und Anthropometrie. Die beiden Schätzwerte der Knochenmasse waren mäßig miteinander korreliert (0,47 bei Männern und 0,53 bei Frauen). Beide zeigen eine Abnahme mit zunehmendem Alter. Die Schätzwerte nahmen zu mit Zunahme der Körpergröße und der Aktivität, waren jedoch ohne Bezug zur Aufnahme von Kalzium oder Vitamin D mit der Nahrung.

Fünf Jahre später wurde die Kortexdicke noch einmal bei 111 Männern und 141 Frauen gemessen. Der Verlust an Knochensubstanz war nicht gleichförmig, einige Probanden zeigten sogar eine Zunahme. Der mittlere Verlust betrug 0,27 mm (SD=0,41) bei Männern und 0,28 (SD=0,40) bei Frauen. Diese Abnahme war ohne Bezug zu Körpergröße oder Aufnahme von Kalzium und Vitamin D.

Résumé. La masse osseuse a été estimée dans un échantillon au hasard de vieillards d'Edinburgh (215 hommes et 272 femmes agés de 62 à 90 ans) à partir de la mesure de l'épaisseur corticale du métacarpe et de la mesure de la densité optique du radius par comparaison avec celle d'une barre métallique sur radiographie. Des données ont aussi été recueillies sur le régime alimentaire, la dépense d'énergie et des variables anthropométriques. Les deux estimations de masse osseuse étaient modérément corrélées (0,47 chez l'homme, 0,53 chez la femme). Toutes deux montraient une décroissance avec l'âge croissant. Les estimations de la masse osseuse croissaient avec le format corporel et l'activité, mais étaient indépendantes de l'absorption alimentaire de calcium ou de vitamine D.

Cinq ans plus tard, l'épaisseur corticale a été remesurée chez 111 hommes et 141 femmes. La perte osseuse n'était pas uniforme; en fait, certains sujets montraient un gain. La perte moyenne était de 0,27 mm (écart-type 0,41) chez l'homme et de 0,28 mm (écart-type 0,40) chez la femme. Cette perte était indépendante du format corporel et de l'absorption de calcium et de vitamine D.

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Bone mass in men with Klinefelter's syndrome and in normal subjects, estimated by the cortical thickness of bone

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Metacarpal cortical thickness has been measured in a sample of 47,XXY men and two control samples of 46,XY men and 46,XX women in the age range 20–70. The results suggest that in this age range cortical thickness in 47,XXY men is more similar to that of normal women than normal men.

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Men with Klinefelter's syndrome have some anthropometric characteristics which resemble those of 46,XX women (Stewart et al. 1959, Milne et al. 1974). In view of the known differences between men and women in respect of cortical thickness of bone, it was decided to measure this variable in men with Klinefelter's syndrome and in normal men and women.

Material and Methods

Men with 47,XXY karyotype were drawn from the Registry of Abnormal Karyotypes in the MRC Clinical and Population Cytogenetics Unit in Edinburgh. Their registry numbers are given in an appendix to this paper. Fifty-one 47,XXY men were available for radiographic examination. These men had been ascertained in endocrine or sub-fertility clinics (22), in general hospitals (13), in mental hospitals (14), in penal institutions (2) (see Table 2). They therefore form an available but not a random sample of 47,XXY men.

Persons of known 46,XY or 46,XX constitution were obtained as respondents from two stratified random samples drawn from a group practice in north-east Edinburgh. The stratification in both cases was by 5-year age-groups from 20–25, up to 56–60, with equal numbers in each group. There were 101 men and 70 women in the age range 20–60 years who were karyotyped at the time of examination. Further simple random samples of older persons from 50 practices in the same area consisted of 30 men and 30 women aged 60–70 years and presumed to be of 46,XY or 46,XX constitution.

Each person had a postero-anterior radiograph of the right hand exposed at a tube-film distance of 112 cm. Measurements were made on the films with an engineer's vernier

Table 1

Reliability of measurements of metacarpal cortical thickness using parametric and non-parametric tests

Observation	Mean difference (cm)	S.E. of mean difference	Significance level	
			"t" test	Wilcoxon test
Same film on 2 occasions	0.015	0.019	>0.05	>0.05
Different films on 2 occasions	0.0013	0.011	>0.05	>0.05

caliper. The mid-point of the right second metacarpal bone was determined. At this point the diameter of the bone (D) and of the medullary cavity (d) were measured. Metacarpal cortical thickness was obtained by subtracting these readings (D–d). The main difficulty in these measurements is that the inner margin of the bone cortex is not always sharp. This margin is easier to distinguish if a jeweller's magnifying eye piece is used. All measurements were made by one observer (J.S.M.).

Reliability

Reliability was studied by exposing films, in eight persons, as described above. The metacarpal thickness was measured on each film on two occasions by the same observer. Further films were exposed on a second occasion in the same eight persons. These films were measured once by the same observer. These data allowed the study of the reliability of the same observer on the same film on two occasions and, in the same subjects, on different films on two occasions.

Each set of paired data was examined using both parametric and non-parametric methods. First, the mean difference was calculated and the "t" test used to determine whether that difference differed significantly from zero. Secondly, the differences between the paired measurements were examined with the Wilcoxon test for paired observations. None of the tests showed significant differences either between occasions on the same films with one observer or between different films of the same people with one observer. The results are summarised in Table 1.

Analysis and Results

Table 2 gives the ages, cortical thickness, and mode of ascertainment for each of the 47,XXY males. Where comparisons are possible there are no detectable differences between the groups by ascertainment apart from those due to age effects.

Mean values with standard deviations and the numbers from whom these statistics are derived are given by decade for each group of subjects in Table 3. Figure 1 displays these mean values $\pm$ 2 standard errors. The increased mean and standard deviation in 47,XXY males aged 30–39 is due to the outlying value of 0.8 for cortical thickness (see Table 2). These results show that in all groups ageing effects, in the shape of diminution of cortical thickness, are detectable from the 40–49 decade onwards. The onset of age effects in this decade has led to further analysis in two overlapping age ranges, i.e. 20–50 and 40–70 years. This has been done because the exact age at which age effects are first detectable cannot be determined.

Linear regressions of metacarpal cortical thickness on age for each group (46,XX, 46,XY and 47,XXY) in the 20–50 and 40–70 age ranges confirm the findings described above (Table 4). There are no detectable ageing effects in the 20–50 age range in any group. A significant diminution of cortical thickness with increasing age is present in the 40–70 age range in each group. The slopes of the regression lines

Table 2

Metacarpal cortical thickness in the 47,XXY males by age and mode of ascertainment

Ascertainment	*1*		*2*		*3*		*4*	
	Age	C.T.	Age	C.T.	Age	C.T.	Age	C.T.
	22	0.54						
	23	0.45						
	24	0.49	20	0.52			20	0.51
	24	0.51						
	25	0.57			26	0.47		
	26	0.48			29	0.52		
	29	0.5						
	30	0.6			31	0.58		
	34	0.53			32	0.53		
	36	0.8						
	37	0.54			37	0.43		
	38	0.51						
	39	0.63					39	0.46
					40	0.37		
	41	0.47						
	43	0.49						
	43	0.61			44	0.47		
	45	0.51						
	47	0.35						
	49	0.51						
	50	0.49	50	0.47	50	0.48		
	50	0.47	50	0.48	56	0.35		
	51	0.55	51	0.43	58	0.39		
			53	0.51				
			55	0.51				
			55	0.42				
			57	0.4				
			58	0.4				
			59	0.45				
			60	0.52	60	0.46		
			61	0.44	63	0.45		
			67	0.37	65	0.33		
			67	0.33				

1 Endocrine and subfertility clinics.
2 Mental institutions.
3 General hospital.
4 Penal and maximum security institutions.

C.T. = Metacarpal cortical thickness.

do not differ significantly in this age range amongst the three groups.

Mean metacarpal cortical thickness is smaller in 46,XX women compared with 46,XY men over most of the 20–70 age range. This is particularly obvious in older women.

The graphs in Fig. 2 display the regressions of metacarpal cortical thickness on age in the 40–70 age range for each group, with standard normal 95 % confidence limits for the mean at each age. The intersections of the regions defined by the 95 % limits show that the 47,XXY men resemble 46,XX women rather than 46,XY men in respect of cortical thickness in this age range.

If the data in the 20–39 year age range are compared between groups, the mean cortical thickness in 47,XXY males is found to be significantly less than that in 46,XY males (t-test, $P < 0.01$), while no significant difference is found between 47,XXY males and 46,XX females. This suggests that 47,XXY males resemble 46,XX females in the 20– to 39–year age range also. A direct comparison of values between groups in this case seems reasonable due to the absence of detectable age effects in this age range.

Discussion

The method used to examine bone mass is a standard one which has been widely used by other workers (Barnett & Nordin 1961, Exton-Smith et al. 1969a, Garn et al. 1966). Although cortical thickness is the primary measurement, some workers have used indices based on cortical thickness modified by diameter, length, or cross-sectional area of the bone to describe their findings. (Barnett & Nordin 1961, Exton-Smith et al. 1969a, 1969b, Garn et al. 1966). These indices behave statistically in a manner similar to the cortical thickness which is the simplest to compute.

Measurements of cortical thickness were found in the present study to have satisfactory reproducibility; this agrees with previous authors' findings (Naor et al. 1972). There is good correlation between cortical thickness measurements of hand bones and the ash content of these bones determined

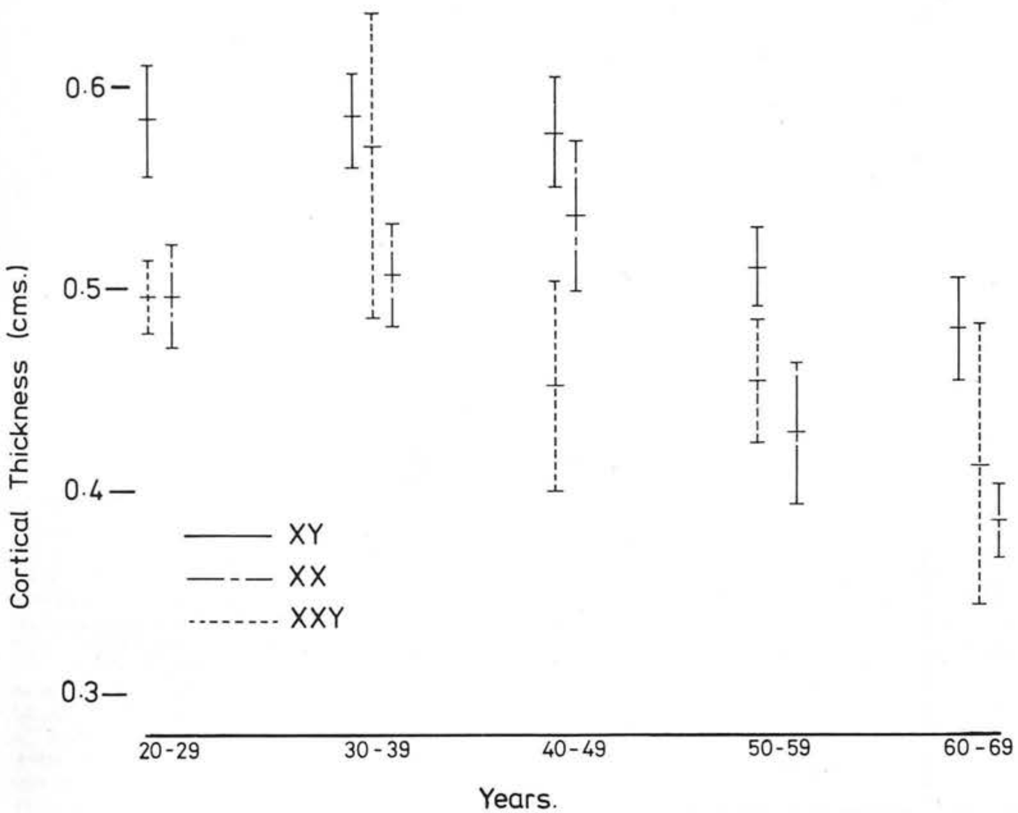

Fig. 1. Mean values by decade for cortical thickness in the three groups. The error bars are two standard errors, either side of the mean values.

after death (Exton-Smith et al. 1969a, Virtama & Mahonen 1960).

Cross-sectional studies have reported decrease in cortical thickness with increasing age, the apparent loss being greater in women (Exton-Smith et al. 1969b, Garn et al. 1967, Milne 1973, Nordin 1971). Although mean values of cortical bone thickness decrease with increasing age in the older population, the variance remains much the same. This suggests that all persons in both sexes lose bone at much the same rate (Newton-John & Morgan 1968). This is only partly confirmed by longitudinal study, which has shown that in some subjects bone loss does not occur with increasing age (Adams et al. 1970, Garn et al. 1966). The present study confirms the apparent loss in both sexes with age, from the fifth decade onwards. In addition, the analysis made above suggests that in respect of cortical bone thickness 47,XXY men resemble 46,XX women rather than 46,XY men–certainly during later life and probably in early adult life as well.

Although a number of the 47,XXY men measured in this study were hospital patients, almost all were ambulant and not bed-ridden. Prolonged bed rest is therefore an unlikely explanation of the thinner bone

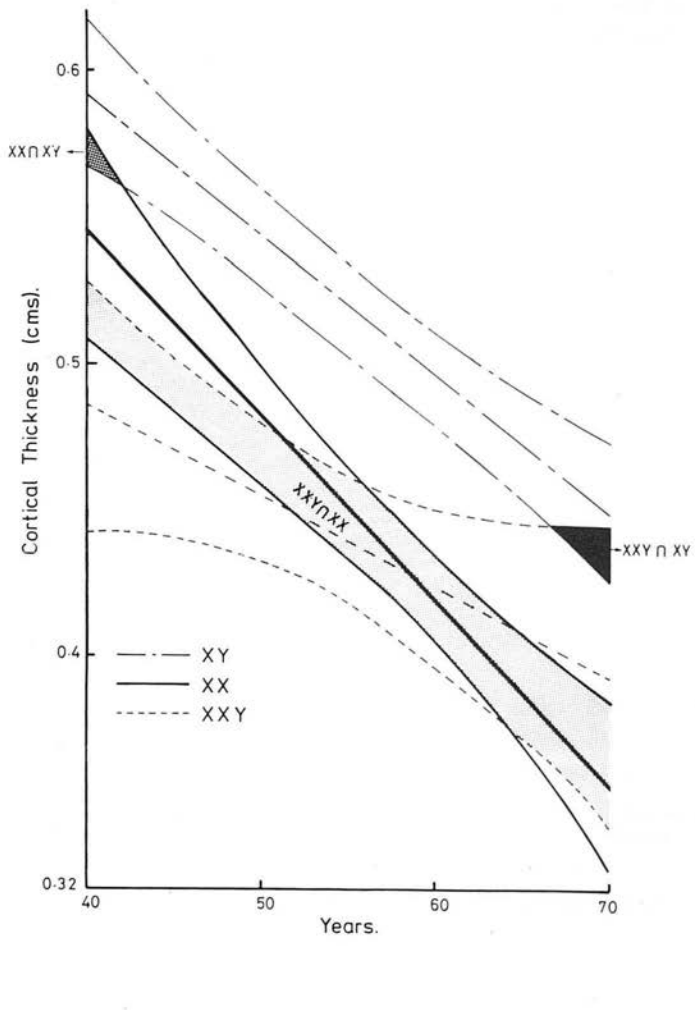

Fig. 2. Linear regressions of cortical thickness on age in the range 40–70 years for the three groups. The two curved lines on either side of each of the three regression lines are 95 % confidence limits for the mean cortical thickness. XXY ∩ XX = intersection of the confidence region for the mean cortical thickness in Klinefelter's with the corresponding region for cortical thickness in normal females. Similar definitions apply to XXY ∩ XY and XX ∩ XY.

Table 3

Mean values with standard deviations (S.D.) by decade of metacarpal cortical thickness (cm) in 46,XY men, 47,XXY men and 46,XX women

Age range	46,XY Men			47,XXY Men			46,XX Women		
	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N
20–29	0.584	0.056	23	0.496	0.027	11	0.496	0.049	18
30–39	0.583	0.055	24	0.561	0.103*	10	0.507	0.051	19
40–49	0.577	0.067	27	0.452	0.061	8	0.536	0.068	16
50–59	0.511	0.045	27	0.455	0.053	15	0.429	0.068	17
60–70	0.480	0.065	30	0.413	0.074	7	0.385	0.051	30

* Mean value and standard deviation if outlying value of 0.8 omitted are 0.534 and 0.064, respectively.

Table 4

Linear regressions of metacarpal cortical thickness on age in two age ranges in 46,XY men, 47,XXY men and 46,XX women

Karyotype	Age range 20–50 years				Age range 40–70 years			
	Const. (at age 20 years)	Regr. coeff. on age	S.E.	N	Const. (at age 40 years)	Regr. coeff. on age	S.E.	N
46,XY	0.5973	−0.0011	0.0008	74	0.5920	−0.0048	0.0007	86
47,XXY	0.5255	−0.0014	0.0018	29	0.4856	−0.0031	0.0014	30
46,XX	0.4871	0.0017	0.0009	53	0.5446	−0.0063	0.0009	63

cortices found in 47,XXY as compared with 46,XY men. In more general terms, the analysis treats the XXY sample as effectively as a random sample from the XXY population. The different modes of ascertainment and environment encountered in this sample could well influence or induce bias in any variable.

Life-long androgen deficiency is probably a feature of Klinefelter's syndrome (Bartalos & Baramki 1967, Polani 1962, Overzier 1963). Gonadal hormones, particularly androgens, have an anabolic action which stimulates growth of all tissues including bone matrix. A secondary effect is calcification in the matrix, forming normal bone. One factor that might explain the difference in cortical thickness between 46,XY and 47,XXY men could be low androgen output.

The other factor likely to be concerned is the extra X chromosome in 47,XXY men which may, in a manner not understood, produce bones resembling these of 46,XX women rather than 46,XY men. The present study cannot separate the possible contributions of the above two factors to the production of thinner bone cortices as observed here in 47,XXY males. The problem could be resolved to a certain extent by analysing data from a random sample of 47,XXY males from the general population in whom both cortical thickness and androgen output had been measured. Current advances in population karyotyping should eventually make such a study feasible.

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APPENDIX

Registry numbers of 47,XXY men in this study (from the Registry of Abnormal Karyotypes, MRC, Clinical and Population Cytogenetics Unit, Western General Hospital, Edinburgh)

8/62	64/65	114/68
11/65	113/61	238/60
68/71	19/66	7/60
288/70	28/59	51/72
190/71	133/65	114/61
10/62	27/69	10/70
58/65	12/62	269/69
119/66	118/60	224/64
52/62	177/60	165/72
80/65	19/62	31/63
243/60	4/60	77/65
89/61	20/63	129/68
158/70	102/63	286/70
242/70	176/70	92/63
19/72	64/60	46/62
152/66	2/68	3/60
153/65	240/68	
281/70		

30

AGE DIFFERENCES IN THE ANDROGYNY SCORE

BY

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AGE DIFFERENCES IN THE ANDROGYNY SCORE

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It has been suggested that the androgyny score, computed to estimate the degree of femininity of build in the male (Tanner, 1951), diminishes with increasing age (Kelsey, 1965; Henderson and Dugard, 1968). This paper describes age differences in the androgyny score in a cross-sectional study of men and women aged 20-90 years.

METHODS

The sample examined consisted of 413 men and 406 women aged 20-90 years. This sample was obtained in two parts. The first contained 215 men and 272 women aged 62-90 years, who formed a simple random sample of the 27,000 older people living in a defined area of Edinburgh. The method of sampling these subjects, who are taking part in a longitudinal study of ageing persons, has been described elsewhere (Milne, Maule, and Williamson, 1971). The second part was composed of 198 men and 134 women aged 20-65 years, who were donors providing blood at the Regional Blood Transfusion Service in Edinburgh. I attended donor sessions and circulated a leaflet requesting volunteers for anthropometry. More people volunteered than could be measured in the time available. Bias was introduced by the Blood Transfusion Service policy of rejecting donors under 5 feet (1·5 m) in height or 8 stone (50·8 kg) in weight. This sample, although not random, is from the population living in Edinburgh. The distribution of Landsteiner blood groups in the samples of older people and of blood donors, who were measured, did not differ significantly from that published for Edinburgh (Kopéc, 1970). In this respect, therefore, the samples do not differ from the population of Edinburgh. The age distribution of the combined samples of older people and blood donors is given in Table I.

Measurements of biacromial (BAD) and bi-iliac (BID) diameters were made from behind with the subjects standing, using the Harpenden anthropometer (Tanner and Whitehouse, 1957). Care was taken that the shoulders were in a relaxed position when measuring BAD, and that firm pressure was exerted with the branches of the anthropometer when measuring BID. The right suprailiac skinfold thickness was measured using the Harpenden caliper as described by Tanner (1959).

TABLE I

AGE AND SEX DISTRIBUTION OF SAMPLE

Age Range	Men	Women
20-24	33	37
25-29	33	19
30-34	28	18
35-39	30	7
40-44	15	11
45-49	17	11
50-54	20	13
55-59	12	8
60-64	55	51
65-69	77	96
70-74	39	56
75-79	34	45
⩾ 80	20	34
Total	413	406

The androgyny score was calculated as 3 × BAD minus 1 × BID (Tanner, 1951). Since the diameters were measured in millimetres, the androgyny score is 10 times the figure as originally described by Tanner.

RELIABILITY

This was studied by measuring the same 12 subjects on two occasions. A reliability coefficient was calculated, using the analysis of variance, by dividing the variance for persons by the sum of the variances due to persons, occasions, and error. Variance due to error was the residual mean square after removing variance due to persons and occasions. Coefficients for the author's variance determined in this way before and after the survey are given in Table II.

TABLE II

INTRA-OBSERVER AND INTER-OBSERVER RELIABILITY STUDIES

	Reliability Coefficients			Number of Subjects
	Biacromial Diameter	Bi-iliac Diameter	Suprailiac Skinfold	
One observer				
Before survey	0·98	0·85	0·98	12
After survey	0·98	0·96	0·93	12
Two observers	0·86	0·88	—	12

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An inter-observer study was carried out by the author and another observer measuring another 12 subjects on one occasion. Measurements were made so that one observer did not see the other at work. The coefficient was calculated with variance due to observers substituted for variance due to occasions. The results of this study (BAD and BID only) are also shown in Table II.

In the analysis of variance, the contributions to the total variance made by persons and occasions were examined using the F test. In all variables in the inter-observer and intra-observer studies the ratio of mean square for persons to mean square for error was significant at the 1% level. The corresponding ratio for occasions was significant only for bi-iliac diameter in 1970 and that just reached the 5% level. With this exception the principal contributor to the total variance was persons, and the observations can be accepted as reproducible.

Results

Frequency distributions of androgyny score, BAD, and BID are given by decade for men and women separately in Figures 1, 2, and 3. For ease of comparison the values used are percentages. The modal value of androgyny score and BAD in both sexes decreases in persons of 60 years and over, while the modal value of BID is greater in older people.

Mean values of the three variables with standard deviations and standard errors are given in five-year age groups in Table III. Inspection suggests little change in androgyny score or BAD in the age range from 20 to the fifties. Women thereafter show a gradual diminution in mean values up to old age but men have a sharp fall in mean values from the fifties to the mid-seventies and thereafter the fall levels off. The mean values of BID in both sexes increase gradually from 20 years of age to the fifties, after which the values seem relatively constant.

These age differences have been described using linear regressions. For each of the three variables, in women, two regression lines have been computed, one from 20 to 49 years and the other from 50 years to old age. In men, similar lines have been used for the regression of BID on age, but for androgyny score and BAD three lines were used covering age ranges 20-59, 55-74, and 70-≥80 years. The age ranges

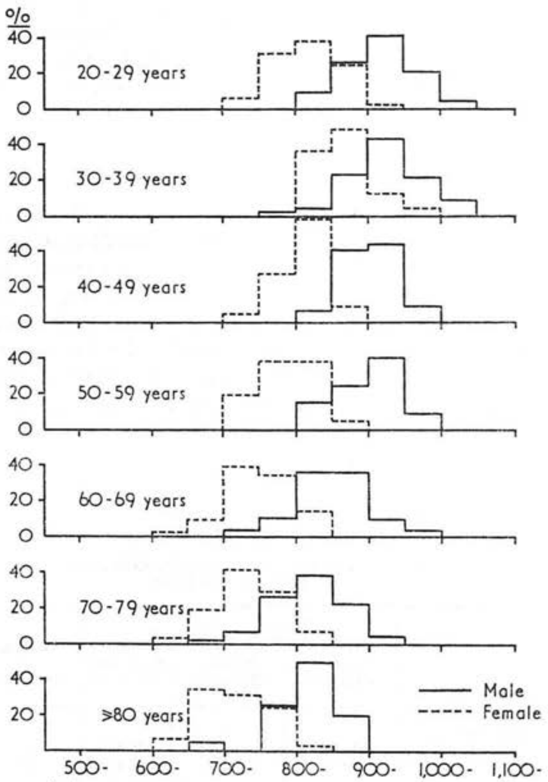

FIG. 1. Frequency distribution of androgyny score (percentages) by decade in men and women.

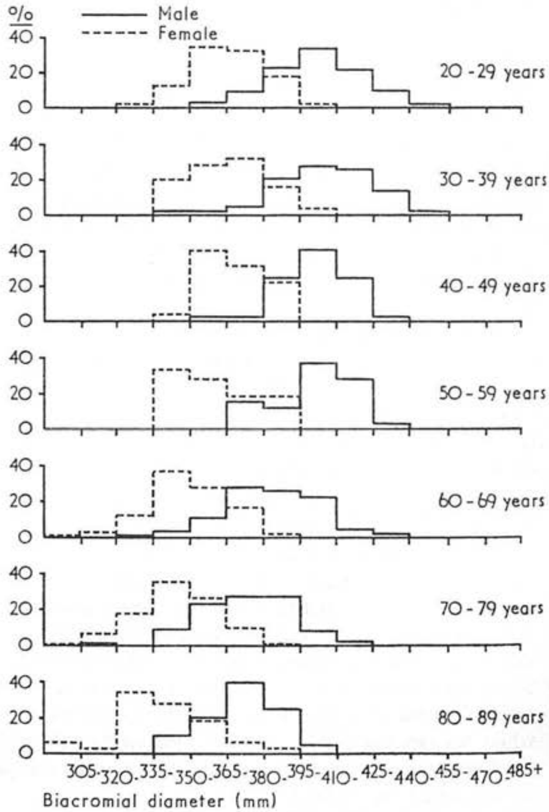

FIG. 2. Frequency distribution (percentages) of biacromial diameter by decade in men and women.

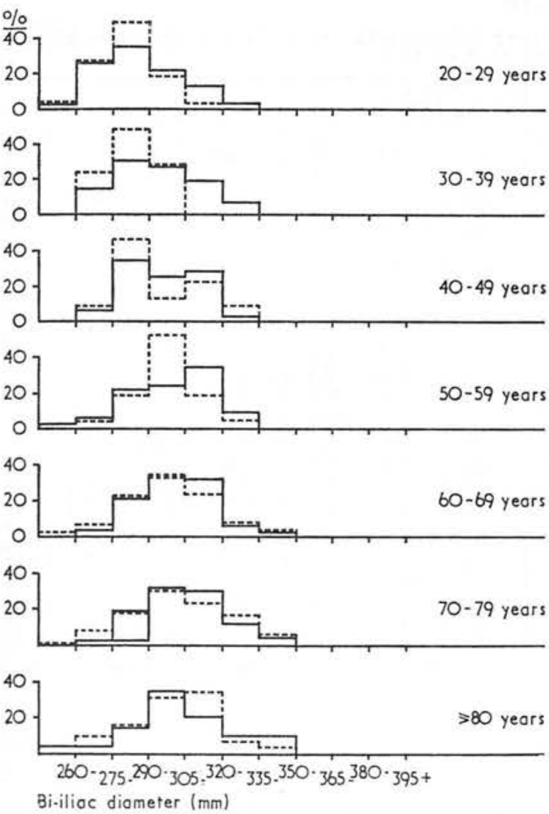

FIG. 3. Frequency distribution (percentages) of bi-iliac diameter by decade in men and women.

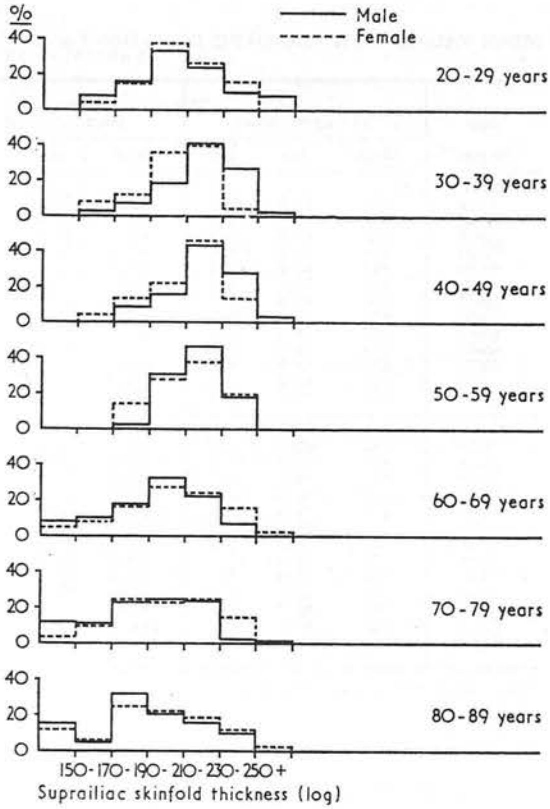

FIG. 4. Frequency distribution (percentages) of right suprailiac skinfold thickness (log transformation) in men and women.

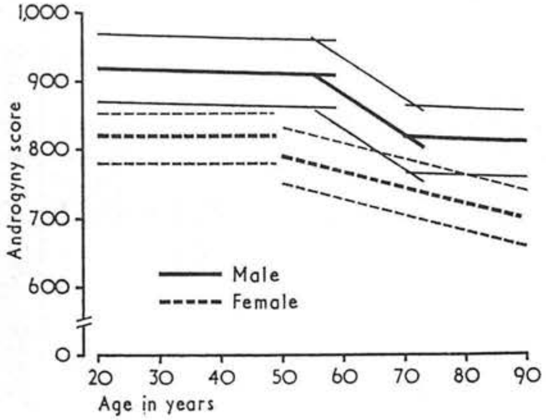

FIG. 5. Regression of androgyny score on age in men and women (± 1 standard error).

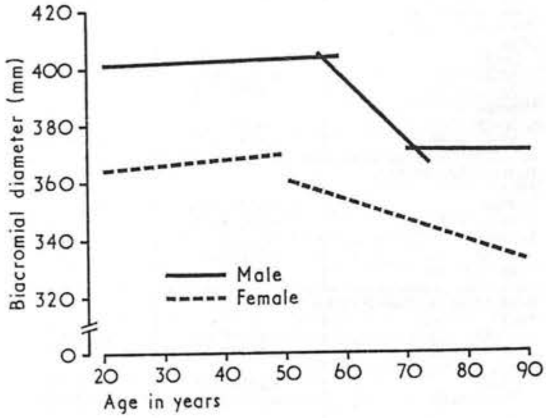

FIG. 6. Regression of biacromial diameter on age in men and women.

TABLE III

MEAN VALUES WITH STANDARD DEVIATIONS AND STANDARD ERRORS FOR ANDROGYNY SCORE AND RELATED VARIABLES IN MEN AND WOMEN

Age	Androgyny Score			Biacromial Diameter (mm)			Bi-iliac Diameter (mm)			Suprailiac Skinfold (log)			
Range	Mean	SD	SE	Mean	SD	SE	Mean	SD	SE	Mean	SD	SE	N
Men													
20-24	908	52·3	9·1	397·9	20·5	3·6	285·5	23·4	4·1	203	25·7	4·5	33
25-29	927	41·1	7·2	404·7	16·2	2·8	286·5	23·9	4·2	209	23·2	4·0	33
30-34	928	47·4	9·0	406·5	18·3	3·5	291·3	16·2	3·1	216	21·8	4·1	28
35-39	916	54·1	9·9	403·2	20·6	3·8	293·2	17·0	3·1	220	18·4	3·4	30
40-44	892	40·6	10·5	396·9	18·1	4·7	298·5	31·2	8·1	214	21·3	5·5	15
45-49	916	35·4	8·6	404·9	12·7	3·1	299·1	17·5	4·2	224	16·7	4·0	17
50-54	906	49·4	11·1	400·2	17·4	3·9	294·5	17·2	3·9	212	14·2	3·2	20
55-59	922	83·4	24·1	408·5	27·7	8·0	303·4	16·5	4·8	224	12·8	3·7	12
60-64	857	48·5	6·6	386·2	18·9	2·6	301·5	16·1	2·2	193	30·0	4·1	54
65-69	843	53·1	6·1	380·9	19·6	2·2	299·6	14·3	1·6	195	30·2	3·4	77
70-74	815	54·9	8·9	371·5	19·6	3·2	299·1	13·4	2·2	183	30·5	4·9	38
75-79	815	45·2	7·8	374·1	18·6	3·2	307·3	19·5	3·3	196	29·5	5·1	34
⩾ 80	811	43·5	9·7	371·1	15·3	3·4	302·8	21·9	4·9	188	32·8	7·5	20
Women													
20-24	818	40·4	6·6	365·4	14·6	2·4	278·4	12·9	2·1	207	19·1	3·1	37
25-29	815	44·4	10·2	367·0	16·1	3·7	285·5	16·6	3·8	206	23·8	5·5	19
30-34	817	39·1	9·2	366·3	15·9	3·8	282·5	12·1	2·8	204	22·4	5·3	18
35-39	812	38·0	14·4	362·9	14·0	5·3	276·7	10·8	4·1	200	25·7	9·7	7
40-44	813	38·6	11·6	369·4	16·3	4·9	294·6	14·6	4·4	210	22·5	6·8	11
45-49	816	29·7	9·0	369·6	9·9	3·0	292·8	20·1	6·1	209	16·9	5·1	11
50-54	801	41·9	11·6	367·1	15·2	4·2	300·5	12·3	3·4	212	17·4	4·8	13
55-59	778	39·0	13·8	355·5	13·3	4·7	289·0	14·9	5·3	213	21·6	7·6	8
60-64	756	36·0	5·1	351·4	13·5	1·9	298·6	17·6	2·5	202	26·3	3·7	51
65-69	743	42·6	4·4	347·1	16·9	1·8	298·2	19·7	2·0	201	32·4	3·3	94
70-74	735	40·8	5·5	346·3	14·8	2·0	303·7	18·7	2·5	203	26·0	3·5	55
75-79	726	49·7	7·5	342·0	19·3	2·9	300·1	19·2	2·9	195	27·4	4·1	44
⩾ 80	716	48·2	8·5	338·7	18·8	3·3	300·5	17·6	3·1	194	31·1	5·5	32

Data missing in 2 men and 6 women

TABLE IV

REGRESSIONS OF ANDROGYNY SCORE AND RELATED VARIABLES ON AGE IN MEN AND WOMEN

Sex and Age Range	Constant	Regression Coefficient (age)	S.E.E. Regression Coefficient	SE of Regression	Mean of Dependent Variable	Mean Age	N
ANDROGYNY SCORE							
Men							
20-59	+925·3325	—0·2605	0·3360	50·4	916	36·0	188
55-74	+1236·6282	—5·9085**	0·9695	54·4	847	66·0	181
70 — ⩾ 80	+844·2635	—0·3956	1·0326	48·9	814	76·1	92
Women							
20-49	+817·6824	—0·0556	0·4450	38·9	816	30·3	103
50 — ⩾ 80	+898·0156	—2·2435**	0·3127	42·8	742	69·7	297
BIACROMIAL DIAMETER							
Men							
20-59	+400·1670	+0·0701	0·1262	18·9	402·7	36·0	188
55-74	+517·9582	—2·0550**	0·3543	19·9	382·4	66·0	181
70 — ⩾ 80	+375·0335	—0·0351	0·3861	18·3	372·4	76·1	92
Women							
20-49	+361·7358	+0·1581	0·1673	14·6	366·5	30·3	103
50 — ⩾ 80	+395·9972	—0·7014**	0·1199	16·4	347·1	69·7	297
BI-ILIAC DIAMETER							
Men							
20-49	+270·9997	+0·6153**	0·2070	21·3	291·0	32·4	156
50 — ⩾ 80	+285·4072	+0·2303	0·1256	16·3	301·0	67·7	255
Women							
20-49	+267·5252	+0·5298**	0·1681	14·7	283·6	30·3	103
50 — ⩾ 80	+289·9760	+0·1393	0·1350	18·5	299·7	69·7	297
SUPRAILIAC SKINFOLD (LOG)							
Men							
20-49	+195·0661	+0·5085*	0·2169	22·3	212	32·4	156
50 — ⩾ 80	+243·7765	—0·7585**	0·2277	29·5	- 192	67·6	255
Women							
20-49	+201·2777	+0·1317	0·2419	21·1	205	30·3	103
50 — ⩾ 80	+235·3916	—0·5016*	0·1987	27·2	200	69·7	298

* $P < 0{\cdot}05$
** $P < 0{\cdot}01$

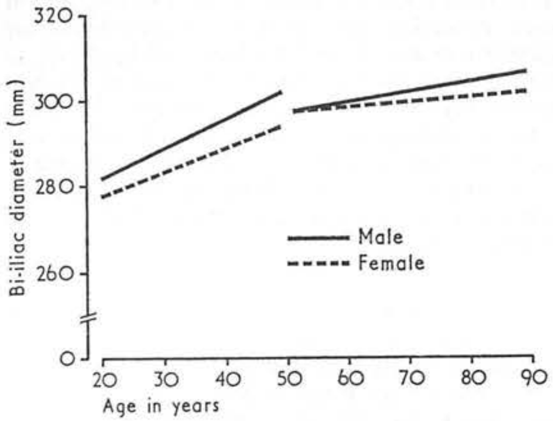

FIG. 7. Regression of bi-iliac diameter on age in men and women.

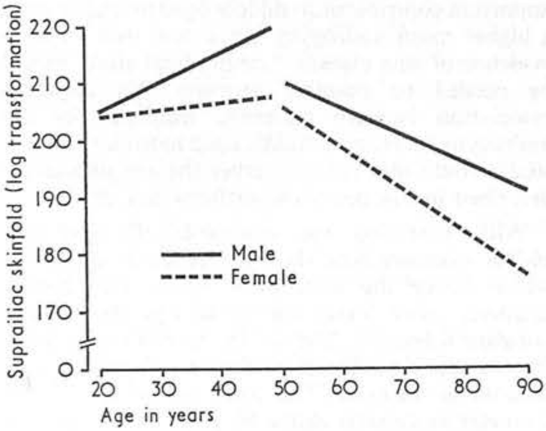

FIG. 8. Regression of right suprailiac skinfold thickness (log transformation) on age in men and women.

used in the regression of these dependent variables on age were selected by examining the table of five-year means (Table III) to discover the age ranges with the greatest and least variation for each dependent variable.

The regressions of androgyny score, BAD, and BID on age are given in Table IV and in Figures 5, 6, and 7. For androgyny score and BAD in women, the regression coefficients for age are significant in the age range 50 to old age but not in the age range 20-49. In men these coefficients are significant in the range 55-74 years but not in age ranges 20-59 and 70 to old age. In men and women the regression coefficient for age in respect of BID is significant in the age range 20-49 but not in older people.

The fall in BAD and the rise in BID with increasing age both tend to lower the androgyny score. The rise in BID with age might be due to increasing obesity. This possibility was investigated by measuring the right suprailiac skinfold thickness. Five-year means of the log transformation of this variable (Edwards *et al.*, 1955) are reported in Table III and its regression on age in Table IV for age ranges 20-49 and 50 to old age (Figure 8). This analysis reveals an increase in the skinfold thickness with increasing age in men, but not in women, up to age 50. Thereafter in both sexes the fall with increasing age is significant. At ages when the androgyny score is falling in value and the BID appears constant, the suprailiac skinfold thickness is also decreasing (Figure 8).

DISCUSSION

This cross-sectional study confirms that there is an age difference in the androgyny score, the decrease in both sexes beginning in the fifties. A sex difference is also present in that the score in women continues to fall up to old age, while in men a steep fall in the years 55-74 levels off in old age. Because the study is cross-sectional, the differences found are likely to have been greatly influenced by the effects of mortality. The mortality rates for 1969 in Scotland for men aged 55-64 and 65-74 are respectively 24·7 and 59·2 per 1,000, the corresponding figures in women being 12·9 and 32·9 (Registrar General for Scotland, 1971). It is possible that an association between this greater mortality, in men compared with women, and the androgyny score in these age groups explains the steep fall, found in men only, in the regression of androgyny on age from 55-74 years. Figure 5 shows that the men who survive this period tend towards 'femaleness' as measured by the androgyny score. Greater 'maleness' as measured by this score may militate against survival in middle age.

Some support is given to this hypothesis by the author's unpublished data concerning men, in the present study, aged 62–74 years. These men form part of the sample being studied longitudinally and have had a full clinical examination including electrocardiography. No comparable information is available about men younger than 62 who were blood donors not studied in such detail. The men aged 62-74 can be divided into those with probable and possible ischaemic heart disease, as defined by Reid, Holland, Humerfelt, and Rose (1966), and those with no evidence of such disease. The mean androgyny score in 20 men with probable ischaemic heart disease is 855 (SE 11·3) compared with 836 (SE 5·1) in 106 men with no evidence of such disease. The possible group has a mean value between these figures. Although the confidence limits of these means overlap, possibly because of small sample sizes, the figures suggest that during the age period where the regression line of androgyny on age falls steeply, men with a disease known to be an important contributor to middle-aged mortality have a higher mean androgyny score than men with no evidence of this disease. Longitudinal study would be needed to examine properly this apparent association between maleness, measured by the androgyny score, and middle-aged mortality. Such a study would also show whether the age differences described in this paper overestimate age changes.

With increasing age, biacromial diameter and bi-iliac diameter both show differences in directions which lower the androgyny score. The bi-iliac diameter, after increasing up to age 50, remains constant thereafter. The fall in the androgyny score in older people is therefore due to a decrease in the biacromial diameter. The constancy of the bi-iliac diameter in persons above 50 years of age and the decrease in suprailiac skinfold thickness in this age group suggest that an increase in bi-iliac diameter due to obesity is not an important cause of the lower androgyny scores in older people. Kelsey (1965) showed in the relatives of schizophrenic patients that an increase with age in bi-iliac diameter was not associated with an increase in weight.

Androgyny score has been studied in relation to mental illness (Ray and Coppen, 1959; Kelsey, 1965; Henderson and Dugard, 1968; Price, 1969) and to sexual disorders (Coppen, 1959; Johnston, 1965). Men who were hypogonadal or who had female sex chromatin were found to have decreased biacromial diameters (Raboch, 1957) while women with hirsuties and increased urinary 17-ketosteroid excretion had an increase in this measurement (Ferriman, Thomas, and Purdie, 1957). The findings in respect of age differences in the present study emphasize the need, mentioned by Kelsey, to allow for age when relating any disorder to the androgyny score.

Measurement figures in the present study agree fairly well with control figures given by other authors (Ray and Coppen, 1959; Kelsey, 1965; Johnston, 1965). One large study (Board of Trade, 1957) in women, of anthropometry in relation to clothing sizes, included the biacromial but not the bi-iliac diameter. In women aged 20-54, the BAD was found to be very close to 350 mm. In corresponding five-year age groups this figure is 15-20 mm less than in the present study. The Board of Trade report gives a clear description of how the BAD was measured but does not mention any instruction to make the measurement with the shoulders of the subject relaxed. This difference in technique may explain the difference in results.

The fall in the androgyny score as age increases may result from changes in the shape of the thorax. The anteroposterior diameter of the thorax is known to increase and the transverse diameter to diminish with increasing age. Increase in anteroposterior diameter is associated with increased kyphosis, in turn associated with changes in the shape of vertebral bodies resulting from senile osteoporosis. These vertebral changes begin after 50 years in women and after 60 years in men. The effect of the change in shape of the thorax is to bring the scapulae closer together with a decrease in biacromial diameter and androgyny score.

SUMMARY

The androgyny score was calculated from biacromial and bi-iliac diameters measured in Edinburgh in 413 men and 406 women aged 20-90. The score showed a fall in both sexes beginning in the fifties. The fall was gradual in women and steeper, with later levelling off, in men. The steep fall in men may be associated with increased mortality among those men with greater degrees of maleness as measured by the androgyny score. Reduction in biacromial diameter was the main factor in the fall of the score. Larger bi-iliac diameters in older people were not associated with increased subcutaneous fat.

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Anthropometry in sex chromosome abnormality

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Anthropometric data have been collected from 47,XXY men, 47,XYY men and 47,XXX women and compared with those of 46,XY men and 46,XX women in the population and in mental subnormality hospitals. Although the 47,XYY men were taller and heavier than the 46,XY men, the other measurements of body size were similar when allowance was made for the greater height. On the other hand, 47,XXY men when compared with 46,XY men had a greater mean subischial height but showed significantly smaller mean values for sitting height, span-height ratio, biacromial diameter and androgyny score. Women with an extra X chromosome were taller than mentally subnormal 46,XX women but their height was the same as that of women in the population. Biacromial diameter and androgyny score were, however, smaller in 47,XXX women compared with 46,XX women from the population, but no difference was found comparing these variables in 47,XXX women and mentally subnormal 46,XX women.

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In 1966 Price and his colleagues described anthropometric data in nine men with a 47,XYY karyotype identified by Jacobs and her colleagues in a chromosome survey of the Scottish State Hospital, Carstairs. The measurements were not significantly different from those found in a group of men with normal karyotype which had been matched with the abnormal group in respect of age, category of mental disorder and, as far as possible, body size. Because of the greater height of the XYY men, there remained a significant difference between the groups in respect of this variable. Casey and his colleagues (1973) were also unable to demonstrate anthropometric differences which were significant except for those associated with height and weight.

In this paper anthropometric variables are described in men with an extra Y chromosome and in men and women with an extra X chromosome. These data have been compared with those obtained from men and women of normal karyotype.

In 16 of the 47,XYY men and in one 47,XXY man, height was a factor in ascertainment. Hence this paper does not describe height differences but investigates differences in other anthropometric variables after appropriate correction for height.

Methods

The persons with sex chromosome abnormalities were drawn from the Registry of Abnormal Karyotypes in the M.R.C. Clinical and Population Cytogenetics Unit in Edinburgh. Their registry numbers are given

Table 1

Age distributions of persons with sex chromosome abnormalities and with known or presumed 46,XX and 46,XY constitution

Group	Age (years)							
	10–	20–	30–	40–	50–	60–	70+	Total
47,XXY men	3	13	6	12	10	2	4	50
47,XYY men	4	7	7	3	6	2	–	29
47,XXX women	1	4	4	4	6	5	2	26
Men from general practice	–	22	25	28	27	–	–	102
Mentally subnormal men	9	15	8	5	9	1	–	47
Mentally subnormal women	2	12	10	7	4	10	2	47
Blood donor men (presumed 46,XY)	–	66	58	32	32	–	–	188
Blood donor women (presumed 46,XX)	–	56	25	22	21	–	–	124

in an appendix to this paper and many have already appeared in previous publications. There were 29 men with a 47,XYY karyotype, 50 with a 47,XXY karyotype and 26 women with a 47,XXX karyotype who were available for measurement during the period of the study. The age distributions are given in Table 1. They were originally identified in a number of ways. Almost half of the 47,XYY men in the study were identified in mental hospitals and slightly more than one third were found in penal institutions. Sixteen of these men were found in surveys of men selected because they were tall. Most of the XXY men were found in subfertility clinics or in hospitals, especially mental hospitals. Almost all the XXX women in the present study were identified in mental subnormality hospitals.

There were several sources of persons presumed or known to be of 46,XY or 46,XX constitution. First was a random sample, stratified for age, of 102 men aged 20 to 60 years from a group practice in north-east Edinburgh. Second was a group of 188 men and 124 women aged 20 to 59 years who volunteered for measurements in blood donor sessions at Edinburgh Royal Infirmary. Third was a group of 47 men and 47 women who were patients in an Edinburgh mental subnormality hospital. The age distributions of these various groups are also given in Table 1.

Body weight was measured with a lever balance to the nearest 100 g. When weight was measured outside the M.R.C. Unit in another hospital or in the home of a patient, a spring balance recorded weight to the nearest 500 g. The spring balance was regularly checked against the lever balance, which was itself periodically calibrated by the manufacturers. Stature was measured with a Harpenden stadiometer, the subject having heels, sacrum and dorsal spine touching the column and the head in the Frankfurt plane. Sitting height was measured using a stool 700 mm in height placed against the column of the stadiometer, with the feet of the subject not touching the floor. Subischial height was calculated by subtracting sitting from standing height. Span was measured from behind, either with a modified Harpenden measuring table fixed to the wall or with the Harpenden anthropometer lengthened by extension bars. Body diameters were measured with the anthropometer, care being taken that the shoulder girdle was relaxed when measuring the biacromial diameter and that firm pressure was exerted with the branches of the anthropometer when measuring bi-iliac diameter. The antero-posterior and transverse thoracic diameters were measured with the anthropometer at the level of the seventh dorsal vertebra. Skinfold thickness was measured with the Harpenden skinfold caliper using the method described by Tanner (1959) and was reported as the log transformation advised by Edwards et al. (1955).

Indices calculated from the above measurements were the span-height ratio and the sitting height-subischial height ratio. Weight (W) was corrected for height (H) as W/H^2 in men and W/H in women, these being the appropriate indices (having minimal correlation with height) in Edinburgh (Milne 1973). The thoracic index was calculated as transverse divided by antero-posterior chest diameter. The androgyny score, devised by Tanner in 1951 to estimate masculinity in women and femininity in men, was computed as 3 $\times$ the biacromial diameter minus the bi-iliac diameter. All measurements were made by one observer (J.S.M.).

Reliability

This was studied, for each anthropometric variable, by measuring the same 10 subjects on each of two occasions. A reliability coefficient was calculated for each variable, using the analysis of variance, by dividing the variance for persons by the sum of the variances due to persons, occasions and error. Variance due to error was the residual mean square after removing variance due to persons and occasions. The nearer the coefficient approaches one, the greater the reproducibility of the measurement. Coefficients for the observer's variance determined in this way before the study began are given in Table 2 .

In the analysis of variance, the contributions to the total variance made by persons and occasions were further examined using the F test. For all variables the ratio of the mean square for persons to the mean square for error (F_1) was significant at the 1 % level. The corresponding ratio for occasions (F_2) was significant only for bi-iliac diameter ($P < 0.05$).

With this exception the principal contributor to the total variance was persons and the observations can be accepted as reproducible. Results of the F test are included in Table 2.

Table 2

Reliability coefficients and F tests for anthropometric variables measured in 10 persons on two occasions by one observer

Anthropometric variable	Reliability coefficient	F_1 M.S. persons/ M.S. error d.f. 9,9	F_2 M.S. occasions/ M.S. error d.f. 1,9
Height	0.99	678.1**	2.93
Sitting height	0.99	285.4**	0.02
Span	0.99	379.3**	0.16
Triceps skinfold	0.96	61.3**	4.63
Subscapular skinfold	0.97	67.2**	0.02
Biacromial diameter	0.98	127.9**	1.08
Bi-iliac diameter	0.96	70.0**	5.41*
Transverse chest diameter	0.97	92.6**	3.48
AP chest diameter	0.93	30.1**	1.65

** $P < 0.01$ * $P < 0.05$

Table 3

Mean values with 95 % confidence limits of anthropometric variables in 47,XYY men, in 46,XY men and in 46,XY men with correction for height and weight

	47,XYY men < 60 years (N = 27)		46,XY men (N = 102)		Corrected variables in 46,XY men (N = 102)	
	Mean	95 % limits	Mean	95 % limits	Mean	95 % limits
Height (mm)	1849.6	1824.5–1874.7	1707.0	1693.4–1720.6	–	–
Sitting height (mm)	958.1	945.0– 971.2	908.1	904.6– 911.6	964.0	949.6– 978.3
Subischial height (mm)	891.5	868.4– 914.6	799.1	794.3– 803.9	885.6	868.0– 903.2
Span (mm)	1840.9	1810.2–1871.6	1744.7	1737.0–1752.4	1878.2	1859.4–1896.9
Sitting height/subischial height ratio	1.08	1.05– 1.11	1.14	1.13– 1.15	1.09	1.06– 1.12
Span/height ratio	0.995	0.985– 1.005	1.022	1.018– 1.026	1.016	1.005– 1.027
Weight (kg)	80.12	74.3– 85.9	70.48	68.43– 72.53	–	–
W/H^2	2.34	2.20– 2.48	2.42	2.36– 2.48	2.33	2.32– 2.34
Triceps skinfold (log)	193.9	181.6– 206.2	186.1	181.7– 190.5	199.6	196.2– 203.0
Subscapular skinfold (log)	205.3	193.6– 217.0	205.0	200.7– 209.3	219.2	216.2– 222.2
Biacromial diameter (mm)	400.6	391.7– 409.5	393.5	390.1– 396.9	413.2	407.1– 419.3
Bi-iliac diameter (mm)	296.4	289.8– 303.0	287.7	284.6– 290.8	298.6	292.9– 304.3
Androgyny score	905.5	878.7– 932.3	883.9	864.2– 903.6	941.0	921.9– 960.1
Transverse chest diameter (mm)	289.3	281.9– 296.7	281.5	277.9– 285.1	292.2	286.5– 298.0
A-P chest diameter (mm)	216.6	207.8– 225.4	216.3	211.8– 220.8	219.9	212.3– 227.5
Thoracic index	1.347	1.289– 1.406	1.313	1.287– 1.339	1.343	1.285– 1.401

Results

The method of sampling persons with chromosome abnormalities introduced bias which cannot be estimated. The comparison of the measurements of these persons with those of 46,XY men and 46,XX women has been made in ways which seek to minimise this bias. Allowance was made, when examining the data from 47,XYY and 47,XXY men, for the relationship of anthropometric variables with height and weight. The random sample of men aged 20–60 from general practice did not show significant regressions on age of the anthropometric variables used in the present study. Precise matching for age was not attempted in examining data from 47,XYY and 47,XXY men because of the absence of age effects in the men in the general practice sample and because of the size of the 47,XYY and 47,XXY samples. Where use was made of data from an Edinburgh subnormality hospital in the comparisons, matching was also environmental. A different type of analysis was needed for each sex chromosome abnormality.

1. *XYY Men*

The samples of 46,XY men measured in the present study did not contain men tall enough to provide controls which could be matched for height and weight with the 47,XYY men. Direct comparison of 47,XYY men with the random sample of 102 men from a group general practice showed the 47,XYY men to be significantly larger in respect of weight, height, sitting height, subischial height and span (Table 3). The span-height ratio and the sitting height-subischial height ratio were significantly larger in 46,XY compared with 47,XYY men (Table 3).

An attempt was made to overcome the bias introduced by the selective sampling of 47,XYY men for height by predicting mean values of the anthropometric variables for a random sample of 46,XY men from the group general practice matched to the height and weight of the 47,XYY men.

This was done by regressing each anthropometric variable on height and weight in the 46,XY group and using the regression equations to correct each variable to the mean height and mean weight of the 47,XYY group. Predicted mean values of anthropometric variables corrected in this way for 46,XY men, with 95 % confidence limits, are given in Table 3. Differences between 46,XY and 47,XYY men have disappeared, with the exception of that for the span-height ratio, which remains significantly larger in XY men. If the correction is made to the mean height and mean weight of the subsample of 47,XYY men, who were not selected from tall men, all differences between 46,XY and 47,XYY men disappear, including that for the span-height ratio.

The method used is an attempt to make the desired comparison with a small sample of 47,XYY men in the absence of 46,XY controls. It is known that 46,XY men of the size required for matching exist, although they were not available in the present study (Casey et al. 1973).

2. *XXY Men*

All available groups of 46,XY men were used to match 46,XY men with 47,XXY men in respect of height and weight. The resulting group of 147 from a total of 337 46,XY men was compared with a group of 50 men of 47,XXY karyotype by parametric and non-parametric methods. Consistent results were obtained from the applications of the different tests. Mean values, with 95 % confidence limits, of the variables measured are given in Table 4. In respect of sitting height, span-height ratio, sitting height-subischial height ratio, biacromial diameter, androgyny score and transverse chest diameter, mean values in 47,XXY men are significantly smaller than those in 46,XY men. The mean value for subischial

Table 4

Mean values with 95 % confidence limits of anthropometric variables in 47,XXY men and in matched controls from 46,XY men

Anthropometric variable	46,XY men (N = 147)		47,XXY men (N = 50)	
	Mean	95 % limits	Mean	95 % limits
Height (mm)	1733.0	1724.4–1741.6	1740.6	1723.5–1757.7
Sitting height (mm)	917.2	912.2– 922.2	901.5	892.7– 910.3
Subischial height (mm)	815.5	809.0– 822.0	839.1	826.3– 851.9
Span (mm)	1763.7	1753.2–1774.2	1751.5	1727.9–1775.0
Sitting height/subischial height ratio	1.13	1.12– 1.14	1.07	1.05– 1.09
Span/height ratio	1.018	1.014– 1.022	1.005	0.999– 1.011
Weight (kg)	69.70	68.18– 71.22	69.70	67.56– 71.85
W/H^2	2.32	2.27– 2.37	2.30	2.15– 2.45
Triceps skinfold (log)	189.0*	186.5– 191.5	199.2	188.3– 210.1
Subscapular skinfold (log)	206.1*	203.7– 208.5	204.0	194.3– 213.7
Biacromial diameter (mm)	397.2	394.4– 400.0	380.1	374.4– 385.8
Bi-iliac diameter (mm)	287.7	284.6– 290.8	289.4	283.9– 294.9
Androgyny score	903.8	896.0– 911.6	850.2	833.6– 866.8
Transverse chest diameter (mm)	281.2	278.1– 284.3	267.4	261.4– 273.4
A-P chest diameter (mm)	209.8	206.4– 213.2	207.8	199.4– 216.2
Thoracic index	1.350	1.328– 1.372	1.303	1.261– 1.345

(*N = 335)

Table 5

Mean values with 95 % confidence limits of anthropometric variables in 47,XXX women, 46,XX mentally subnormal women and presumed 46,XX blood donor women

Anthropometric variable	47,XXX women (N = 26)		46,XX mentally subnormal women (N = 47)		46,XX blood donor women (N = 124)	
	Mean	95 % limits	Mean	95 % limits	Mean	95 % limits
Height (mm)	1601.4	1567.8–1635.0	1535.2	1517.8–1552.6	1623.9	1613.5–1634.3
Sitting height (mm)	840.9	821.2– 860.6	813.4	800.9– 825.9	868.8	863.0– 874.6
Subischial height (mm)	760.5	738.5– 782.5	721.8	708.7– 734.9	755.1	748.6– 761.6
Span (mm)	1596.2	1555.3–1637.1	1542.5	1523.8–1561.3	1632.2	1621.5–1642.9
Sitting height/subischial height ratio	1.11	1.07– 1.15	1.13	1.11– 1.15	1.15	1.14– 1.16
Span/height ratio	0.997	0.983– 1.011	1.005	0.995– 1.015	1.005	1.001– 1.009
Weight (kg)	63.30	55.7– 70.9	61.4	58.0– 64.8	61.1	59.5– 62.6
W/H	3.96	3.48– 4.44	3.99	3.79– 4.19	3.76	3.67– 3.85
Triceps skinfold (log)	218.9	209.0– 228.8	224.4	218.3– 230.5	224.9	222.3– 227.5
Subscapular skinfold (log)	222.2	210.2– 234.2	221.6	213.2– 230.0	213.2	209.6– 216.8
Biacromial diameter (mm)	349.3	341.6– 357.0	346.9	341.8– 352.1	365.9	363.3– 368.5
Bi-iliac diameter (mm)	290.5	279.1– 301.9	280.7	273.9– 287.6	285.7	282.9– 288.5
Androgyny score	757.4	737.6– 777.1	760.0	744.7– 775.3	811.9	804.7– 819.1
Transverse chest diameter (mm)	247.5	235.5– 259.5	249.9	244.0– 255.7	258.8	256.0– 261.6
A-P chest diameter (mm)	200.7	188.9– 212.5	197.5	189.8– 205.2	185.5	182.5– 188.5
Thoracic index	1.249	1.179– 1.319	1.282	1.234– 1.330	1.404	1.380– 1.428

height is significantly larger in 47,XXY compared with 46,XY men.

The two skinfold measurements in the table were matched for body weight only, since skinfold thickness is known to be independent of height. In this matching 335 men of presumed 46,XY karyotype were used and no significant difference was found, in respect of subcutaneous fat, between 46,XY and 47,XXY men. The other mean values in the table were not significantly different.

3. *XXX Women*

Mean values and 95 % confidence limits of the measurements recorded in 47,XXX women are shown in Table 5 together with similar data from mentally subnormal 46,XX women and from female blood donors. The latter group is presumed to be of 46,XX constitution. Significant differences between 47,XXX women and 46,XX mentally subnormal women were found in respect of height and subischial height only, the mean values of these variables being less in the 46,XX women. The comparison of 47,XXX and blood donor women revealed mean values to be significantly less in 47,XXX than in donor women in respect of sitting height, biacromial diameter, androgyny score and thoracic index, but the mean value of the antero-posterior thoracic diameter was significantly larger. All significant differences present between donor women and 47,XXX women were also found between donor women and 46,XX mentally subnormal women.

Some help in the examination of these significant differences was obtained from the linear regression of the variables concerned with age in the three groups of women. An ageing effect was present in antero-posterior thoracic diameter in all three groups. The regressions showed that no real difference existed amongst the groups and that apparent differences were due to the age distribution within the samples. Similar age effects explained the apparent differences in thoracic index. No effects were detected which could explain the smaller biacromial diameter in 47,XXX and 46,XX mentally subnormal women. Although an ageing effect is found in the androgyny score, this is due to an increase in bi-iliac diameter with increasing age, and does not therefore explain the differences found.

No age effects were found in respect of sitting height but the differences that were observed may be due to height effects, since the mean values of height increase from 46,XX mentally subnormal women through 47,XXX women to donor women, the difference being greater between 47,XXX women and 46,XX mentally subnormal women than that between mean values of 47,XXX women and donor women.

The significantly smaller subischial height of 46,XX mentally subnormal women when compared with 47,XXX females or with donor women may also be explained by the differences in height since subischial height contributes even more to height differences between individuals than does sitting height.

The tests of significance and the calculation of confidence limits as described above are based on the assumption that the variables concerned are normally distributed.

Discussion

Although many descriptions of 47,XYY men are based on samples selected for tallness (Abdullah et al. 1969, Akesson et al. 1969, Marinello et al. 1969, Melynk et al. 1969, Noel et al. 1969), studies exist on 47,XYY men, not selected for height, which show that their mean height is greater than that of the population (Price et al. 1966). The mean height of 47,XYY patients examined by Price and his colleagues in Carstairs Hospital was 1800 mm. In the present study the mean height of 47,XYY men not selected for tallness was 1816 mm.

Court Brown (1968) gave details of 47,XYY men from a number of studies where the subjects were not selected by height. The mean height of these men was 1820 mm. The mean height of 47,XYY men in two English State Hospitals as recently described by Casey et al. (1973) was 1818 mm. Court Brown thought that 50 % of 47,XYY men would be 1830 mm or more in height and this estimate is confirmed by Casey et al.

Direct comparison of a random sample of men from general practice with 47,XYY men in the present study shows the latter to be significantly taller and heavier, while the 46,XY men have a significantly larger sitting height – subischial height ratio. The difference in the ratio may be due to the fact that subischial height contributes a relatively greater proportion than does sitting height to the difference between tall and short people. This difference in ratio disappears when the sitting height and subischial height in the 46,XY men are corrected to the mean height and weight of the sample of 47,XYY men.

This correction, which was made to bring anthropometric variables of 46,XY men in the general practice sample up to values corresponding to the mean height and weight of the sample of 47,XYY men, results in corrected mean values for 46,XY men significantly larger than the uncorrected 46,XY means. Variables with significantly larger corrected mean values are transverse thoracic diameter, bi-iliac diameter, biacromial diameter, androgyny score, span, sitting height, subischial height and both skinfold thicknesses. These larger mean values, however, have confidence limits which still overlap those of the mean values in 47,XYY men. The conclusion seems to be that 47,XYY men have phenotypes similar to but proportionately larger than those of 46,XY men.

Men of 47,XXY constitution are often described in text books as eunuchoid (Hamerton 1965, Thompson & Thompson 1966, Bartalos & Baramki 1967, Kuppermann 1963). Some descriptions emphasise greater lower limb length as characteristic (McKusick 1964, Bartalos & Baramki 1967, Howard & Scott 1958). Stewart and his colleagues (1959) not only described greater lower limb length, but also recorded the span-height difference as less in 47,XXY compared with 46,XY men. The fundamental difference between eunuchs and 47,XXY men seems to be that while failure of epiphyseal closure results in longer upper and lower limbs in eunuchs compared with normal men, 47,XXY men have longer lower limbs but relatively shorter upper limbs than normal men. The effect hence cannot simply be due to reduced mean testicular hormone production. This difference is confirmed in the present study by the finding of greater subischial height and smaller ratios of sitting height to subischial height and of span to height in 47,XXY men compared with 46,XY men. The 95 % confidence limits of mean arm span in the present study overlap in the two groups. Hence the reduced span – height ratio in 47,XXY men is presumably due to greater lower limb length.

Stewart et al. (1959) regarded the increase in lower body segment length as the most useful diagnostic difference between 47,XXY and 46,XY men. They cast doubt on the finding by Raboch (1957) that trunk length is reduced in 47,XXY men. The present study, using controls matched for height and weight, does show a significantly smaller mean sitting height in 47,XXY men. The greater subischial height of 47,XXY men is unlikely to be due to delayed epiphyseal closure even if this occurs, since it is present before puberty (Tanner et al. 1959).

The mean height of 47,XXY men in the present study is significantly greater than the mean heights of mentally subnormal men (95 % limits 1656.8 mm–1702.2 mm) or of men in a random sample from an Edinburgh general practice (95 % limits 1695.4 mm–1720.6 mm). The mean values for height and span in chromatin positive men given by Stewart et al. (1959) were respectively 1753 mm and 1793 mm. The original description of Klinefelter's syndrome (Klinefelter et al. 1942) yielded mean values of height 1779 mm and of span 1811 mm. Of these four results only height in the study of Stewart et al. lies within the 95 % limits of 47,XXY men in the present study. The other values are significantly larger. The mean height of men with Klinefelter's syndrome in the recent study by Casey et al. was 1727 mm. This figure lies within the 95 % confidence limits of the mean height of 47,XXY men in the present study.

The present study has shown significantly smaller mean values, in 47,XXY compared with 46,XY men, for biacromial diameter, androgyny score and transverse chest diameter. Raboch (1957) reported smaller biacromial diameters in chromatin positive men, a finding confirmed in the present study. The androgyny score (Tanner 1951) receives its principal contribution from the biacromial diameter (Milne 1972). In 47,XXY men the mean androgyny score lies nearer to the value found in 46,XX women than to that for 46,XY men. The transverse chest diameter is significantly correlated with the biacromial diameter (Milne 1973) and is hence smaller in 47,XXY men. Data concerning the physiques of children and of 47,XXY men (Tanner et al. 1959) suggest that XX may inhibit the development of mesomorphic build in girls and hence perhaps also in 47,XXY men. A recent study by Hunter (1969), while confirming the greater height and leg length in 47,XXY compared with

46,XY men, also reported narrower shoulders and slimmer build in 47,XXY men.

It has been said that 47,XXX women do not differ in phenotype from 46,XX women (Polani 1965). In the present study 47,XXX women do not differ from blood donor women in respect of most anthropometric variables. Where differences from donor women occur, they also occur in a population which is environmentally similar to that of 47,XXX women, namely the 46,XX mentally subnormal group. It is therefore not possible to say whether the differences from donor women exist because of the extra X chromosome in 47,XXX women or because of environment. The differences should be interpreted with caution because of the policy of the Regional Blood Transfusion Service to exclude as donors women who are less than 1524 mm in height or 54.5 kg in weight. This policy must bias some anthropometric data towards higher mean values.

The 47,XXX women are significantly taller than mentally subnormal 46,XX women and of similar height to 46,XX women who are not mentally subnormal. The registry of Abnormal Karyotypes in Edinburgh has records of height in 11 of 47,XXX women who are not mentally subnormal. The mean height in these women does not differ significantly from the mean height of the 47,XXX women in the present study. These findings suggest that the extra X chromosome which in these women increases the risk of confinement in a mental subnormality hospital (Court Brown 1969) is not accompanied by the reduced height usually associated with mental subnormality. However, the precise I.Q. levels of the control group in the present study are not known and the reduced height of the control group when compared with 47,XXX women might not apply if the severely mentally subnormal were excluded.

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Appendix

Registry numbers of subjects described (From the Registry of Abnormal Karyotypes, M.R.C. Clinical and Population Cytogenetics Unit, Western General Hospital, Edinburgh)

47,XYY Men		
156/68	120/65	122/65
134/65	123/65	356/67
209/68	24/69	82/70
190/70	146/70	30/71
101/72	301/71	2/71
140/69	29/69	25/69
140/68	139/68	88/68
128/68	46/68	45/68
28/68	395/67	341/67
340/67	317/67	
47,XXY Men		
8/62	7/60	10/62
64/65	115/60	27/69
304/70	288/70	74/72
27/61	224/64	10/70
114/68	17/72	58/65
119/60	92/69	40/63
239/68	28/59	12/62
11/65	41/69	269/69
113/61	69/61	119/66
238/60	51/72	118/60
68/71	190/71	235/60
19/66	133/65	222/64
59/62	358/67	4/72
61/65	114/61	52/62
177/60	242/68	115/61
19/62	88/71	80/65
164/72	165/72	

47,XXX Women

215/60	221/60	56/65
234/60	165/61	32/59
24/71	10/60	7/65
187/60	232/70	176/61
145/61	174/61	160/64
112/61	52/66	233/60
25/63	172/69	166/61
189/60	5/65	128/64
124/64	175/61	

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SEPARATUM

Geront. clin. *14:* 36–42 (1972)

The ESR in Older People[1]

J. S. MILNE[2] and J. WILLIAMSON[3]

The erythrocyte sedimentation rate (ESR) has been measured in the first examination in a longitudinal study of aging persons in Edinburgh. The group of 487 persons (215 men, 272 women) form a random sample of persons aged 62 and upwards from a defined area of Edinburgh. This sample has been fully described elsewhere [MILNE *et al.*, 1971]. The ESR was measured in 211 men and 258 women.

Method

The method used was that described by DAWSON [1960] in which blood from a sequestrene tube, with isotonic sodium citrate solution added as 20% of its volume, is allowed to sediment in a suspended Westergren tube whose lower end is closed by a rubber cap. Readings were made at the end of 1 h. All estimations were performed within 2 h of taking the blood.

Results

Table I shows the frequency distribution of the results for men and women separately in the age ranges 62–69, 70–79 and 80+. Since these distributions are markedly positively skewed the median is reported in table II as a measure of central tendency together with 5th and 95th percentiles. The table shows a tendency for the ESR to increase with age more so in men than in women, and for values in women

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The ESR in Older People[1]

J. K. Milne[2] and J. Williamson[3]

[illegible] were obtained [illegible] in a longitudinal study of older people in Edinburgh. The group of [illegible] between 1958 and [illegible] drawn from a random sample of persons aged [illegible] and upwards in a defined area of Edinburgh. This sample [illegible] fully described elsewhere [Milne et al., 1971]. The ESR was measured in [illegible] men and [illegible] women.

Method

The [illegible]

Results

Table I shows the frequency distribution of ESR results for men and women separately in the age groups [illegible]. Since these distributions were markedly positively skewed, the median is reported in table II as a measure of central tendency together with [illegible] and [illegible] percentiles. The table shows a tendency for the ESR to increase with age, more so in men than in women, and for values in women

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Table I. Frequency distribution of ESR in 3 age groups in males and females

Age	Number of persons	ESR mm in 1st hour								
		1–9	10–19	20–29	30–39	40–49	50–59	60–69	70–79	80+
Males										
62–69	121	62	33	10	8	5	2	1	0	0
70–79	70	37	15	6	6	3	2	1	0	0
80+	20	6	3	5	3	0	2	0	0	1
All males	211	105	51	21	17	8	6	2	0	1
Females										
62–69	133	48	43	24	10	1	2	2	2	1
70–79	94	32	33	8	3	10	2	2	1	3
80+	31	4	15	4	4	3	1	0	0	0
All females	258	84	91	36	17	14	5	4	3	4

Table II. ESR (mm in 1st hour) as percentiles in 3 age groups in men and women

Age	Percentile values			
	Number of persons	5th	50th	95th
Males				
62–69	121	1.0	9.8	43.4
70–79	70	1.0	9.5	47.8
80+	20	1.7	21.5	59.5
All males	211	1.0	10.0	47.6
Females				
62–69	133	1.4	13.7	51.3
70–79	94	1.5	14.5	66.0
80+	31	3.9	17.2	47.7
All females	258	1.5	14.5	55.7

to be higher than those in men. Zero-order correlation coefficients between age and ESR are 0.20 for males ($N=210$, $P<0.01$) and 0.12 for females ($N=257$, $P>0.05$) confirming the tendency for ESR to increase with age in males but not in females.

It is suggested in the literature [Böttiger and Svedberg, 1967; Dawson, 1960; Boyd and Hoffbrand, 1966; Ansell and Bywaters, 1958] that the upper limit of the 'normal' ESR rises with age. The

Table III. ESR above and below 20 mm in 1st hour in 3 age groups in men and women

Age	ESR mm in 1st hour				
	1–19	⩾20	⩾20 mm percent	totals	
Males					
62–69	95	26	21.5	121	χ^2 10.01
70–79	52	18	25.7	70	$P<0.01$
80+	9	11	55.0	20	
				211	
Females					
62–69	91	42	31.6	133	
70–79	65	29	30.8	94	χ^2 0.70
80+	19	12	38.7	31	$P>0.05$
				258	

present sample has been divided into 2 groups with ESR 1–19 and with ESR ⩾20, and χ^2 is used to test the association of this division of the ESR with age and sex. For sex $\chi^2=2.03$ and with 1 degree of freedom $P>0.05$. This suggests that in this sample men and women do not differ in the proportions with ESR values above and below 20. Table III shows the proportions for the 3 age groups in each sex. For men χ^2 is 10.01 and with 2 degrees of freedom $P<0.01$ and for women χ^2 is 0.70 and with 2 degrees of freedom $P>0.05$. Inspection of table III suggests that more men have an ESR greater than 20 mm as age increases but that this is not so in women. χ^2 has also been used in men and women separately to test the association of an ESR value above or below 20 mm with the presence of bacteriuria, ischaemic heart disease and chronic respiratory symptoms. Table IV shows the results which indicate that there is no association in men or women between ESR above or below 20 mm and the presence or absence of bacteriuria, ischaemic heart disease or chronic cough and phlegm. Ischaemic heart disease is accepted as present if Rose's questionnaire [ROSE, 1962] is positive and/or Q/QS changes are present in the ECG. Chronic cough and phlegm is defined as present for at least 3 months of the year as in the MRC Questionnaire on bronchitis [1966].

Table IV. Association of ESR above and below 20 mm in 1st hour with bacteruria, ischaemic heart disease and chronic cough and phlegm

Diagnosis	Condition present		Condition absent		χ^2	P
	ESR		ESR			
	1–19	≥20	1–19	≥20		
Bacteriuria males	3	3	152	51	–	–
Bacteriuria females	18	11	151	71	0.41	>0.05
Ischaemic heart disease, males	33	13	123	42	0.15	>0.05
Ischaemic heart disease, females	26	14	149	69	0.17	>0.05
Cough and phlegm, males	48	19	108	36	0.27	>0.05
Cough and phlegm, females	17	7	157	74	0.08	>0.05

The ESR is equal to or greater than 20 mm in 55 men and 83 women (table I). In the men possible reasons were found in 12, i.e. carcinoma 5, rheumatoid arthritis 1, anaemia 1, infection 5 (chronic urinary infection 1, present chest infection 3, varicose ulcer 1). On the other hand 5 men with carcinoma had an ESR less than 20 mm. In the women possible reasons were found in 22, i.e. carcinoma 2, rheumatoid arthritis 12, myeloma 1, anaemia 2 and infection 6 (cholecystitis 1, chronic urinary infection 2, dacryocystitis 1, varicose ulcer 2). On the other hand, the ESR was less than 20 mm in women with chronic urinary infection 1, psoriatic arthropathy 1, anaemia 2. Therefore, in at least two thirds of men and women with an ESR greater than 20 mm no obvious reason was found.

There were 9 men and 16 women with an ESR equal to or greater than 50. In the women possible reasons were present in 9, i.e. carcinoma 1, rheumatoid arthritis 7 and varicose ulcer 1. In the men possible reasons were present in 3, i.e. rheumatoid arthritis 1, chronic urinary infection 1 and present chest infection 1. Therefore, in at least 50% of persons with an ESR greater than 50 mm no obvious reason was found.

Discussion

Most reported series report the mean which may be an inappropriate measure of central tendency when the distribution is so positively skewed. It remains skewed after logarithmic transformation of our material. OLBRICH [1948] reports means for age ranges 60–69, 70–79 and 80–98 with no upward trend with age, the largest mean being 14.0. WILHELM and TILLISCH [1951] on the other hand, in the decades from 60 to 89 report a rise of the mean from 15.3 ± 0.9 to 18.5 ± 1.3. RENBOURN and ELLISON [1952] reported no difference between means for men and women in corresponding decades from 60–90+ and analysis of variance showed no significant difference among the means. HILDER and GUNZ [1964] report rising mean and standard deviation with aging. PINCHERLE and SHANKS [1967] think the ESR rises with age but flattens out after age 60. DAWSON [1960] regards 5–10 mm for males and 5–15 mm for females as the normal range but thinks in adults over 50 years higher values may be normal. ANSELL and BYWATERS [1958], taking the upper limit of normal as 20 mm/h, found an unexplained high ESR (i.e. >20 mm) in 51 of 900 patients attending a rheumatology clinic. Some eventually developed rheumatoid arthritis but a proportion were not explained. The authors advise being wary of a high ESR but suggest it may not matter especially in the aged. BOYD and HOFFBRAND [1966] after excluding known causes of high ESR such as urinary infection, malignancy, recent infarct, venous thrombosis, rheumatoid arthritis and chronic bronchitis, found 21.5% of 303 elderly hospital inpatients with no apparent cause for a high ESR. In particular they were able to exclude urinary infection as a cause.

GRIFFITHS *et al.* [1970] in a study of elderly females admitted to hospital report a frequency distribution of ESR in which the median is 30.1 mm, a figure more than double the median of 14.5 mm in women in the present study. This emphasizes the difference between a hospital population and the general population.

The experience of the present authors would suggest that of a random sample of the population some 20% of males and some 24% of females would have an ESR greater than 20 mm without apparent cause. This rather surprisingly agrees with BOYD and HOFFBRAND since their subjects were in hospital.

Taking the sample as a whole, 25 persons of 469 (5.3%) have an ESR greater than 50 mm and in half of these no cause is evident. Taking 20 mm as the upper limit of normal, bacteriuria, ischaemic heart disease and chronic respiratory symptoms show no association with a raised ESR. Of 12 patients with carcinomata, 5 had an ESR less than 20 mm. All 13 patients with rheumatoid arthritis had an

ESR greater than 20 mm. A rise with age is not a striking feature in the present study which agrees with the varying age effects quoted above. It might well be thought that the ESR was a measurement of little value in the aged since in those persons in whom it is likely to be high, e.g. rheumatoid arthritis, the diagnosis can be made without it, and in a high proportion of those with a high ESR no cause is apparent. Specificity and sensitivity being low, it has no place in 'screening'.

Summary

Percentiles are reported for the ESR in a random sample of persons aged 62 and upwards. These show some increase with age and higher values with women. Taking 20 mm as the upper limit of normal, evidence is presented of a rise in age with men and of an absence of association of ESR with bacteriuria, ischaemic heart disease or chronic respiratory symptoms. Some ESR greater than 20 mm (20% of all men, 24% of all women) have no apparent cause. The ESR is of doubtful value as a test or in multiphasic screening in older people.

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~~The authors wish to thank Dr. S. H. Davies of the Haematology Department of the Royal Infirmary of Edinburgh in whose laboratory these estimations were carried out.~~

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Geront. clin. *14:* 32–35 (1972)

Plasma Urea Concentration in Older People[1]

J. S. MILNE[2] and J. WILLIAMSON[3]

Plasma urea concentration was measured during the first examination of a longitudinal study of aging persons being carried out in Edinburgh. The subjects measured were 215 men and 272 women aged 62 years and upwards forming a random sample of 27,000 older people living in a defined area of the city. The method of sampling with a comparison of respondents and nonrespondents has been described elsewhere [MILNE *et al.*, 1971]. This sample, although a random one from the general population, tends by virtue of the age of the subjects to contain more persons with pathological conditions than a sample of younger persons would.

Method

Blood collected by venepuncture was sent in Lithium Heparin tubes to the Clinical Chemistry Laboratory in the Royal Infirmary, Edinburgh, where it was analysed by the diacetyl monoxime method in the autoanalyser.

Results

The frequency distribution for plasma urea concentration in mg% in the above sample of older men and women in Edinburgh is shown in table I. The distribution is positively skewed with a small number

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Gerontologia Clinica
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Plasma Urea Concentration in Older People[1]

[illegible] and J. Williamson

Plasma urea concentration was measured during the first examination of a longitudinal study of older people being carried out in Edinburgh. The subjects examined were 213 [illegible] 275 women aged 62 years and upwards forming a random sample of [illegible] pensionable age living in a defined area of the city. The [illegible] of [illegible] and [illegible] has been described elsewhere [illegible]. [illegible] to contain more persons with pathological conditions than [illegible] younger persons would.

Method

[illegible]

Results

The frequency distribution for plasma urea concentration [illegible] in the above sample of older men and women [illegible] is shown in table 1. The distribution is positively skewed with a small number

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Table I. Plasma urea concentration in older men and women. Percentages in brackets

Sex	Plasma urea, mg%								Missing values	Totals
	10–19	20–29	30–39	40–49	50–59	60–69	70–79	80+		
Men	5 (2.3)	41 (19.1)	85 (39.5)	58 (27.0)	12 (5.6)	7 (3.3)	1 (0.5)	2 (0.9)	4 (1.9)	215
Women	2 (0.7)	62 (22.8)	121 (44.5)	46 (16.9)	21 (7.7)	3 (1.1)	2 (0.7)	1 (0.4)	14 (5.1)	272

Table II. Mean plasma urea concentration values in 3 age groups of older men and women

Age and sex	Number of persons	Mean	SD	Between group sum²	Within group sum²	F	DF
Males							
62–69	119	35.70	8.52	1,973.29	22,776.10	9.01[1]	2,208
70–79	72	38.24	11.37				
80+	20	46.30	15.53				
All men	211	37.57	10.83				
FEMALES							
62–69	133	34.82	9.50	566.32	24,845.56	2.91	2,255
70–79	96	35.52	9.46				
80+	29	39.69	12.09				
All women	258	35.63	9.92				

[1] Significant at 0.001 level.

of values in the range 60–80+ mg%. In table II are displayed means and standard deviations and the numbers of persons from whom these statistics are derived, for plasma urea concentration in 3 age groups in men and women and in all men and all women in the sample. Inspection of the table shows a rise in mean values and an increase in the size of the standard deviation as age increases. Analysis of variance shows no significant difference among the means for women ($F=2.91$, degrees of freedom 2,255) but reveals a significant difference among the means for men ($F=9.01$, degrees of freedom 2,208, $p<0.01$). If the differences are examined between the means in each of the possible pairings in men, no significant difference is found between males of age 62–69 and age 70–79 ($t=1.63$, degrees of freedom 191), but a

Table III. Percentile values of plasma urea concentration in older men and women

Sex	Percentile	Plasma urea, mg%
Men (211)	5th	20.2
	50th	35.4
	95th	57.6
Women (258)	5th	20.6
	50th	33.9
	95th	55.0

significant difference is present between males of age 70–79 and age 80+ ($t=2.12$, degrees of freedom 90, $p<0.05$).

Examination of the difference between the means for all males and for all females gives a result which just reaches the 5% level of significance ($t=2.00$, degrees of freedom 467, $p<0.05$). However, examination of the difference between means for males and females in corresponding age groups does not reveal any significant difference (age 62–69, $t=0.77$, degrees of freedom 250; age 70–79, $t=1.64$, degrees of freedom 166; age 80+, $t=1.56$, degrees of freedom 47). The significant difference between means for all males and all females would need confirmation from further samples before being accepted.

The median and 5th and 95th percentiles for all men and all women are listed in table III. As would be expected from the positively skewed distribution curve the medians for men (35.2 mg%) and women (33.9 mg%) are smaller than the means for men (37.57 mg%) and women (35.63 mg%) respectively.

Discussion

RENBOURN and ELLISON [1952] published figures for plasma urea for men and women aged 60–90+. Although based on smaller numbers (total sample 46 men and 38 women) their results were similar in that mean values tended to rise with age particularly in men and no significant differences were found between men and women in corresponding decades. CAMPBELL *et al.* [1968] reported mean values for men aged 65–74 of 32.7 mg% and for women aged 65–74 of 32.9 mg%. The mean for men of all ages was 31.8 mg% (SD=6.5) and for women of all ages was 28.7 mg% (SD=7.1). The difference between these means was significant. These authors thought plasma urea increased as age increased perhaps by 1.5 mg/decade in women. Their figures for older men and women although not directly comparable because of age grouping are lower than in the present study and much lower than those of RENBOURN and ELLISON.

OLBRICH [1948] working in Edinburgh reported figures of non-protein nitrogen in blood which after multiplication by 2.1/7th gave urea values in each age group more than double those in the present study. His mean values did rise with age especially in men but the difference between means for all men and all women was not significant (t=1.88, degrees of freedom 94). The subjects examined by OLBRICH were in a longstay hospital which explains the difference from the present study of a random sample of the ordinary older population.

Summary

Plasma urea concentration was measured in a sample containing 215 older men and 272 older women. The mean value for all men was 37.57 mg% and for all women was 35.63 mg%. The difference between these means is just significant. Plasma urea concentration increases significantly with age in men but not in women. Median values are less than means in accordance with the positive skewing of the distribution.

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Hemoglobin, hematocrit, leukocyte count, and blood grouping in older people

INTERNATIONAL GERIATRICS

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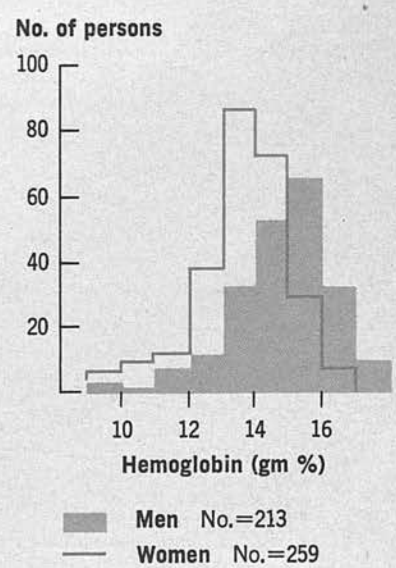
During the first phase of a longitudinal study of aging persons in Edinburgh, hematologic examination was performed and ABO and Rhesus groupings were determined. The subjects, 215 men and 272 women between 62 and 90 years of age, formed a random sample from a population of 27,000 older people living in a defined area of Edinburgh. The method of sampling, with a comparison of respondents and nonrespondents, has been described elsewhere.[1]

Methods Blood was collected in sequestrene tubes and in plain test tubes, which were sent to the hematologic laboratory and to the laboratory of the Regional Blood Transfusion Service, respectively. Hemoglobin was estimated by the cyanmethemoglobin method,[2] packed cell volume was measured by a microhematocrit technic,[2] and white cell count was estimated with a Coulter model A counter. The standard deviation of the mean difference of paired hemoglobin estimations from the same blood specimen is 0.3 with a hemoglobin of 5.9 gm per 100 ml and 0.4 with a hemoglobin of 9.9 gm per 100 ml. The standard deviation of the mean difference of paired white cell counts from the same blood specimen, expressed as coefficient of variation, is 8 percent. Normal ranges in this laboratory are: packed cell volume, 40 to 54 percent in men and 36 to 47 percent in women; mean corpuscular hemoglobin concentration, 32 to 38 percent; and white cell count, 4000 to 10,000 per cubic millimeter. Data were examined by standard statistical methods.[3]

Results *1. Hemoglobin.* The frequency distribution of hemoglobin (gm percent) is shown in figure 1. The distribution in both men and women is negatively skewed with positive kurtosis (table 1). Table 2 shows means and standard deviations in three age groups of men and women. The mean for all men is significantly higher than that for all women ($p<0.01$).

2. Packed cell volume (PCV). The frequency distributions of packed cell volume for men and women are shown in figure 2. These distributions are negatively skewed with positive kurtosis (table 1). Mean values and standard deviations for men and women are given in table 2. The mean for all men is significantly higher than that for all women ($p<0.01$). The correlation coefficient between hemoglobin concentration and PCV is 0.88 for all men and 0.86 for all women.

Figure 1.
Frequency distribution of hemoglobin.




473 ml. (1 pint)
Isuprel®
brand of
isoproterenol
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Elixir
S290EF
6 mg.
12 mg.
45 mg.
150 mg.
19%
Winthrop

Table 1.
Tests of skewness and kurtosis of hematologic variables in older men and women.

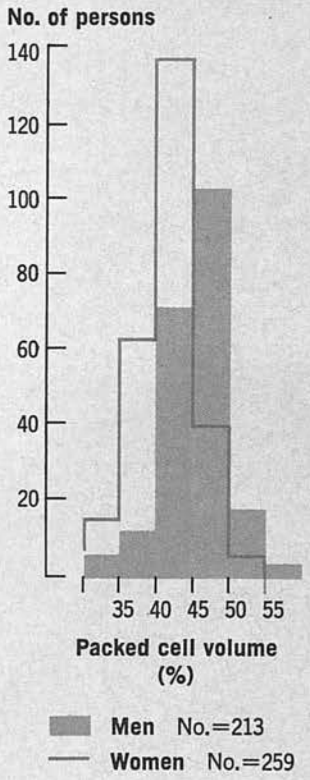
Measurement	Sex	No.	g_1 (skewness)*	p (one tail)	g_2 (kurtosis)†	p‡
Hemoglobin	M	213	−1.024	<0.01	+2.221	<0.01
	F	259	−1.035	<0.01	+2.151	<0.01
Packed cell volume	M	213	−0.581	<0.01	+1.707	<0.01
	F	259	−0.364	<0.01	+0.728	<0.05
Mean corpuscular hemoglobin concentration	M	213	−0.599	<0.01	+3.956	<0.01
	F	259	−0.041	N.S.	+0.004	N.S.
White blood cells	M	213	0.232	N.S.	−0.481	N.S.
	F	259	+0.682	<0.01	+0.697	<0.05

*The quality of asymmetry shown by a frequency distribution
†The peakedness or flatness of the graphic representation of a frequency distribution
‡From Snedecor and Cochran (1967) Table A 6(ii)

Table 2.
Mean values and standard deviations for hemoglobin, packed cell volume, mean corpuscular hemoglobin concentration and white blood cells in older men and women.

		Hemoglobin (gm %)		Packed cell volume (%)		Mean corpuscular hemoglobin concentration (%)		White blood cells (per cu mm)	
Age group	No.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Men									
62-69	121	14.98	1.21	45.36	3.40	33.10	1.68	7,738	1,868
70-79	72	14.56	1.82	44.43	4.94	32.95	1.77	7,569	2,125
80+	20	13.93	1.73	42.40	4.54	32.97	2.00	7,342	1,510
Total	213	14.76	1.53	44.82	4.18	33.05	1.74	7,645	1,934
Women									
62-69	134	13.60	1.32	41.34	3.67	33.04	1.68	6,888	1,886
70-79	94	13.53	1.65	40.98	4.45	33.03	1.96	7,211	2,196
80+	31	13.23	1.38	40.16	3.68	32.94	1.63	6,663	1,570
Total	259	13.53	1.46	41.05	3.99	33.04	1.78	6,979	1,981

Figure 2.
Frequency distribution of packed cell volume.



3. Mean corpuscular hemoglobin concentration (MCHC). Frequency distributions for men and women are given in figure 3. The distribution in women does not differ significantly from the gaussian curve but in men it is negatively skewed with positive kurtosis. Mean values and standard deviations in table 2 show no significant difference between all men and all women.

4. Leukocyte count. Distributions are shown in figure 4. The curve for men does not differ significantly from the gaussian curve but is positively skewed with positive kurtosis in women (table 1). Mean values and standard deviations are given in table 2. The mean for all men is significantly higher than that for all women ($p<0.01$), although this difference can hardly be clinically important.

5. The effect of age. The regressions of the hematologic variables (described above) on age are given in table 3. Significant age differences are found only for hemoglobin and packed cell volume in men, in whom the mean values decrease as age increases (table 2). This age effect is not found in women.

6. Red cell grouping. ABO and

Figure 3.
Frequency distribution of mean corpuscular hemoglobin concentration.

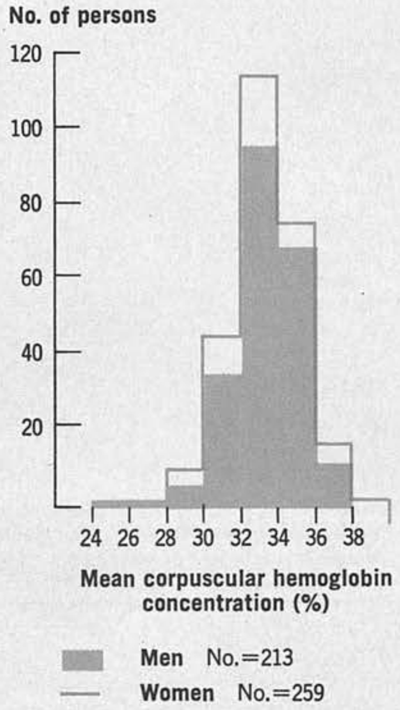


Table 3. *Regression of hematologic variables on age in older men and women.*

	Mean	a (constant)	b (age)	S.E. b	D.f.	F.	p	S.D. around regression	Mean age
Men									
Hb	14.76	+17.293	−0.0362	0.0160	1,211	5.12	<0.05	1.486	
PCV	44.82	+52.058	−0.1034	0.0436	1,211	5.61	<0.05	4.058	69.99
MCHC	33.05	+32.810	+0.0034	0.01888	1,211	0.03	N.S.	1.756	
WBC	7,645.00	+9,319.7	−23.9207	20.8269	1,211	1.32	N.S.	1,937.5	
Women									
Hb	13.53	+14.848	−0.0185	0.0139	1,257	1.79	N.S.	1.464	
PCV	41.05	+44.756	−0.0522	0.0377	1,257	1.91	N.S.	3.985	71.10
MCHC	33.04	+33.979	−0.0132	0.0168	1,257	0.62	N.S.	1.779	
WBC	6,979.0	+6,169.6	+11.3837	18.8126	1,257	0.37	N.S.	1,987.3	

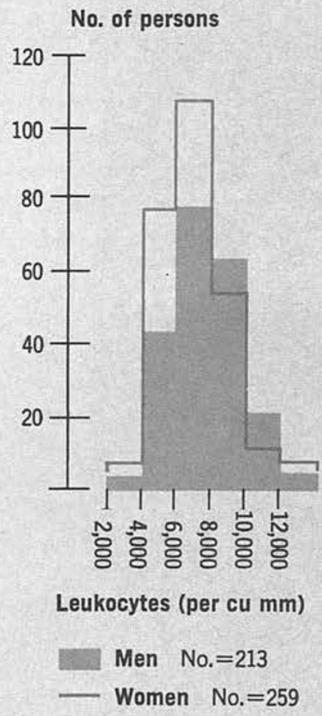
Table 4.
Red cell grouping in older men and women.

	Red cell group				
	O	A	B	AB	Total
Men	112 (52.8%)	67 (31.6%)	29 (13.7%)	4 (1.9%)	212
Women	123 (48.1%)	95 (37.1%)	29 (11.3%)	9 (3.5%)	256

Table 5. *Percentages of red cell groups in Edinburgh as a whole and in men and women in the sample.*

				Z		
Red cell group	**All Edinburgh (both sexes combined)**	**Men in sample**	**Women in sample**	**All Edinburgh and men in sample**	**All Edinburgh and women in sample**	**Men and Women in sample**
	No.=6,662	**No.=212**	**No.=256**			
O	49.9	52.8	48.1	0.83	0.56	1.02
A	36.2	31.6	37.1	1.44	0.29	1.25
B+AB	13.9	15.6	14.8	0.68	0.38	0.24
	No.=4,131	**No.=211**	**No.=256**			
D neg	16.4	21.3	14.5	1.69	0.83	1.89
D pos	83.6	78.7	85.5			

Figure 4.
Distribution of leukocyte count.



Rhesus groups were determined in 212 men and 256 women taking part in the study. Table 4 shows the results for ABO grouping. Rhesus grouping revealed 45 (21.3 percent) men and 37 (14.5 percent) women who were D negative. Kopec[4] described the distribution of the red cell groups in the United Kingdom. Her figures for Edinburgh are shown in table 5, together with figures for men and women in the sample. Kopec reports group B and group AB combined and her figures are for men and women combined. A comparison has been made of the difference in proportion between Kopec's Edinburgh figures and men and women in the sample for groups O, A, B + AB, and D negative. The last column in table 5 compares proportions for these groups in men and women in the sample. In no case does Z reach a significant figure. There is no evidence, therefore, that the distribution of red cell groups in the sample of older people differs from the distribution reported by Kopec in Edinburgh's population as a whole, nor does the distribution in older men appear to be different from that in older women.

Discussion The study which agrees most closely with the present authors' hemoglobin figures is that of Semmence,[5] carried out in Yorkshire. His mean values for men are: age 65 to 70, 14.5 gm percent; age 71 to 82, 14.2 gm percent; and age 83 and above, 13.8 gm percent. For women in the same age groups, he reports mean values of 13.5, 13.6, and 14 gm percent, respectively. The age groups are not strictly comparable with those in the present study but figures are higher for men than for women and show a decrease with age. Semmence reported 5 percent of men and 13 percent of women with hemoglobin less than 11.84 gm percent. The present study has 12 men (5.6 percent) and 27 women (9.9 percent) with hemoglobin less than 12 gm percent.

Twelve men and 27 women had hemoglobin values of less than 12 gm percent.

Two studies[6,7] report higher mean values than those recorded by the present authors. Orchard,[7] using an alkaline hematin method, reported mean levels higher than in the present study, with a mean for all men over 65 of 15.46 gm per 100 ml (S.D., 1.72) and for all women over 65 of 14.58 gm per 100 ml (S.D., 1.81). These means are significantly higher at the 1 percent level than those in the present study for men and for women. Several studies[8-18] report lower mean values, all in older people with roughly comparable age ranges. A decrease with age is reported in men by Hawkins, Speck and Leonard[10] and Natvig,[18] while several studies report no age difference in men.[6,9,12]

In women, Hawkins, Speck and Leonard,[10] report no age differences at age 20 and above and Natvig[18] no differences at age 30 and above. Shapleigh, Mayes and Moore[12] report no consistent rise or fall with age, but Campbell and associates[6] report a small fall after the age of 65. Sex differences reported suggest either higher figures in men[6,7,10,13,18,19] or no important difference.[8,9,14,15] Natvig[18] reports 1.6 percent of women age 60 to 69 with hemoglobin less than 11 gm per 100 ml, while the present study includes 4.4 percent of women age 62 to 69 with those values. In men age 60 to 69 he found 1.5 percent with values less than 11.8 gm per 100 ml and 3.5 percent with values less than 12.5 gm per 100 ml. The present study has, in the age group from 62 to 69, 0.8 percent less than 11.9 gm per 100 ml and 6.6 percent less than 12.9 gm per 100 ml.

Packed cell volume is reported as differing in the sexes, with larger values in men in some studies,[14,15,19,20] but others report little or no difference.[8,9,16] Apart from Jefferson, Hawkins and Blanchauer[19] and Olbrich,[14] most studies report lower figures for men than the present one, whereas, in women, the results may be lower,[15,16] similar[19,20] or larger.[9,14] Orchard[7] reports a mean value for men of 44.62 percent, which does not differ significantly from the present study, but the mean value for women of 42.29 percent is significantly higher than that in the present study ($p<0.05$).

The WHO Technical Report, Series No. 182,[21] suggests the lower limit of normal for mean corpuscular hemoglobin concentration is 34 in both sexes. The present study reports a mean value of 33 percent in both sexes and Kilpatrick[9] reports mean values of 30.6 and 30.42 percent in men age 65 to 74 and 75 and above, respectively, and of 31.3 and 30.36 percent in women in these two age groups. Kilpatrick and Hardisty[22] found a decline of mean corpuscular hemoglobin concentration in men of 0.031 percent per year, which would agree with the low values in the present study compared with the normal range based on younger people reported by the laboratory that made the measurements.

Reports of leukocyte counts in the literature are similar to those of the present authors.[7,12,14,20]

Little attention should be paid to differences in reported values since, over the 30 years for which references are given, methods of estimation vary a good deal. The present study shows clear differences between means for men and women in values for hemoglobin and packed cell volume and a clear decrease in the means of these two variables in men as age increases.

The World Health Organization has suggested[21] that the lower limit of nor-

Continued on page 124

mal for hemoglobin below which anemia can be considered to exist is 14 gm percent for men and 12 gm percent for women. In the present sample this would place 25.6 percent of the men and 9.9 percent of the women in the anemic group. This is an unexpectedly high figure for men. The distribution curve is negatively skewed in men and women, being reasonably normal looking until 13 gm percent in men and 12 gm percent in women, after which a long negative tail begins. Cut-off points for anemia at these levels would label 10.7 percent of the men and 9.9 percent of the women as anemic.

Negatively skewed distributions of hemoglobin in women are reported by the Medical Research Council,[23] Berry, Cowin and Magee,[24] Kilpatrick and Hardisty,[22] and Elwood.[25] Kilpatrick and Hardisty[22] and Elwood[25] obtained their results from random samples and their highly significant values for skewness are also found in women in the present study. Kilpatrick and Hardisty[22] did not report skewness in men. The presence of highly significant skewness in men in the present study may be due to the fact that a greater proportion of older men had correspondingly lower hemoglobin levels. Longitudinal study would be needed to investigate this.

Mean hemoglobin and corpuscular hemoglobin concentration levels may be misleading.

Women in the present study had a negatively skewed distribution of packed cell volume, as reported by Elwood, but there was significant positive kurtosis in the present study as opposed to no significant kurtosis in the study done by Elwood.[25] Results for packed cell volume in the present study gave more marked negative skewness and positive kurtosis in men than in women. Elwood reported no skewness but positive kurtosis in the distribution of mean corpuscular hemoglobin concentration in women.

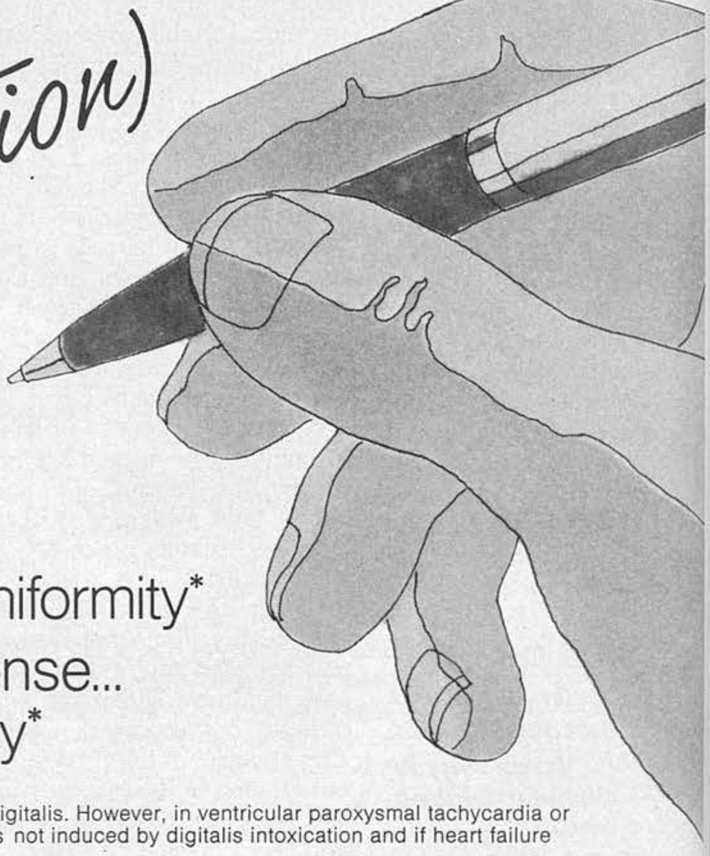
The present study found neither skewness nor kurtosis in women but in men the differences from normal were highly significant for both. In the present study results of the white cell count found positive skewness and positive kurtosis in women, but departures from normal in men were not significant. In spite of these departures from normality, the results have, in the present study, been reported with means and standard deviations; but it is worth remembering Elwood's conclusion from his study of women in the community that means of hemoglobin and mean corpuscular hemoglobin concentration levels may be misleading.

The failure to show a difference in the proportions of blood groups in the sample of older people from those in the general population of Edinburgh, at an age where elimination by death might have changed the proportions, emphasizes the desirability of using random samples of the population in attempts to associate blood groups and disease. Table 5 suggests a higher prevalence of D-negative men in the present sample compared with women and with the Edinburgh population. Although this difference does not reach statistical significance in this sample, it is worth bearing in mind in some future study.

Summary In the first examination of a longitudinal study of a random sample of aging persons, hemoglobin, packed cell volume, mean corpuscular hemoglobin concentration, leukocyte count, and red cell groups were determined in 213 men and 259 women. Significant sex differences were found between the mean values of hemoglobin (men, 14.74 gm percent; women, 13.53 gm percent), packed cell volume (men, 44.77 percent; women, 41.07 percent), and leukocyte count (men, 7,645; and women, 6,979 per cubic millimeter). No sex differences appeared for mean corpuscular hemoglobin concentration or red cell grouping. Significant decreases with increasing age were found in mean values for hemoglobin and packed cell volume in men only. ABO and Rhesus groups in the sample did not differ in proportion from published figures for the general population in Edinburgh. Hematologic findings are compared with reports in the literature.

Continued on page 126

Lanoxin
[digoxin]
(no substitution)



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precision quality control...
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predictable patient response...
• proven biologic availability*

Contraindications: There are no absolute contraindications to digitalis. However, in ventricular paroxysmal tachycardia or ventricular fibrillation, it should be used *only* in refractory cases not induced by digitalis intoxication and if heart failure has developed.

Precautions: If the patient has been given digoxin during the previous week or any other less rapidly excreted drug of the digitalis group during the previous two weeks, the dose of Lanoxin brand Digoxin must be reduced accordingly. Because of impaired renal function and excretion in elderly patients, they frequently require lower than recommended doses.

Potassium loss in patients sensitizes the heart to digitalis intoxication even with recommended doses. The diuretic agents as well as electrolyte manipulations by the physician are major causes of potassium depletion in cardiac patients. Under these conditions, it may be necessary to reduce the usual dosages of Lanoxin brand Digoxin during digitalization and maintenance.

Digoxin is usually ineffective in cases of cardiac failure due to mechanical causes which are independent of myocardial diseases, e.g., cardiac tamponade, or to disorders not primarily of cardiac origin, as severe anemia. Despite a variable or poor response to digoxin in the presence of active rheumatic carditis, the development of cardiac failure is an indication for its use.

Effects of Overdosage and Treatment: The symptoms of overdosage with digoxin are quite similar to those occurring with other digitalis preparations. The most common toxic manifestations are anorexia, nausea, vomiting and various cardiac arrhythmias, including ventricular extrasystoles and paroxysmal supraventricular tachycardia or fibrillation with A-V block. In general, the gastrointestinal manifestations of toxicity with digoxin precede the cardiac arrhythmias occurring from overdosage. Furthermore, because of the rapid dissipation of digoxin, manifestations of toxicity are of short duration, usually lasting from a few hours to one or two days.

If necessary, potassium chloride may be administered as an intravenous infusion containing (adult dosage) 40 milliequivalents in 500 cc. of 5% dextrose in water, given over the course of 1 hour and repeated, if required, until a total of 120 milliequivalents have been given (1 mEq. KCl = 74.5 mg.). Electrocardiographic monitoring should be conducted and the infusion halted immediately upon the appearance of peaking of the T-waves. For children, the intravenous infusion dosage of potassium chloride would be 5 to 10 milliequivalents in 100 cc. of 5% dextrose in water given over the course of 1 hour, repeated if required, to a total of 15 to 30 milliequivalents. For more serious intoxication with abnormal cardiac rhythms, potassium chloride may be given orally in divided doses totalling 4 to 6 grams per day (adults) or 1 to 2 grams (children) provided renal failure is not present.

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Lanoxin® digoxin

*Complete literature available on request from Professional Services Dept. PML.

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Reprint requests may be sent to Dr. Milne at the Royal Victoria Hospital, Edinburgh, EH4 2DN, Scotland.

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International brief

Improved prognosis in Wegener's granulomatosis

The prognosis in Wegener's granulomatosis, invariably fatal in the past, may be comparatively favorable with early diagnosis and combined immunosuppressive treatment with a cytostatic drug such as azathioprine or chlorambucil and prednisolone, followed by careful hematologic controls. Such is the experience of G. Berglund and his associates at Sahlgren's Hospital, University of Göteborg, Sweden.

The team recommends an initial dosage of azathioprine, 3 mg/kg, or if chlorambucil is preferred, 0.2 mg/kg, along with 1 mg/kg of prednisolone. The latter should be decreased to a maintenance dosage of 5 to 10 mg daily, according to the clinical response. The highest possible maintenance dosage of azathioprine must be determined from white cell counts; with chlorambucil, platelet counts are generally more determinative of the maximum maintenance dosage.

Treatment of five patients with Wegener's granulomatosis with the combination therapy was described in *Acta Medica Scandinavica* (191:5, 1972). Three of the five were in good general condition 48, 14, and 8 months after commencement of the therapy, with improved or stable renal function. In a fourth patient the disease was too far advanced for him to be helped, and in the fifth, chlorambucil could not be maintained at an adequate dosage because of hemorrhagic diathesis.

35

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SEPARATUM

Geront. clin. *14:* 56–60 (1972)

Bowel Habit in Older People[1]

J. S. MILNE and J. WILLIAMSON

Abstract. In a random sample of older people, frequency of bowel movement ranged from less than once in 3 days to more than twice daily. 71 % of men and 67 % of women had 1 bowel movement daily. 38 % of men and 50 % of women used laxatives. A significantly greater proportion of men over than under the age of 70 years used laxatives. No age effect was found in women. The use of laxatives diminished as frequency of bowel action increased.

Frequency of bowel movement and use of laxatives were investigated during the first examination of a longitudinal study of older people being carried on in Edinburgh. The subjects studied were 215 men and 272 women, aged 62–90 years who formed a random sample of 27,000 older people living in a defined area of the city. The method of sampling with a comparison of respondents and non-respondents has been described elsewhere [MILNE *et al.*, 1971].

Methods

Subjects were examined by one observer (J.S.M.) using a questionnaire followed by a full physical examination. The part of the questionnaire relating to bowel habit enquired about frequency of bowel movement, recent change in bowel habit and use of laxatives (Appendix A). Reproducibility of the questionnaire was tested before the study began [MILNE *et al.*, 1970] by administering the questionnaire to 30 persons. 6 weeks later, the same observer asked the same 30 subjects the same questions. Of the 30 persons 24 produced answers giving the same frequency of bowel movement on both occasions. 22 of the 24 were recorded as having one bowel movement daily.

[1] This work was supported by a grant from the Secretary of State for Scotland via the Advisory Committee on Medical Research.

Results

Frequency of bowel movements are given in table I. The distributions are symmetrical about a frequency of once daily for both sexes and for different age groups in the range 62–90 years of age. The table, therefore, divides the data by sex but not by age. 71% of the men and 67% of the women claim to have a bowel movement once daily. The range of frequency is from less than twice weekly to more than twice daily.

Questions about recent (less than 1 year previously) change of bowel habit revealed 2 men and 5 women with recent diarrhoea and 4 men and 8 women with recent constipation. One of the men with recent diarrhoea had a carcinoma of the rectum, discovered as a result of his participation in the survey. Long-standing (more than a 1-year duration) constipation was admitted by 3 men and 1 woman. 95% of the men and 93% of the women had no change in bowel habit.

The use of laxatives is shown in table II for men and women of less than 70 years of age and of 70 years and upwards. 38.5% of the men and 50% of the women use laxatives, the greater use by women being significant (χ^2, 6.30; $p<0.05$). Of those persons who use laxatives, $^2/_3$ of the men and just over $^1/_2$ of the women claim to take them as required rather than regularly. A significantly larger proportion of men aged 70 years and over use laxatives compared with men of less than 70 years (χ^2, 17.23; $p<0.001$). The age difference in women is not significant.

If the use of laxatives is compared with frequency of bowel movement as in table III it can be seen that the proportion of persons using laxatives

Table I. Frequency of bowel movement in older people. Percentages in brackets

Number of bowel movements	Men (n=215)	Women (n=272)
<1/3 days	1 (0.5)	3 (1.1)
1/3 days	3 (1.4)	16 (5.9)
1/2 days	23 (10.7)	37 (13.6)
1 daily	152 (70.7)	183 (67.3)
2 daily	30 (14)	24 (8.8)
>2 daily	4 (1.9)	4 (1.5)
No data	2 (0.9)	5 (1.8)

Table II. Use of laxatives in older people

Age and sex	Laxatives		No data	χ^2
	not used	used (% of row total)		
Men				
62–69 years	89	32 (26)	2	17.23
+70 years	42	50 (54)		$p<0.001$
Women				
62–69 years	76	60 (44)	4	3.82
+70 years	58	74 (56)		NS

diminishes as frequency of bowel movement increases. Even so, 3 men and 10 women whose bowels moved oftener than once daily used laxatives.

Two men and 4 women were demented and could not answer questions. One woman with an ileostomy answered the question about laxatives but the frequency of her bowel movement was not recorded.

Discussion

The frequency distribution of the frequency of bowel movement has the symmetrical appearance characteristic of many biological variables. CONNELL *et al.* [1965] made a study of bowel habit which included 400 persons from general practice of whom 111 were aged 60 years or more. No age differences in bowel habit were found in the 400 subjects. 81% of persons aged 60–69 years and 83% of those over 70 years in the study of CONNELL *et al.* [1965] had 5–7 bowel actions weekly. These results are similar to those in the present study. PARKS [1943] is cited by CONNELL *et al.* [1965] as reporting a 1939–1940 study of 1,115 postal workers, younger than persons in the present study, in whom 52.7% had one bowel action daily and 41% had more than one daily. HARDY [1945], reporting a study in 440 nurses, records 59% with one action daily, 32% with more than one daily and 9% with less than one. PARKS [1943] and HARDY [1945] both studied younger groups than the present study and the proportion recorded as having more than one bowel action daily is larger.

The figures for use of laxatives in table III suggest that older people cling to outmoded medical ideas current in their youth and regard infrequent

Table III. The association of bowel habit with use of laxatives in older people

Number of bowel movements	Men			Women		
	laxatives not used	laxatives used	% of row total as 'used'	laxatives not used	laxatives used	% of row total as 'used'
<1/3 days	0	1	100	1	2	67
1/3 days	0	3	100	1	15	94
1/2 days	6	17	74	10	27	73
1 daily	94	58	38	103	80	44
2 daily	27	3	10	15	9	38
>2 daily	4	0	0	3	1	25
No data	2	–	–	5	–	–

bowel movement as a sign of ill health. Laxatives are recorded as being used by 38% of men and 50% of women in the present study. CONNELL *et al.* [1965] reported 29.3% of all age groups in a general practice used laxatives but the percentage increased proportionately with age, from 5.6 at age 30–39 years and 11.9 at age 40–49 years to 30.2 at age 60–69 years. PARKS [1943] is cited by CONNELL *et al.* [1965] as reporting the use of laxatives in 20% of persons aged 30–39 years and 28.6% of those aged 40–49 years. These figures of 30 years ago are much larger than those in the corresponding age groups in the 1963–1964 study of CONNELL *et al.* [1965] Persons aged 30–39 and 40–49 years when studied by PARKS [1943] are now aged 60–69 and 70–79 years. Presumably, the present day greater use of laxatives by older people compared with younger, reflects the habits of the younger people studied by PARKS [1943] 30 years ago.

The sex difference for the use of laxatives found in the sample seems to be confined to persons under 70 years of age of whom 26% of men and 44% of women use laxatives. In persons aged 70 years and over, the proportions using laxatives are almost equal in men (54%) and women (56%).

BROCKLEHURST [1970] emphasises the association of disease in the elderly with change of bowel habit. CONNELL *et al.* [1965] suggest that bowel action less than 3 times weekly or more than 3 times daily should alert the doctor to consider disease as a cause. In the present study the man with the carcinoma of the rectum presented at one extreme of the frequency distribution with 4 bowel movements per day.

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Appendix A

Questions asked concerning bowel habit

(1) How often do your bowels move?
(2) Has there been any recent change in this?
(3) If so, are you troubled with — diarrhoea / constipation / both
(4) If diarrhoea, is it — recent / long-standing
What if any is the reason for it?
(5) If constipation, is it — recent / long-standing
What if any is the reason for it?
(6) Do you take any opening medicine or laxatives?
If yes, do you take it regularly or only when needed?

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THE FEET OF OLDER PEOPLE

By J. S. Milne* and J. Williamson**

Information was collected about pathological conditions of the feet during the first examination in a comprehensive longitudinal study of ageing persons being carried on in Edinburgh. The subjects examined were 215 men and 272 women aged 62–90 years who formed a simple random sample of the 27,000 older people living in a defined area of the city. The method of sampling with a comparison of respondents and non-respondents has been described elsewhere (Milne et al. 1971).

Methods

One question in a structured questionnaire about physical health ascertained whether the subject attended anywhere for chiropody and if so whether attendance was regular. Both feet were examined during the physical examination and the presence or absence of the conditions listed in Table 1 recorded. All examinations were made by one observer (J. S. M.).

TABLE 1. Abnormal conditions of feet in older people with prevalence of disability and use of chiropody

Foot condition	Condition absent	Condition present	Number with disability	Number of disabled who use chiropody	Per cent. of sample with condition	Per cent. of sample with disability	Per cent. of sample with disability without chiropody	No data
Men								
Corns	152	60	11	3	28·3	5·2	3·8	3
Hallux valgus	139	73	3	2	34·4	1·4	0·5	3
Bursitis	191	21	3	1	9·9	1·4	0·9	3
Onychogryphosis	173	39	17	4	18·4	8·0	6·1	3
Hammer toe	184	28	3	1	13·2	1·4	0·9	3
Hallux rigidus	199	13	1	0	6·1	0·5	0·5	3
Metatarsalgia	129	82	3	3	38·9	1·4	—	4
Pes cavus	192	19	1	1	9·0	0·5	—	4
Women								
Corns	86	180	38	17	67·7	14·3	7·9	6
Hallux valgus	71	195	10	6	73·3	3·8	1·5	6
Bursitis	143	123	21	11	46·2	7·9	3·8	6
Onychogryphosis	221	45	12	6	16·9	4·5	2·3	6
Hammer toe	227	39	8	3	14·7	3·0	1·9	6
Hallux rigidus	257	9	0	0	3·4	0	—	6
Metatarsalgia	86	179	14	12	67·5	5·3	0·8	7
Pes cavus	250	16	1	1	6·0	0·4	—	6

Results

The prevalence of the various conditions is given in Table 1 which also shows the amount of disability in the sample caused by foot trouble and the percentage of the sample who have disability of the feet but do not attend for chiropody. Corns, hallux valgus with associated bursitis and metatarsalgia have a prevalence in women more than twice that in men ($p<0{\cdot}01$). There is no significant sex difference in the prevalence of onychogryphosis, hammer toe, hallux rigidus or pes cavus.

Of the conditions listed an age difference in prevalence is found only in hammer toe in men. A significantly greater proportion of men of 70 years and over have hammer toe compared with men less than 70 years ($p<0{\cdot}01$).

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THE FEET OF OLDER PEOPLE

By J. S. Moore* and J. Williamson**

Information was collected about pathological conditions of the feet during the first examination in a comprehensive longitudinal study of ageing currently being carried out in Edinburgh. The subjects examined were [illegible] men and [illegible] women aged [illegible] years who formed a simple random sample of the [illegible] older people living in a defined area of the city. The method of sampling, with a comparison of respondents and non-respondents, has been described elsewhere (Milne et al. 1971).

Methods

One question in a structured questionnaire about physical health asked whether the subjects attended [illegible] a chiropodist and, if so, whether their attendance was regular. Both feet were examined during the physical examination and the presence or absence of the conditions listed in Table I recorded. All examinations were made by one observer (J. S. M.).

TABLE I. [illegible]

Foot condition	[illegible]
Men	
Corns	[illegible]
Hallux valgus	[illegible]
Bunions	[illegible]
[illegible]	[illegible]
Hammer toe	[illegible]
Hallux rigidus	[illegible]
Metatarsalgia	[illegible]
[illegible]	[illegible]
Women	
Corns	[illegible]
Hallux valgus	[illegible]
Bunions	[illegible]
[illegible]	[illegible]
Hammer toe	[illegible]
Hallux rigidus	[illegible]
Metatarsalgia	[illegible]
[illegible]	[illegible]

Results

The prevalence of the various conditions is given in Table I which also shows the amount of disability in the sample caused by foot trouble and the percentage of the sample who have disability of the feet but who do not attend for chiropody. Corns, hallux valgus with associated bunions and metatarsalgia have a prevalence in women more than twice that in men [illegible]. There is no significant sex difference in the prevalence of the [illegible].

Of the conditions listed an age difference in prevalence was found only in hammer toe in men. A significantly greater proportion of men [illegible] years and over have hammer toe compared with men less than [illegible].

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Chiropody services are used by 24 per cent. of the men and 51 per cent. of the women in the sample. The greater usage by women is significant ($p<0{\cdot}01$). Usage is occasional in 5 per cent. of the men and 10 per cent. of the women. No age difference in the use of chiropody is found in women, the percentages of users above and below 70 years being respectively 53 per cent. and 49 per cent. The corresponding percentages in men are 36 per cent. and 15 per cent., this difference being significant, ($p<0{\cdot}01$). If users and non-users of chiropody are compared in respect of the conditions listed in Table 1, no significant relationship emerges in men. In women, a greater proportion of those with hallux valgus ($p<0{\cdot}01$) and with onychogryphosis ($p<0{\cdot}05$) make use of chiropody than do persons without these conditions.

Disability is defined in this paper as present if the pathological condition of the foot acts in such a way as to increase the difficulties of ordinary living in older people. A severe condition alleviated by chiropody is not said to cause disability. With this definition in mind, Table 1 shows the commonest disability in men to be onychogryphosis with 8 per cent. of the sample affected, most of whom have no treatment. The only other common disability in men is from corns and three quarters of the affected persons do not seek treatment. Corns are by far the commonest cause of foot disability in women. More than half of those affected are not professionally treated. The group of related conditions (hallux valgus, bursitis and metatarsalgia), besides being common in women, are important causes of disability. It is seen from the table that metatarsalgia seems to lead most men and women who have it to seek chiropody. Onychogryphosis remains an appreciable cause of disability in women.

The numbers of persons with multiple abnormalities of the feet are given for men and women in Table 2. The columns of the table give the numbers

TABLE 2. Multiple Abnormal Conditions of the Feet in Older Men and Women. Percentages in Brackets

Sex	Number of abnormal conditions of feet							No data	Totals
	0	1	2	3	4	5	6		
Men ..	51 (24·2)	65 (30·8)	48 (22·7)	25 (11·8)	14 (6·6)	5 (2·4)	3 (1·4)	4	215
Women	19 (7·2)	24 (9·1)	54 (20·4)	65 (24·5)	62 (23·4)	39 (14·7)	2 (0·8)	7	272

of persons with none and one or more up to six of the abnormal conditions listed in Table 1. No person was found to have more than six of the conditions. This table reveals that 24 per cent. of the men but only 7 per cent. of the women suffer from none of these conditions. It is also apparent that a greater proportion of women compared with men have two or more disabilities simultaneously.

The nutrition of the skin of the toes was thought to be inadequate in five men and three women, all of whom had peripheral arterial disease. One of the men had actual necrosis. Erythema ab igne was noted in 11 per cent. of women and 4 per cent. of men, being significantly commoner in women ($p<0{\cdot}01$).

Discussion

Sheldon (1948) investigated feet in the Wolverhampton survey by questioning without examination. Trouble with their feet was admitted by 26·1 per cent.

of the men and 44·6 per cent. of the women. These figures would underestimate prevalence in the present study but would overestimate disability. However, disability in the present study may have a lower prevalence because of the increase in chiropody services since 1948. Sheldon did not find the sex difference in prevalence of corns reported in this paper but did report a greater female prevalence of bunions and other deformities. He noted disablity to be commoner in older than in younger men, but to be equally common in women in the whole age range of his survey. This is perhaps reflected in the present report by the increased use of chiropody by older compared with younger men, but not by older compared with younger women. The estimate by Sheldon that 28 per cent. of his sample needed chiropody although only 5 per cent. obtained it, shows an interesting difference from the 31 per cent. of the present sample who use chiropody services regularly.

In Sheffield, Hobson and Pemberton (1955) reported foot abnormalities similar to those reported here although they saw plantar warts which were not found in the present study. They found a female preponderance of most abnormalities with an equal sex prevalence for onychogryphosis. Their estimate that 67 per cent. of men and 70·9 per cent. of women would have benefited from chiropody is rather larger than that suggested by the present study.

Exton-Smith (1960) giving details of 120 older people being treated by chiropodists finds corns and callosities as the commonest conditions with thickening of nails as the next commonest group. He mentions an estimate by the National Corporation for the Care of Old People that about 20 per cent. of the older population might be expected to need chiropody. In the present Edinburgh sample even with 31 per cent. receiving regular treatment there are 3·8 per cent. of all the men and 7·9 per cent. of all the women who have corns and need but do not seek treatment.

Shine (1965) demonstrated the importance of shoes as a cause of foot trouble when he surveyed the partially shoe wearing community of St. Helena, where only 2 per cent. of unshod persons had hallux valgus. In persons who had worn shoes for 60 years 16 per cent. of men and 48 per cent. of women suffered from hallux valgus. These prevalence figures are lower than those in the present study but reflect the same sex difference.

The results of a survey in a state geriatric institution in Pennsylvania (Helfand 1969) agree with the present study in demonstrating a greater prevalence of corns and hallux valgus in women and a greater proportion of men compared with women who have no abnormal foot conditions.

Good mobility is important especially in the elderly. The present study reports a proportion of older persons with disabling foot conditions who do not use the chiropody service. Treatment of these people could increase further the contribution already made by chiropody to the prevention of those mental and physical evils resulting from immobility in the elderly. The importance of such treatment has been emphasised by Neale (1968) in an article describing care of the feet in the elderly.

Summary

In a random sample of older people in Edinburgh common foot disabilities were corns, hallux valgus and metatarsalgia, all with a preponderance in women while onychogryphosis and other deformities were less common and without a sex difference in prevalence. Although 31 per cent. of the sample

received chiropody regularly, a substantial proportion of persons, particularly with corns and onychogryphosis, lacked the chiropody required.

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MODERN GERIATRICS

Urinary Symptoms in Older People

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Urinary Symptoms in Older People

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Few population studies have been made of urinary infection in older people(1,2), hence urinary symptoms and bacteriuria have been studied during the first examination in a longitudinal study of ageing persons being carried out in Edinburgh. The subjects were 215 men and 272 women aged 62-90 years who formed a random sample from a population of 27,000 older people living in a defined area of Edinburgh. The method of sampling has been described elsewhere(3) with a comparison of respondents and non-respondents.

METHODS

A questionnaire by one of us (J.S.M.) was used to collect information about urinary symptoms under the headings of present and past pain on urination, frequency of passing urine, nocturia and history of past urinary infection. Four questions about urgency, stress and noticing wetness at night, or at any other time, were used to investigate incontinence of urine. To assess prostatic symptoms men were also asked about difficulty in starting urination, alteration in the stream, dribbling and retention of urine. Reproducibility of the questionnaire was tested before the study began(4). Midstream urines were collected without washing by asking women to separate the labia, start passing urine and, without stopping the flow, to insert a waxed cardboard container into the stream. This method was found satisfactory in general practice(5). Men were asked to retract the foreskin, start passing urine and then to insert the container into the stream without stopping the flow. The adequacy of these methods is confirmed by the fact that of 476 urines cultured, only 4 (1 male, 3 female) were contaminated.

Urine was cultured immediately in the Research Unit using a 3 mm loop dipped vertically into the uncentrifuged urine and spread over one quadrant of medium in a Petri dish. Media used were McConkey's medium and blood agar. Plates were incubated overnight at 37 °C, the remaining urine being refrigerated meanwhile. Any urine which grew 100 or more colonies was sent in a refrigerated container to the Bacteriology Laboratory, City Hospital, Edinburgh, where a quantitative culture was done and sensitivities determined. The accuracy of this method had been tested earlier by sending 50 urines to the laboratory after culture in the Research Unit. Of 24 urines found in the Research Unit to have 100 or more colonies, the laboratory isolated an organism in significant numbers (100,000 per ml) in 13. There were no false negatives from the Research Unit. This technique was used to save laboratory time. Any urine with no growth in the Research Unit was not further examined. Labstix (Ames Company) were used to test for proteinuria.

The diagnosis of Chronic Brain Syndrome was made after full psychiatric examination by one of us (M.M.M.).

RESULTS

These are reported for individual symptoms:

1. Present pain on passing urine

'*Have you any pain on passing urine at present?*' Relatively few men and women in the sample admitted present dysuria (Table I). The symptom was significantly commoner in older compared with younger women (Table II) but not in older compared with younger men.

2. Past pain on urination

'*Have you ever had such pain in the past?*' This was a common symptom, especially in women (Table I). Just under half of the men and women admitting dysuria had experienced more than one episode. A greater proportion of the women (77%) compared with

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Table 1

URINARY SYMPTOMS IN OLDER MEN AND WOMEN

	Males				*Females*					
Symptom	*Yes*	*% Yes*	*No*	*No data*	*Yes*	*% Yes*	*No*	*No data*	χ^2	*p*
Present dysuria	9	4·2	204	2	7	2·6	261	4	0·95	>0·05
Past dysuria	23	10·9	188	4	64	23·9	204	4	13·34	<0·01
Increased frequency	71	33·3	142	2	62	23·1	206	4	6·06	<0·05
Past frequency	15	7·2	193	7	35	13·2	231	6	4·45	<0·05

Table 2

THE FREQUENCY AND SEVERITY OF NOCTURIA IN THREE AGE GROUPS OF OLDER PEOPLE
Brackets contain percentages of row totals

	Nocturia					
	None	*Once*	*Twice*	*> Twice*	*No information*	*N*
Males						
62-69	77 (63·6)	33 (27·3)	7 (5·8)	4 (3·3)	1	122
70-79	27 (37·5)	23 (32)	17 (23·6)	5 (6·9)	1	73
80+	5 (25)	8 (40)	5 (25)	2 (10)	0	20
All males	109 (51·2)	64 (30)	29 (13·6)	11 (5·2)	2	215
Females						
62-69	64 (47)	47 (34·6)	17 (12·5)	8 (5·9)	1	137
70-79	41 (41)	28 (28)	20 (20)	11 (11)	1	101
80+	9 (28)	10 (31·4)	6 (18·7)	7 (21·9)	2	34
All females	114 (42·5)	85 (31·7)	43 (16·1)	26 (9·7)	4	272

the men (52%) with dysuria had experienced the first episode more than five years before being examined. This difference, which was significant, suggested that the first episode of dysuria might tend to occur earlier in life in women. Past dysuria was admitted by a significantly greater proportion of older compared with younger women (Table 11). The same was not true of older men (Table 10).

3. Present frequency of urination

'*Has there been any change in how often you pass urine in a day?*' Significantly more men than women admitted increased frequency (Table 1). Of those with increased frequency, in both sexes 70% had developed the symptom in the previous five years. It was significantly commoner in older compared with younger women, but not in older compared with younger men. Past incidents of frequency are commoner in women than in men (Table 1) and a greater proportion of women than men had first experienced the symptom more than five years previously.

4. Nocturia

'*Do you rise to pass urine at night?*' This symptom was admitted by half the sample with no sex difference in prevalence (Table 2). The table suggests that the

Table 3 THE AGE DIFFERENCE IN THE PROSTATIC SCALE IN MEN				
	Score on prostatic scale			
Age group	<2	>2	%>2	*Total*
62-69	87	34	(28)	121
70-79	42	30	(41·7)	72
80+	9	11	(55)	20
				213

χ^2 6·74. Degrees of freedom 2. $0{\cdot}01 < p < 0{\cdot}05$.

Table 4 'HAVE YOU EVER HAD CYSTITIS OR A CHILL OR INFECTION IN YOUR BLADDER?' (WOMEN ONLY)			
Answer	*Number*	*Past symptoms*	*Number*
Yes	66	none	21
		dysuria alone	17
		frequency alone	2
		dysuria and frequency	26
No	~~15~~ 22	dysuria alone	15
		frequency alone	1
		dysuria and frequency	6
			88

Table 5 INCONTINENCE OF URINE IN OLDER MEN AND WOMEN				
	Incontinence			
	None	*Mild*	*Severe*	*Total*
Men	161 (75%)	43 (20%)	11 (5%)	215
Women	158 (58%)	102 (37·5%)	12 (4·5%)	272

χ^2 17·63, D.f. 2, $p < 0{\cdot}01$.

Table 6 INCONTINENCE AND DEMENTIA IN OLDER MEN AND WOMEN. Percentages of row totals in brackets				
	Chronic brain syndrome			
Incontinence	*None*	*Mild*	*Severe*	*Totals*
Males				
None	152	7 (4·3)	2 (1·2)	161
Mild	41	2 (4·7)	0 (0)	43
Severe	9	0 (0)	2 (22·2)	11
				215
Females				
None	145	9 (5·7)	4 (2·5)	158
Mild	92	6 (5·9)	4 (3·9)	102
Severe	7	1 (8·3)	4 (33·3)	12
				272

proportion of men with nocturia increases as age increases, and that the proportion of men getting up more than once nightly rises with age. Only the latter is statistically significant in men above and below 70 years. Only 5% of men get up more than twice nightly. Age effects in women are similar but 10% of all the women get up more than twice each night.

5. Prostatic symptoms

A scale with a maximum value of 8 was constructed to describe these, one point being scored for each of *dysuria*, *frequency by day*, *nocturia*, *difficulty in starting urination*, *weakening of stream*, *dribbling history of retention* and *history of infection*. Of 215 men, 11 had had a prostatectomy, 3 had prostatic carcinoma and 2 were demented. Of the remaining 199, 46 scored zero on the scale, 92 scored 1 or 2 and the remaining 61 scored from 3 to 7. Table 3 shows the data arranged for men in 3 age groups with scores of up to 2 and more than 2. The data have been split at 2 because disability from prostatic symptoms is slight at this point, e.g. some frequency by day and up once at night. The 14 men with prostatectomy and carcinoma mentioned above have been included in Table 3 as scoring more than 2. The increase in the proportion of men with a score greater than 2 as age increases is statistically significant.

6. A history of past urinary infection

This is present in 11% of men and 33% of women, the difference being highly significant. A history of past infection is recorded in the present study in those who answer 'yes' to a question about '*cystitis, chill or infection in the bladder*' and in those who have a history of previous dysuria, or increased frequency, or both. As shown in Table 4 these criteria lead to a presumptive diagnosis of past urinary infection in 88 women, which leaves 180 women with a negative history and 4 in whom no history was available. Figures extracted from the records of a general practice in East Lothian, 12 miles east of Edinburgh, in 1962 [Milne(6)] revealed that in the previous sixteen years 46 of 166 women aged 62 or more in 1962 had had a urinary infection. This information was based on a diagnosis made at the time of infection. Comparison of the Edinburgh and East Lothian figures gives χ^2 1·28 and $p > 0{\cdot}05$. This suggests the questions used in the survey are reasonably good estimators of past urinary infection when compared with contemporary records of infection. Examination of the proportions of men and women above and below the age of 70 years with a previous urinary infection (Tables 10 and 11) reveals no significant age difference in either sex.

7. Incontinence of urine

This was estimated by 4 questions except in the case of 2 men and 3 women severely demented for whom statements by the ward sister were used to answer the questions.

(a) *Do you lose control of your bladder if unable to go to the lavatory as soon as you need to pass urine?* 20% of all men and women were troubled in this way.

(b) *Does your urine come away if you cough or sneeze?* 6% of men and 31% of women had stress incontinence. (χ^2 49·53, $p < 0{\cdot}001$).

Table 7

BACTERIURIA IN OLDER MEN AND WOMEN

	Bacteriuria					
	Present	*% Present*	*Absent*	*Contaminated*	*No information*	*Total*
Males	6	(2·8)	205	1	3	215
Females	30	(11·5)	231	3	8	272

χ^2 12·19 Degrees of freedom 1 $p < 0{\cdot}001$

Table 8

BACTERIURIA COMPARED WITH URINARY SYMPTOMS IN 260 OLDER WOMEN

Symptom		*Bacteriuria* Absent	*Bacteriuria* Present	χ^2 all 1 degree of freedom
Present dysuria	*absent*	225	~~5~~ 28	—
	present	~~28~~ 5	2	
Present frequency	*absent*	181	~~48~~ 21	
	present	~~21~~ 49	9	1·16
Nocturia	*absent*	98	~~132~~ 11	
	present	~~11~~ 132	19	0·40
Past dysuria	*absent*	177	~~53~~ 21	
	present	~~21~~ 53	9	0·71
Past urinary tract infection	*no*	160	~~70~~ 19	
	yes	~~19~~ 70	11	0·48
Proteinuria	*absent*	212	~~18~~ 27	corrected for continuity
	present	~~27~~ 18	3	0·005
Urgency	*absent*	185	23	
	present	45	7	0·235
Stress incontinence	*absent*	155	23	
	present	75	7	1·09
'Wet at night'	*no*	226	30	
	yes	4	0	—
'Wet other times as well'	*no*	225	29	
	yes	5	1	—

No information available in 12 women

(c) *Are you wet at night?* 2% of men and 3% of women were wet at night.

(d) *Are you wet at any other time?* 4% of men and 3% of women were incontinent by day.

The numbers of incontinent persons are rather small for significance testing in (c) and (d). If answers to (a) and (b) are combined as 'mild incontinence' and to (c) and (d) as 'severe incontinence', Table 5 shows the distribution of incontinence classified in this way in men and women in the sample. Inspection of the table shows 5% of men and 4·5% of women to have severe incontinence while 20% of men and 37·5% of women have mild incontinence. The significant difference present in the table is the result of the difference in the proportions of men and women with mild incontinence, due to a preponderance of stress incontinence in women. If Table 5 is collapsed into 11 men with and 204 without severe incontinence, and 12 women with and 260 without severe incontinence, the difference is not significant, i.e. men and women in the sample do not differ as regards the proportion with urinary incontinence except for the significantly greater proportion of women with stress incontinence.

Incontinence of urine, mild or severe, is compared with chronic brain syndrome, mild or severe, in Table 6. Chronic brain syndrome includes senile dementia, arteriosclerotic dementia and other organic brain conditions. Severe cases have obvious dementia. Mild cases are persons more demented than expected for the chronological age. The numbers with chronic brain syndrome are rather small but it can be seen from the table that in both sexes severe dementia is associated with severe incontinence.

Incontinence, defined as present if the answer to any of the 4 original questions is 'Yes', has been compared in men and women above and below 70 years (Tables 10 and 11). No significant age difference was found in either sex with this broad definition. There are too few persons with severe incontinence to examine the age effect.

Urine Examination

Proteinuria is present in some degree in 10% of the men and 8% of the women, no significant difference being present. Significantly more men over than under 70 have proteinuria but no age difference is found in women. (Tables 10 and 11.) Significantly more women (11·5%) than men (2·8%) have bacteriuria of 100,000 or more organisms per ml (Table 7). In both sexes all organisms except one were coliforms. The numbers in men are small, but in women the proportion with bacteriuria increases as age increases, 8% of those aged 62-69, 14% of those aged 70-79 and 30% of those aged 80 and over. Significantly more women over than under 70 are found to have bacteriuria. (Table 11.)

Table 9
BACTERIURIA COMPARED WITH URINARY SYMPTOMS IN 211 OLDER MEN

Symptom		*Bacteriuria*	
		Absent	*Present*
Present dysuria	*absent*	197	5
	present	8	1
Present frequency	*absent*	138	2
	present	67	4
Nocturia	*absent*	105	3
	present	100	3
Past dysuria	*absent*	181	5
	present	23	0
Past infection	*no*	184	5
	yes	21	1
Urgency	*absent*	167	3
	present	38	3
Stress incontinence	*absent*	194	6
	present	11	0
'Wet at night'	*no*	204	5
	yes	1	1
'Wet other times as well'	*no*	200	5
	yes	5	1
Proteinuria	*absent*	188	3
	present	17	3
Prostatic scale	< 2	134	3
	> 2	58	2

No information available in 4 men

Bacteriuria is compared with various urinary symptoms for women in Table 8, and for men in Table 9. In women there is no association in the sample between present bacteriuria and past dysuria, present frequency of passing urine, nocturia, past infection, urinary incontinence or proteinuria. In men the numbers with bacteriuria are too small for satisfactory statistics but the trend in Table 9 is the same as in women with the exception of proteinuria where the figures suggest an association of bacteriuria with proteinuria. If the prostatic scale is split at 2 as before the trend does not suggest any association with bacteriuria. Of the 14 persons with prostatectomy or carcinoma of prostate only 1 had bacteriuria.

DISCUSSION

Although many papers have been published about symptoms and urinary infection in the elderly only two (1,2) have based their report on study of the general population. Prevalence figures in the present study tend to be lower than the other two. Comparisons are made in Table 12 in which percentages are rounded to the nearest whole number.

Figures for frequency of passing urine by day in the present study are closer to those of Sourander(1) than

Table 10

AGE EFFECT IN URINARY SYM?TOMS IN OLDER MEN

Symptom or sign	*<70 years*		*> 70 years*		χ^2
	Symptom present	*Symptom absent*	*Symptom present*	*Symptom absent*	*(all 1 degree of freedom)*
Past dysuria	15	105	8	83	0·54
Present frequency	38	83	33	59	0·46
Incontinence	28	93	26	66	0·74
Past infection	14	107	9	83	0·16
Nocturia (Yes/No)	77	44	60	32	0·054
Proteinuria	7	114	14	78	5·17*

* Significant at 5% level

Table 11

AGE EFFECT IN URINARY SYMPTOMS IN OLDER WOMEN

Symptom or sign	*<70 years*		*> 70 years*		χ^2
	Symptom present	*Symptom absent*	*Symptom present*	*Symptom absent*	*(all 1 degree of freedom)*
Present dysuria	0	136	7	125	5·64*
Present frequency	22	114	40	92	7·58**
Past dysuria	40	96	24	108	4·62*
Incontinence	54	82	59	73	0·71
Nocturia (Yes/No)	72	64	82	50	2·27
Past infection	49	87	35	97	2·84
Proteinuria	7	128	15	113	3·68
Bacteriuria	10	124	20	107	4·40*

* Significant at 5% level   ** Significant at 1% level

Table 12

COMPARISON OF THREE POPULATION SURVEYS OF URINARY SYMPTOMS AND SIGNS IN OLDER PEOPLE (Percentages)

Symptom or sign	*Sourander*		*Brocklehurst et al.*		*Present study*	
	Male	*Female*	*Male*	*Female*	*Male*	*Female*
Frequency by day	25	25	14	9	33	21
Present pain on micturition	6	13	7	13	9	7
History of urinary infection	13	42	—	—	11	33
Nocturia	—	—	70	61	49	58
Nocturia x 1 nightly	56	67	38*	34*	62	55
Urgency	—	—	28	32	21	21
Stress incontinence	—	—	3	12	6	31
Bacteriuria	11	33	3 (<70) 20 (> 70)	20	3	12
Proteinuria	12	10	—	—	10	8

* Calculated from Tables 1, 4 and 5 (Brocklehurst *et al., 1971*)

of Brocklehurst *et al.*(2). This may be because the present authors ask if the subject passes urine more often than formerly, while Brocklehurst *et al.* use a two-hour interval to distinguish increased frequency. Both Brocklehurst *et al.* and the present study report significantly more men than women with this symptom.

Present pain on passing urine (which Brocklehurst *et al.* call 'scalding') has similar proportions in all three studies except for fewer women in the present one. Neither Brocklehurst *et al.* nor the present authors found a significant difference in prevalence between men and women. A history of previous urinary infection is recorded with similar prevalence by Sourander and the present authors.

Nocturia is more prevalent in males in the work of Brocklehurst *et al.* than in the present study, but prevalance is similar in the two studies in females.

For nocturia once nightly the present study agrees with Sourander, but the figures of Brocklehurst *et al.* comparing nocturia once nightly with more than once nightly in women above and below 70 years, report significantly more women above 70 who rise more than once ($p < 0 \cdot 01$). Similar breakdown of figures in the present study agrees ($p < 0 \cdot 05$). A comparison by Brocklehurst *et al.* of the proportion of men above and below 80 years rising once and more than once nightly again shows significantly more older men rising oftener than once nightly ($p < 0 \cdot 01$). The same breakdown in the present study shows a significant difference in men above and below 80, as well as in men above and below 70. By contrast it has been shown above that comparison of those with and without nocturia of any degree does not reveal a significant increase in the numbers with nocturia in men or women as age rises.

Precipitancy (or urgency) is more prevalent in both sexes in the study of Brocklehurst *et al.* than in the present study, but neither study detects a significant difference between the sexes.

Stress incontinence is reported by Brocklehurst *et al.* in 2·7% of males and 12% of females compared with 5·6% of men and 31·2% of women in the present study. Both studies report a significant difference between men and women. The very much larger prevalence of stress incontinence in the present study may reflect difference in the type of question asked. Brocklehurst *et al.* ask about stress after asking about incontinence in general, and only when that is present, whereas the present study asks all persons a question about stress incontinence. Other figures for incontinence in the three studies are not comparable.

Bacteriuria in women is reported by Sourander(1) as 33%, by Brocklehurst *et al.*(2) as 20% and in the present study as 11·5%. In the general female population Kass(7) reported significant bacteriuria (defined as 100,000 organisms per ml) in 6% of all females, a figure confirmed in East Lothian in 1966(5). Hagenfeldt *et al.*(8) found 16% of female hospital patients with bacteriuria whereas Marple(9) reported 31% and Loopuyt(10) had prevalences varying from 48% aged 60-69 to 80% over 80 years of age in hospital patients. On the other hand Kaitz and Williams(11) describing hospital patients reported bacteriuria in 15% of women under 70 and 30% over 70.

The results in respect of bacteriuria in the present study differ significantly from the other two surveys especially the Finnish one. The other 2 surveys cover women aged 65+ and the present study 62+.

When the prevalence of bacteriuria is compared in persons with and without symptoms, in women in the present study no significant association appears for bacteriuria with diurnal frequency, present pain on passing urine, nocturia or incontinence. Brocklehurst *et al.* agree with this and report a significant symptomatic association with bacteriuria only for difficulty in passing urine, whereas Sourander finds significant associations between bacteriuria and diurnal frequency, present pain on passing urine and incontinence. The figures for men in the present study are too small for comparison. Sourander and Brocklehurst *et al.* both report a significant association between history of prostatectomy and bacteriuria. In the present study one of 11 persons who had had a prostatectomy had bacteriuria.

Although no significant association was found in the present study between bacteriuria and incontinence, severe incontinence, as defined, was present in 23 patients of whom 2 had bacteriuria, 14 had no growth on culture and 7 urines were not examined. Six of the 7 unexamined urines relate to hospital patients who were suffering from severe dementia and severe incontinence and who came from the group where infected urine would be expected(12,13,14). Although the other 16 patients suffer from 'severe' incontinence as defined above, they are living at home and are much less disabled by incontinence than the hospital patients.

The association suggested by figures in the present study between chronic brain syndrome and incontinence is in line with the studies of Brocklehurst *et al.*(2) and Isaacs and Walkey(13).

SUMMARY

The prevalence of urinary symptoms and bacteriuria is described for a random sample of older people in Edinburgh. 4·2% of men and 2·6% of women have present

dysuria while 11% of men and 24% of women have had dysuria in the past; 33% of men and 23% of women have present frequency of urination; 7·2% of men and 13·2% of women have had frequency in the past; 49% of men and 57·5% of women have nocturia. Significantly more men and women over than under 70 years of age are up more than once at night. 69% of men have no or only minimal prostatic symptoms. Past infection had occurred in 10·8% of men and 32·8% of women. Mild incontinence occurred in 20% of men and 37·5% of women. Severe incontinence was present in 5% of men and 4·5% of women. Severe incontinence was associated with severe dementia. Proteinuria was found in 10% of men and 8·4% of women while bacteriuria occurred in 2·8% of men and 11·5% of women. Bacteriuria could not be shown to have association with present or past symptoms. Significant sex differences were found in the prevalence of present frequency (proportion greater in men) and of past dysuria, past frequency, past infection and stress incontinence (all proportions greater in women). Age differences showing a larger proportion over 70 years were noted in women with present dysuria, past dysuria, present frequency and bacteriuria and in men with prostatic symptoms and proteinuria. Men over 80 were more likely to have nocturia.

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The Ankle Jerk in Older People

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Abstract. Fewer people both male and female have ankle jerks as age increases. Significantly fewer women than men have an ankle jerk in the age group 63–69.

It has been stated that the ankle jerk is commonly absent over 70 years of age [HOWELL, 1947, 1970]. The present paper describes the numbers with and without an ankle jerk in 185 males and 210 females aged 63 years and upwards.

These people are those persons who in 1969 and 1970 have had a second examination in a longitudinal study of aging persons. The first examination in 1968 and 1969 included 215 men and 272 women born in 1905 or earlier and forming a random sample from a defined area of Edinburgh. This sample has been described elsewhere [MILNE *et al.*, 1971].

During clinical examination, the ankle jerk was tested with the patient lying supine, with the knee flexed and with slight contraction in the calf muscles. The ankle jerk was recorded as present if elicited on at least one side.

The results in men and women are shown in table I and table II respectively. These tables can be collapsed for males into table III and for females into table IV. It is clear from the tables that in both sexes the proportion of persons with an ankle jerk does diminish as age increases. χ^2 calculated for males in table III is 28.03 and for females in table IV is 8.36. In both there is one degree of freedom and in both P is <0.01. There are therefore significantly fewer males and females of 70 years and upwards who have ankle jerks than persons younger.

Table I. Ankle jerk in 3 age groups of older men

Age	Ankle jerk			
	Present	(% of row total present)	Absent	Total
63–69	80	(80%)	20	100
70–79	30	(46%)	35	65
80+	6	(30%)	14	20
				185

Table II. Ankle jerk in 3 age groups of older women

Age	Ankle jerk			
	Present	(% of row total present)	Absent	Total
63–69	63	(65%)	34	97
70–79	44	(52%)	41	85
80+	7	(25%)	21	28
				210

Table III. Ankle jerk in older men above and below 70 years

Age	Ankle jerk			
	Present	(% of row total present)	Absent	Total
<70	80	(80%)	20	100
$\geqslant 70$	36	(42%)	49	85
				185

If from the figures in table III and table IV the difference between proportions having an ankle jerk is examined in males and females less than 70 years, Z is 2.38 and $0.01 < P < 0.05$. The difference between proportions having an ankle jerk in males and females aged 70 years and more reveals Z to be 0.39 and $P > 0.05$.

Table IV. Ankle jerk in older women above and below 70 years

Age	Ankle jerk			
	Present	(% of row total present)	Absent	Total
<70	63	(65%)	34	97
≥70	51	(45%)	62	113
				210

This means that significantly fewer females than males have an ankle jerk under 70 years of age but this difference disappears after the age of 70.

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Leucocyte Ascorbic Acid Levels and Vitamin C Intake in Older People

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Summary

Leucocyte ascorbic acid (L.A.A.) levels and vitamin C intake were measured in a random sample of men and women aged 62-94 years. L.A.A. distributions are positively skewed but log normal. L.A.A. mean values show no age difference in men but are significantly lower in older women. The mean value for all women (23·88 μg/10⁸ cells) is significantly higher than that for all men (18·11 μg/10⁸ cells). L.A.A. values are significantly higher in both sexes in the six months July to December. Vitamin C intake distributions are positively skewed but not improved by log transformation. No significant age or sex differences were found except that a significantly greater proportion of men over than of those under 70 years have intakes less than 30 mg daily. Mean intake is significantly higher in men but not in women in the six months April to September, though in both sexes a significantly greater proportion have intakes less than 30 mg daily in October to March compared with April to September. Fifty per cent. of men and 58% of women have intakes less than 30 mg daily, 23·6% of men and 28·1% of women have intakes less than 20 mg daily, and 4·7% of men and 3% of women have intakes less than 10 mg daily. These percentages increase during the winter. A moderate correlation is present between vitamin C intake and L.A.A. level. L.A.A. levels increase in parallel with but lag behind seasonal increases in vitamin C intake.

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Introduction

Leucocyte ascorbic acid (L.A.A.) levels were shown to be a good indicator of the ascorbic acid content of the body by Crandon *et al.* (1940). Since ascorbic acid status is important in clinical geriatrics, L.A.A. levels and vitamin C intake were measured in a longitudinal study of ageing persons being carried out in Edinburgh. The persons studied were 215 men and 272 women aged 62-94 years who were a random sample of 27,000 older people living in a defined area of the city. The method of sampling with a comparison of respondents and non-respondents has been described elsewhere (Milne *et al.*, 1971). The examinations were performed during the period January 1968 to January 1970.

Methods

L.A.A. was measured by the method of Denson and Bowers (1961). Preliminary work showed that specimens taken too late for analysis on the same day were satisfactory on the next, provided the supernatant fluid was removed immediately the red cells had sedimented and refrigerated until analysed. To ensure uniformity all specimens were treated in this way and sent to the laboratory as soon as possible after collection. Any specimen not analysed within 24 hours was rejected. Results were obtained in 204 men and 247 women. Data are missing in 36 persons because of delay or damage in transit, technical difficulties in the laboratory, or failure to obtain blood.

Dietary histories covering one week were obtained by one of us (M.E.L.) from 212 men and 263 women. These histories were taken within a few days of the blood being taken for analysis. Food tables prepared by the Ministry of Health were used to calculate the vitamin C intake. Since the initial examinations in the longitudinal study were spread over two years, vitamin C intake and L.A.A. were measured at all seasons.

All subjects in the study had a full clinical examination. No person had signs of scurvy but two men, one of whom had previously been in hospital with scurvy, had an L.A.A. level of zero. The data were examined by standard statistical methods (Snedecor and Cochran, 1967).

Reproducibility of L.A.A. Assay.—From each person 6 ml of blood was taken, 3 ml being placed in each of two universal containers with diluent and treated as described above. This procedure was carried out in 10 people, each of whom therefore had two assays of L.A.A. performed on blood taken at the same time. The mean difference between paired specimens was 5·36 $\mu g/10^8$ W.B.C. and the standard deviation of the mean difference was 4·63 (calculated from $\sqrt{\Sigma d^2 \div 2n}$).

Results

L.A.A. AND AGE

The distributions of L.A.A. levels in men and women are shown in Fig. 1. These are positively skewed with positive kurtosis. Logarithmic transformation of the data produces the distributions shown in Fig. 1, which do not differ significantly from

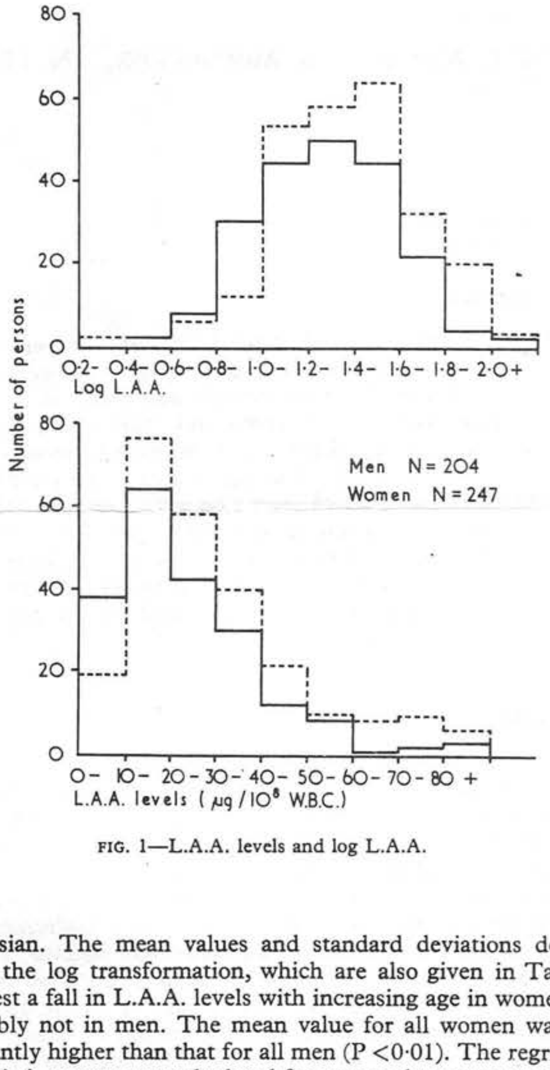

FIG. 1—L.A.A. levels and log L.A.A.

Gaussian. The mean values and standard deviations derived from the log transformation, which are also given in Table I, suggest a fall in L.A.A. levels with increasing age in women but possibly not in men. The mean value for all women was significantly higher than that for all men ($P < 0{\cdot}01$). The regression of L.A.A. on age was calculated for men and women separately, the equations being, in men,

$$\text{Log L.A.A.} = 1{\cdot}3046 - 0{\cdot}00067 \times \text{age (S.E.E. } 0{\cdot}0035)$$

and in women,

$$\text{Log L.A.A.} = 2{\cdot}0183 - 0{\cdot}00899 \times \text{age (S.E.E. } 0{\cdot}00281).$$

The decrease in L.A.A. with increasing age is significant in women ($P < 0{\cdot}01$) but not in men.

From Table II it can be calculated that 52% of men in the age group less than 70 years have L.A.A. levels less than 20 μg and 51% of men in the age group 70 years or over have such levels. The difference between these groups is not significant. A similar age division in women shows 30% of those less than 70 years and 47% of those of 70 years and over have L.A.A. levels less than 20 μg. The difference between these groups is significant (χ^2 7·71, $P < 0{\cdot}01$)—that is, a greater proportion of older women have lower levels of L.A.A.

TABLE I—*Mean Values in μg/10⁸ W.B.C. and Standard Deviations of L.A.A. (Derived from Log Distribution) in Three Age Groups of Older Men and Women*

Age	Men			Women		
	Mean	S.D.	N	Mean	S.D.	N
62-69 years	17·70	8·70	115	26·42	13·04	129
70-79 ,,	19·82	11·21	71	23·23	11·51	89
80+ ,,	14·62	6·32	18	16·52	8·77	29
All	18·11	9·38	204	23·88	11·83	247

TABLE II—*L.A.A. Levels in Three Age Groups in Older Men and Women*

Sex and Age	L.A.A. (μg/10⁸ W.B.C.)				No Data	N
	<10	10-19	20-29	≥30		
Men:						
62-69	23	37	29	26	7	122
70-79	14	18	11	28	2	73
80+	3	10	3	2	2	20
Total	40	65	43	56	11	215
Women:						
62-69	6	33	36	54	8	137
70-79	8	28	19	34	12	101
80+	5	15	3	6	5	34
Total	19	76	58	94	25	272

SEASONAL VARIATION IN L.A.A.

The seasonal variation in L.A.A. levels is shown in Table III. The mean value for men in the second six months of the year is significantly higher than in the first six months ($P < 0{\cdot}01$).

TABLE III—*Mean Values for L.A.A. Levels (Derived from Log Distribution) in Quarters of the Year in Older Men and Women (μg/10⁸ W.B.C.)*

Sex and Quarter	Mean	S.D.	N	t
Men:			204	
January-March ..	15·38	7·60	57	
April-June	15·17	6·91	49	
July-September ..	25·70	10·53	38	
October-December	23·39	11·40	60	
January-June ..	15·28	7·24	106	5·13
July-December ..	24·21	11·15	98	P<0·01
Women:			247	
January-March ..	21·23	10·49	73	
April-June	22·18	11·99	64	
July-September ..	24·21	11·79	45	
October-December	27·99	13·77	65	
January-June ..	21·68	10·47	137	2·13
July-December ..	26·36	12·91	110	P<0·05

A similar, less striking, but nevertheless significant trend is present in women ($P < 0{\cdot}05$). The difference between mean values for men and women in the six months January to June is significant ($P < 0{\cdot}01$) but the difference in the six months July to December is not. Women seem to have significantly higher L.A.A. levels than men in the first six months of the year only.

In the six months January to June 68% of men have levels less than 20 μg in contrast to 33% of men with such levels in the six months July to December (computed from Table IV). The

TABLE IV—*L.A.A. Levels in Different Quarters of the Year in Older Men and Women*

Sex and Quarter	L.A.A. (μg/10⁸ W.B.C.)				N
	<10	10-19	20-29	≥30	
Men:					
January-March ..	18	19	10	11	58
April-June ..	10	26	7	7	50
July-September ..	3	6	13	15	37
October-December	9	14	13	23	59
Whole year ..	40	65	43	56	204
Women:					
January-March ..	6	29	16	22	73
April-June ..	5	23	7	29	64
July-September ..	3	11	17	14	45
October-December	5	13	18	29	65
Whole year ..	19	76	58	94	247

difference between these groups is significant (P <0·01). In women in the six months January to June 46% have levels less than 20 μg compared with 29% with such levels in the six months July to December. The difference between these groups is also significant (P <0·01).

VITAMIN C INTAKE AND AGE

Frequency distributions for vitamin C intake in men and women are shown in Fig. 2. Though these distributions are positively skewed and have positive kurtosis in women, logarithmic

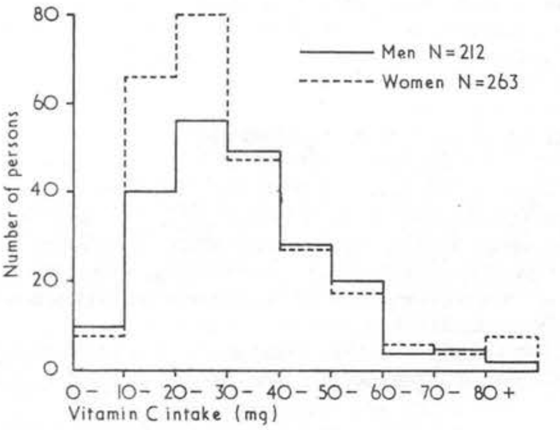

FIG. 2—Frequency distribution for vitamin C intake.

transformation does not bring them any nearer a Gaussian distribution. They are therefore reported untransformed. The mean intake for all men (32·43 mg, S.D. 15·95, N 212) does not differ significantly from that for all women (31·48 mg, S.D. 19·50, N 263). No significant age difference is found by the regression of vitamin C intake on age in men and women separately.

Calculation based on Table V shows that 42% of men under 70 years have a vitamin C intake of less than 30 mg daily compared with 59% of men of 70 years and over. The difference between these groups is significant (χ^2 6·11, P <0·05). In women under 70 years 54% have an intake of less than 30 mg daily compared with 64% of those 70 years and over. The difference is not significant. Comparison of the sexes shows 50% of men and 58% of women with intakes of less than 30 mg

TABLE V—*Vitamin C Intake in Three Age Groups in Older Men and Women*

Sex and Age	Vitamin C Intake (mg Daily)				No Data	N
	<10	10-19	20-29	⩾30		
Men:						
62-69 ..	2	22	27	70	1	122
70-79 ..	8	10	22	31	2	73
80+ ..	0	8	6	6	0	20
Total ..	10	40	55	107	3	215
Women:						
62-69 ..	4	29	39	62	3	137
70-79 ..	3	22	34	39	3	101
80+ ..	1	15	7	8	3	34
Total ..	8	66	80	109	9	272

daily. The difference is just significant (χ^2 3·86, P <0·05) suggesting that a marginally greater proportion of women than men have intakes of less than 30 mg daily. In men intakes of less than 10 mg daily occur in 4·7%, of less than 20 mg daily in 23·6%, and of less than 30 mg daily in 50%. In women intakes of less than 10 mg daily occur in 3%, of less than 20 mg daily in 28·1%, and of less than 30 mg daily in 58%.

SEASONAL VARIATION IN VITAMIN C INTAKE

In contrast to L.A.A. levels, in men lower values for vitamin C intake are in the first and fourth quarters of the year and higher values in the second and third quarters (Table VI). The difference in men between the means for the six-month periods October to March and April to September is significant (P <0·01). In women the means for the six-month periods do not differ significantly. Comparison of the differences in men and women between the means for the six-month periods shows no significant difference for October to March or for April to September.

TABLE VI—*Mean Values for Vitamin C Intake in Quarters of the Year in Older Men and Women (mg Daily)*

Sex and Quarter	Mean	S.D.	N	*t*
Men			212	
January-March ..	28·54	15·49	58	
April-June ..	34·23	16·79	50	
July-September ..	38·45	16·47	43	
October-December	30·46	14·35	61	
October-March ..	29·78	14·70	119	2·95
April-September ..	36·18	16·70	93	P<0·01
Women:			263	
January-March ..	28·54	21·47	78	
April-June ..	37·48	23·14	67	
July-September ..	29·63	12·14	50	
October-December	30·49	16·77	68	
October-March ..	29·45	19·37	146	1·93
April-September ..	34·12	19·54	117	N.S.

In men examined in the six months October to March 63% have an intake of less than 30 mg daily compared with 39% in the six months April to September (computed from Table VII). The difference is significant (χ^2 7·82, P <0·01). In women 65% have an intake of less than 30 mg in the six months October to March compared with 51% in the six months April to September. This difference also is significant (χ^2 5·04, P <0·05).

TABLE VII—*Vitamin C Intake in Different Quarters of the Year in Older Men and Women*

Sex and Quarter	Vitamin C Intake (mg Daily)				N
	<10	10-19	20-29	⩾30	
Men:					
January-March ..	3	16	19	20	58
April-June ..	2	8	12	28	50
July-September ..	2	4	8	29	43
October-December	3	12	16	30	61
Whole year	10	40	55	107	212
Women:					
January-March ..	3	24	24	27	78
April-June ..	2	18	9	38	67
July-September ..	1	10	20	19	50
October-December	2	14	27	25	68
Whole year	8	66	80	109	263

RELATION BETWEEN L.A.A. AND VITAMIN C INTAKE

The relation between L.A.A. levels and vitamin C intake is shown in Table VIII. Data from this table were used to compare, in the sexes separately, L.A.A. levels above and below 20 μg with vitamin C intakes above and below 30 mg daily. The association was highly significant (χ^2 for men 22·92, for women 17·61), suggesting in both sexes that lower values of vitamin C intake are associated with lower L.A.A. levels and vice versa.

Zero order correlation coefficients were calculated between vitamin C intake and L.A.A. level in the three age groups in men and women. The correlation was never more than moderate (r for all men 0·45 and for all women 0·36) with a range of values in the different age and sex groups from 0·12 to 0·62. Linear regressions were calculated in the hope of predicting vitamin C intake from L.A.A. level, but the confidence limits proved to be

TABLE VIII—*Vitamin C Intake Compared with L.A.A. Levels in Older Men and Women*

L.A.A. (µg/10⁸ W.B.C.)	Vitamin C Intake (mg Daily)				Total
	<10	10–	20–	≥30	
Men:					215
<10	6	12	16	5	39
10–	2	17	15	31	65
20–	0	5	14	23	42
≥30	1	3	8	44	56
Absent or incomplete					13
Women:					272
<10	3	8	3	2	16
10–	3	28	22	20	73
20–	1	13	18	25	57
≥30	1	10	29	54	94
Absent or incomplete					32

so large that the prediction would be of no value in clinical work. The regressions are therefore not reported.

Discussion

Comparisons with other studies of L.A.A. are difficult because of the transformation of data in the present study into logarithms. The untransformed data are so skew that mean values are misleading and it would be necessary to use the median as a measure of central tendency. Log transformation is justified not only because it produces distributions not differing significantly from the Gaussian distribution but also because it stabilizes the variance. While direct comparison of mean values with those described elsewhere is not possible, reported effects of age, sex, and season can be compared. Brook and Grimshaw (1968) found no significant changes in L.A.A. levels as age increased, and Kataria *et al.* (1965) thought mean values in older people at home did not differ significantly from those in younger normal people. This is in contrast to the present findings of significant decrease with increasing age in mean values in women. Other studies have reported mean values in older people at home considerably lower than those in younger people (Bowers and Kubik, 1965; Andrews *et al.*, 1966). Seasonal changes in L.A.A. level were described by Andrews *et al.* (1966). They found levels higher in October than in February, but the difference was small in old people at home. By contrast the present study shows well-marked seasonal differences in men but less so in women.

It has been suggested (Department of Health and Social Security, 1969) that a vitamin C intake of 30 mg daily is adequate for human needs. Indeed this is three times the dose needed to cure or prevent experimental scurvy in human volunteers (Bartley *et al.*, 1953). Nevertheless, Allen *et al.* (1968), in a survey of 250 households in the United Kingdom, found 25% with intakes of less than 30 mg per person per day and 5% with intakes of less than 20 mg per person per day. They also found that in February and March 54% of households examined failed to achieve an average intake of 31 mg per person per day. Intakes have been reported as highest in the third quarter and lowest in the first quarter of the year (*Nutrition Reviews*, 1969). Disregarding season 50% of men and 58% of women in the present study have intakes of less than 30 mg daily, 24% of men and 28% of women have intakes of less than 20 mg, and 4·7% of men and 3% of women have intakes below 10 mg daily, a level indicated above as coming close to that which can produce scurvy. In the six months October to March 63% of men and 65% of women have intakes of less than 30 mg daily. Intakes described by Andrews *et al.* (1966) in outpatients had as the lower limit of the range 15 mg in October and 10 mg in February. Exton-Smith (1970) found in elderly women living alone a mean daily intake of 37·6 mg of ascorbic acid but 45% had intakes of less than 30 mg and 10% of less than 10 mg. It seems that in Edinburgh at the present time half of the older people studied have intakes below the recommended level.

Several workers (Bowers and Kubik, 1965; Brocklehurst *et al.*, 1968; Andrews *et al.*, 1969) have reported rises in mean L.A.A. level after the administration of vitamin C. The present study offers no information about this, but the L.A.A. levels rise in the second half of the year in parallel with, but lagging behind, the rise in vitamin C intake in the summer months. Andrews *et al.* (1966) found a correlation of only 0·15 ($P > 0{\cdot}05$) between L.A.A. and vitamin C intake. The present study reports a higher correlation than this, but in the regression equation to predict vitamin C intake from L.A.A. level the confidence limits are so large that the prediction is of little help to the clinician.

Srikantia *et al.* (1970) reported that volunteers saturated with vitamin C had 18 µg/10⁸ W.B.C. as the highest L.A.A. level. Though Windsor and Williams (1970) produced some evidence that the lower limit of normal for L.A.A. was 15 µg/10⁸ W.B.C., 20 µg lies between the mean values for all men and all women in the present study. Accordingly levels above and below 20 µg were used in analysing the relation between L.A.A. levels and vitamin C intake.

The low vitamin C intakes found in the present study suggest that vitamin C supplements are needed by older people, especially in the first and fourth quarters of the year. Further analysis in the present study may show whether certain groups of older people are more likely to have low intakes—for example, persons living alone or with mental or physical disability.

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A dietary survey of older people in Edinburgh

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1. Dietary histories covering 1 week were obtained from 212 men and 263 women, aged 62–90 years, who formed a random sample of the older people living in a defined area of Edinburgh. The histories were validated by 2 d weighed-diet records for 219 of the subjects.

2. Nutrient intakes are given as mean values and standard deviations, and as percentage distributions of intake relative to the recommended intakes of nutrients. Intakes are also related to factors which might affect diet adversely.

3. Mean values obtained suggested that intakes were less than recommended intakes for more nutrients for women than for men, particularly values for energy and vitamin D. Values for percentage distributions indicated that a substantial proportion of all subjects had low intakes of ascorbic acid and vitamin D, that the energy intake of many women was low and that for most nutrients a greater proportion of men than of women had the recommended intake. Factors associated with significant proportions of subjects with less than the recommended intakes were mental illness in women and deafness and severe dyspnoea in men.

4. Possible action to improve the diet of the elderly is discussed.

The results of a nutrition survey of the elderly (Department of Health and Social Security, 1972) suggested that the diet of older people is qualitatively similar to, but less in quantity than that of the rest of the population. A longitudinal study of ageing persons has been in progress in Edinburgh since 1968. So far the subjects have been examined on three separate occasions. Food intake was studied during the first of these three examinations. The results, which are described in this paper, although broadly similar to those of the survey, are capable in some respects of different interpretation.

METHODS

Subjects

The subjects studied were 215 men and 272 women, aged 62–90 years, who were a simple random sample of 27000 older people living in a defined area of Edinburgh. The method of sampling with a comparison of respondents and non-respondents has been described in detail elsewhere (Milne, Maule & Williamson, 1971).

Dietary survey

Dietary histories covering 1 week were obtained by one of us (M.E.L.) from 212 men and 263 women. Weighed-diet records for 2 d were also obtained from 219 of the subjects. The latter were not selected from all subjects by random sampling but because they were able to see and co-operate. They may therefore have been less impaired intellectually than some of the others. Dietary histories were compared with weighed-diet records by subtracting, for each individual, nutrient intakes obtained by

Table 1. *Validation of dietary histories for older people, assessed by comparing diet histories covering 1 week and weighed-diet records for 2 d*

(Mean values with their standard errors for differences between daily intake assessed by diet history and by weighed-diet record, and correlation coefficients (r) between dietary histories and weighed-diet records for 219 subjects)

	Mean difference	SE of mean difference	Statistical significance of mean difference from zero: t	P	r*
Energy: kcal	61.32	14.66	4.18	<0.01	0.94
MJ	0.26	0.06			
Total protein (g)	−0.17	0.62	0.28	NS	0.87
Fat (g)	2.61	0.86	3.02	<0.01	0.89
Carbohydrate (g)	9.54	1.83	5.22	<0.01	0.94
Calcium (mg)	42.44	9.81	4.32	<0.01	0.87
Iron (mg)	−0.24	0.15	1.65	NS	0.76
Vitamin A (μg retinol equivalent)	−90.38	212.13	0.43	NS	0.62
Thiamin (mg)	0.004	0.009	0.44	NS	0.85
Riboflavin (mg)	0.003	0.022	0.14	NS	0.86
Nicotinic acid (mg)	−0.65	0.17	3.82	<0.01	0.92
Ascorbic acid (mg)	2.31	1.01	2.28	<0.05	0.70
Vitamin D (μg cholecalciferol equivalent)	−0.33	0.22	1.50	NS	0.79
Pyridoxine (mg)	−0.011	0.013	0.85	NS	0.89

NS, not significant.
* For all results: $P < 0.01$.

weighing from those obtained by history. From the differences the mean difference with its standard error was calculated for energy intake and for each nutrient (Table 1). The t test was used to determine whether the mean differences differed significantly from zero. Of the thirteen nutrients in Table 1, for seven the mean difference did not differ from zero and for the remainder the differences, although statistically significant, were not large. Also given in Table 1 are correlation coefficients between dietary intakes determined by history and by weighing.

Food tables prepared by the Ministry of Health (Disselduff, Marr & Robertson, 1968) were used to calculate the intakes given in Tables 2 and 3. The dietary histories were obtained in the subjects' homes a few days after examination of the subjects by a physician (J.S.M.) and a psychiatrist (M.M.M.). Both these workers used a semi-structured questionnaire to obtain information about past and present health. Full clinical examination was done and a number of variables associated with ageing were measured. Particular attention was paid to factors which might affect the intakes adversely. Angina and intermittent claudication were diagnosed using Rose's questionnaire (Rose & Blackburn, 1968). Dyspnoea and persistent cough and phlegm were estimated using the Medical Research Council Committee on the Aetiology of Chronic Bronchitis (1965) questionnaire on respiratory symptoms. Information about other physical disabilities was collected during clinical examination. Mental illness was assessed at a full psychiatric examination.

Height was measured with a Harpenden stadiometer (Holtain Ltd, Brynberian, Crymych, Dyfed, Wales) and body-weight, wearing clothing weighing less than 500 g, was measured with a lever balance accurate to 100 g. Relative weights were calculated by expressing measured body-weights as percentages of the appropriate desirable 'weight-for-height' taken from the tables of the Metropolitan Life Insurance Company (Halpern, Glenn & Goodhart, 1960), using the median weight for the medium-sized body frame. Handgrip was measured with a mercury manometer (Milne, Maule, Cormack & Williamson, 1972). Visual acuity was assessed with Snellen's types and hearing loss was assessed by pure-tone audiometry. Respiratory function was examined with a Vitalograph spirometer (Vitalograph Ltd, Maids Moreton House, Buckingham) and $FEV_{1.0}\%$ (Milne & Williamson, 1972*a*) calculated from the results.

The dietary histories were obtained and the examinations done during the period January 1968–January 1970. A sociological assessment was also made of the same subjects in their own homes a few months after the other examinations, and the findings have been used in the present study. Classification of social class was based on that of the General Register Office (1966).

RESULTS

The dietary findings (nutrient intakes) are given first as mean values and standard deviations for groups of men and of women aged 62–74 years and 75–90 years. Secondly the findings for the same four groups are expressed as the percentage of each group who consumed less than 50, 50–99 and 100 or more % of the recommended intakes of various nutrients (Department of Health and Social Security, 1969). Finally the groups of subjects taking the recommended intakes or less for six of the nutrients are considered in relation to the presence of certain 'risk' factors which might be associated with the consumption of poorer diets.

Tables 2 *and* 3. Mean values and standard deviations for the intakes of energy and of the various nutrients are given for the two age groups of men in Table 2 and for the same age groups of women in Table 3. The results suggested that more intakes for women than for men were below those recommended, particulary those for energy and vitamin D. For most nutrients, intake decreased progressively with age.

Tables 4 *and* 5. The percentage distributions of the relative intakes (intake as a percentage of the recommended intake (Department of Health and Social Security, 1969)) of nutrients for the two age groups of men and of women are given in Tables 4 and 5 respectively. The only items for which 75% of the subjects ate the recommended amount or more were total protein, calcium and nicotinic acid. This was true for both groups of men and for the younger group of women. For the older group of women the only nutrient with this level of intake was Ca. At the opposite extreme a substantial proportion of all subjects (between 10 and 44%) eat less than 50% of the recommended intakes of ascorbic acid and vitamin D. The values for percentage distribution of intake suggested that many men and women eat diets deficient in ascorbic acid and vitamin D and confirmed that energy intake was low for many women and that for most nutrients a greater percentage of men than women had recommended intakes.

Table 2. *Daily intakes* of various nutrients for two age groups of older men, obtained from dietary histories covering 1 week*

(Mean values and standard deviations)

	Age groups			
	62–74 years (n 158†)		75–90 years (n 54)	
	Mean	SD	Mean	SD
Energy: kcal	2494	587	2176	546
MJ	10·5	2·5	9·1	2·3
Total protein (g)	74·5	16·5	69·5	17·3
Fat (g)	102·8	27·8	90·8	26·2
Carbohydrate (g)	293·8	78·4	266·2	73·7
Calcium (mg)	958	293	964	276
Iron (mg)	11·7	3·0	10·7	2·8
Vitamin A (μg retinol equivalent)	1158	631	1004	504
Thiamin (mg)	0·9	0·2	0·9	0·2
Riboflavin (mg)	1·7	0·6	1·5	0·5
Nicotinic acid (mg)	17·0	7·8	13·5	6·6
Ascorbic acid (mg)	32·5	14·7	32·3	19·4
Vitamin D (μg cholecalciferol equivalent)	3·1	2·6	2·4	2·2
Pyridoxine (mg)	1·3	0·4	1·2	0·4
Energy (%) from:				
Protein	12·1	1·9	13·0	2·2
Fat	37·5	7·2	37·8	6·5
Carbohydrate	44·1	5·2	46·0	6·3
Alcohol	6·3	—	3·2	—

* Calculated from dietary histories using food tables (Disselduff, Marr & Robertson, 1968).
† Three missing values.

Clinical information is available for two men and five women whose energy intake was less than 50% of the recommended amount. One man had a painful healing operation wound in his mouth and the other was socially deprived. Of the five women, one later died of a carcinoma of the colon, one had diabetic retinopathy with severe osteoarthritis of the hip, one had poor vision with fixed flexion in both knees and the remaining two had no discoverable reason for low intake.

The following 'risk' factors were not found to have any association with intake for six nutrients (energy, protein, Ca, iron, ascorbic acid, vitamin D): intermittent claudication, visual acuity ($\geqslant$ 6:60), haemoglobin (< 120 g/l), $FEV_{1\cdot0}$(< 60%), congestive heart failure, persistent cough and phlegm, reduced hip movement, reduced knee movement, stroke, living alone, recent bereavement. There were several factors apparently associated with intakes lower than the recommended levels for one particular nutrient. These were for men: angina, ascorbic acid; regular attention from doctor, energy; not married, Fe; social class III, IV or V, ascorbic acid; for women: peptic ulcer, vitamin D; handgrip (< 120 mm Hg), ascorbic acid; neurosis, ascorbic acid; not married, vitamin D. These seven isolated instances may have occurred by chance in 264 χ^2 tests used in assessing 'risk' factors. However, bilateral handgrip below 120 mm Hg is known to be associated with dementia (Milne *et al.* 1972) and

Table 3. *Daily intakes* of various nutrients for two age groups of older women, obtained from dietary histories covering* 1 *week*

(Mean values and standard deviations)

	Age group			
	62–74 years (n 190†)		75–90 years (n 73‡)	
	Mean	SD	Mean	SD
Energy: kcal	1771	394	1648	331
MJ	7·4	1·7	6·9	1·4
Total protein (g)	57·8	11·2	54·4	12·3
Fat (g)	85·2	22·8	74·5	17·1
Carbohydrate (g)	203·0	54·3	201·0	49·5
Calcium (mg)	799	216	786	216
Iron (mg)	9·0	2·0	8·1	2·1
Vitamin A (μg retinol equivalent)	1014	542	825	353
Thiamin (mg)	0·8	0·2	0·7	0·2
Riboflavin (mg)	1·2	0·3	1·1	0·4
Nicotinic acid (mg)	9·6	2·3	8·7	2·5
Ascorbic acid (mg)	32·3	18·1	29·4	22·9
Vitamin D (μg cholecalciferol equivalent)	2·0	1·6	1·8	1·6
Pyridoxine (mg)	0·9	0·2	0·9	0·2
Energy (%) from:				
Protein	13·3	2·1	13·3	1·7
Fat	43·1	5·0	40·7	4·9
Carbohydrate	43·2	5·7	45·7	5·5
Alcohol	0·4	—	0·3	—

* Calculated from dietary histories using food tables (Disselduff, Marr & Robertson, 1968).
† Three missing values.
‡ Six missing values.

reduced intake of ascorbic acid in men of social classes III, IV and V may reflect the greater likelihood of buying fruit by men in social classes I and II.

There were however three groups of 'risk' factor in which values for intake which were significantly inadequate, were predominant. For men these were dyspnoea of grade 3 (Medical Research Council Committee on the Aetiology of Chronic Bronchitis, 1965) or more, and hearing loss of 30 dB or more in the lower frequencies. For women, five significantly inadequate values were associated with the presence of mental illness, particularly dementia.

Table 6. Mean heights and body-weights and standard deviations are given in Table 6 for the four groups of subjects. Relative body-weights (body-weight as a percentage of desirable 'weight-for-height') of 120% or more were found in 37% of men and 56% of women. There was no difference between those with relative weights above and below 120% in respect of intakes above and below those recommended except for protein and Fe for men, for whom the intake in a greater percentage of the heavier group was greater than that recommended.

Table 4. *Percentage of older men of two age groups whose daily intake of various nutrients was different from that recommended by the Department of Health and Social Security* (1969)

Intake as a percentage of recommended intake ...	62–74 years (*n* 158*) <50	62–74 years 50–99	62–74 years ≥100	62–74 years Recommended intake	75–90 years (*n* 54) <50	75–90 years 50–99	75–90 years ≥100	75–90 years Recommended intake
Energy	1·2	40·5	58·2	2350 kcal 9·9 MJ	—	53·7	46·3	2100 kcal 8·8 MJ
Total protein	0·6	15·8	83·5	59 g	—	14·8	85·2	53 g
Calcium	0·6	4·4	94·9	500 mg	—	—	100·0	500 mg
Iron	1·3	26·0	72·8	10 mg	1·9	38·9	59·3	10 mg
Vitamin A	1·3	19·6	79·1	750 μg retinol equivalent	—	31·5	68·5	750 μg retinol equivalent
Thiamin	1·9	50·0	48·1	0·9 mg	1·9	29·6	68·5	0·8 mg
Riboflavin	3·2	56·3	40·5	1·7 mg	3·7	72·2	34·1	1·7 mg
Ascorbic acid	10·2	35·5	54·4	30 mg	16·7	44·4	38·9	30 mg
Vitamin D	17·7	37·4	44·9	2·5 μg cholecalciferol equivalent	26·0	46·3	27·8	2·5 μg cholecalciferol equivalent
Nicotinic acid	—	20·9	79·1	11 mg†	—	16·7	83·3	9 mg†
Pyridoxine	20·3	74·7	5·1	2 mg	40·7	55·5	3·7	2 mg

* Three missing values.
† British Medical Association (1950) recommended intake.

Table 5. *Percentage of older women of two age groups whose daily intake various nutrients was different from that recommended by the Department of Health and Social Security* (1969)

Intake as a percentage of recommended intake …	62–74 years (n 190*)				75–90 years (n 73†)			
	<50	50–99	⩾100	Recommended intake	<50	50–99	⩾100	Recommended intake
Energy	2·1	73·7	24·2	2050 kcal 8·6 MJ	1·4	72·6	26·0	1900 kcal 8·0 MJ
Total protein	—	25·8	74·2	51 g	1·4	31·5	67·1	48 g
Calcium	—	8·4	91·6	500 mg	—	8·2	91·8	500 mg
Iron	2·1	67·9	30·0	10 mg	6·8	76·7	16·4	10 mg
Vitamin A	0·5	32·6	66·8	750 µg retinol equivalent	1·4	53·5	45·2	750 µg retinol equivalent
Thiamin	1·1	67·4	31·6	0·8 mg	2·7	52·0	45·2	0·7 mg
Riboflavin	5·3	64·7	30·0	1·3 mg	2·7	78·1	19·2	1·3 mg
Ascorbic acid	12·6	43·6	43·7	30 mg	17·8	46·6	35·6	30 mg
Vitamin D	32·6	46·3	21·1	2·5 µg cholecalciferol equivalent	43·8	42·5	13·7	2·5 µg cholecalciferol equivalent
Nicotinic acid	0·5	20·0	79·5	8 mg‡	2·7	41·1	56·2	8 mg‡
Pyridoxine	71·6	28·4	—	2 mg	78·1	21·9	—	2 mg

* Three missing values.
† Six missing values.
‡ British Medical Association (1950) recommended intake.

Table 6. *Heights and body-weights of older men and women of two age groups, whose dietary history was studied*

(Mean values and standard deviations)

Age group	Height (m)		Body-weight (kg)	
	Mean	SD	Mean	SD
Men				
62–74 years (n 159)	1·676	0·0666	67·8	11·98
75–90 years (n 52)	1·661	0·0777	69·2	12·74
Women				
62–74 years (n 190)	1·551	0·0652	62·9	12·37
75–90 years (n 74)	1·521	0·0611	57·7	12·65

DISCUSSION

The recommended intakes of the Department of Health and Social Security (1969) are known to be based on scanty evidence (Hyams, 1973) and are therefore of doubtful value in assessing nutritional status. However, in the absence of satisfactory tests for slight malnutrition, the dietary intakes in this survey have been expressed as percentages of the recommended intakes.

There was no gross evidence of malnutrition on clinical examination in the present study. Anaemia of all kinds, based on the WHO (1959) definition, was present in only 8% of persons examined (Milne & Williamson, 1972*b*). Two men had zero levels of leucocyte ascorbic acid, suggesting that overt scurvy was imminent; in fact one of the men, who had lived alone in a poor area, had had scurvy some years previously. The largest group with abnormal nutrition was the 'overweight' group but there was no difference between those with relative weights of 120% or more and those with relative weights less than this in respect of intakes above and below those recommended, except for protein and Fe for men, for whom the intake in the 'overweight' group was greater than that recommended. Possible clinical reasons for low energy intake have been discussed (see p. 520).

The surveys most suitable for comparison with the present study are that reported by the Panel on Nutrition of the Elderly (Department of Health and Social Security, 1972) (DHSS survey) and one recently published in Glasgow (Macleod, Judge & Caird, 1974*a*, *b*, 1975).

In both the DHSS survey and the Glasgow survey, as in the present study, mean energy intakes in men exceeded those in women, and in both sexes energy intake decreased with age. Mean values were similar in the three surveys and although mean values for men were similar to recommended values those for women were less than recommended values. Recommended energy intakes are based on the decrease known to occur in the basal metabolic rate as age increases (Bender, 1971). In the present study, the percentage of subjects taking less than the recommended amount were 42–54% for men and approximately 75% for women. In view of the known good health of many people with energy intakes less than the recommended amount, this may only indicate that the values recommended for women are too high. Alcohol supplied 6·3 and 3·2 % respectively of the energy intakes of younger and older groups of men in our survey but less than 0·5 % of the energy intake of women.

Mean values for total protein intake in the present study were similar to those in the DHSS survey and the Glasgow survey. Minimum daily protein requirements are given as 45 g for men and 38 g for women (Department of Health and Social Security, 1969). In the present study values for 2·5 % or less of the men and 5 % of the women were below the minimum.

For other nutrients in Tables 2 and 3, mean intakes are similar in the three surveys. For ascorbic acid mean intakes in our study are similar to those found in the northern areas surveyed in the DHSS survey. A government report on household food consumption states that diets in Scotland and in northern England contain comparatively little fresh fruit and fresh green vegetables (Ministry of Agriculture, Fisheries and Food, 1973). Other studies mention the probability of reduced intakes of ascorbic acid in the elderly (Brin, Dibble, Peel, McMullen, Bourquin & Chen, 1965; Exton-Smith, 1968; Bender, 1971). Mean values for vitamin D intake were lower in our survey than in the DHSS survey, although in both surveys and in the Glasgow survey, the men had a higher mean intake than the women. In our survey this could be because, on the whole, more men than women eat margarine. Low intakes of vitamin D were also found in the Glasgow survey. Exton-Smith (1968) commented on the frequency of low intakes of vitamin D in the elderly.

We believe that the present study showed inadequate intakes of vitamin D and ascorbic acid in a considerable proportion of elderly subjects in Edinburgh in 1968–9. With respect to the low intake of vitamin D, this agrees with the high prevalence of osteomalacia reported in Scotland (Anderson, Campbell, Dunn & Runciman, 1966; Chalmers, Conacher, Gardner & Scott, 1967). Recent work on the effects of high intake of ascorbic acid in protecting against the common cold and alleviating its symptoms (Wilson, 1971; Hume & Weyers, 1973) suggests that it may be needed in larger amounts than 30 mg daily. The DHSS survey report suggests giving fortified foods or prophylactic vitamins to some 'high-risk' groups of the elderly; in particular, fortified milk in containers capable of preserving milk against the effects of sunlight is mentioned. Health education for the elderly, as advised in the report of the DHSS survey, is obviously important where diet is concerned.

The present study associates disability with possible malnutrition in respect of deafness and dyspnoea in men and mental illness in women. The association of mental illness with reduced intake has been described by others, particularly with dementia (Exton-Smith, 1971) and depression (Exton-Smith, Stanton & Windsor, 1972) as in the present study. Malnutrition has also been associated with locomotor disorders (Exton-Smith, 1971), bereavement and regular medical attention (Bender, 1971) but the present study does not support these relationships. More sophisticated analysis of diet in certain disabled groups is needed.

The acceptance rates are similar in the three surveys being 70 % in the DHSS survey and the Glasgow survey, and 65 % in our study. This relatively high refusal rate is common to other surveys of the elderly (Cochrane, 1954; Seiler, Welstead & Williamson, 1958; Cartwright, 1959) and perhaps has to be accepted as an inevitable disadvantage of surveying this part of the population. Some evidence in the present study suggested that non-respondents were marginally more healthy (Milne *et al.* 1971).

Finally the authors agree with the report of the DHSS survey that there is need for follow-up studies of subjects with different extents of adequacy of dietary intake. Stanton & Exton-Smith (1970) have shown that despite apparent reductions in intake with increasing age in cross-sectional surveys, longitudinal studies suggest that decreasing intake with increasing age is associated with disability; healthy subjects maintain the same intakes as they grow older. The present study is prospective to allow follow-up of the health of survivors. It will also be possible to relate survival to dietary intake at the first examination thus investigating the possible prognostic value of the dietary survey.

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CHAPTER 2

Prevalence of Incontinence in the Elderly Age Groups

J. S. MILNE

INTRODUCTION

Urinary incontinence "can impose restrictions on our daily activities or way of life; be the reason for admission being refused to a residential home and for being unwelcome as a visitor or as a member of any group or club. It may cause families to declare that the burden of caring for someone at home is too great and request hospital care for their relatives" (Elphick, 1970). Indeed, it has been estimated that urinary incontinence is the cause of more than 20% of admissions to geriatric units (Shuttleworth, 1970). Prevalence studies of a condition with such widespread effects can help by defining the size of the problem.

DEFINITION OF URINARY INCONTINENCE

In epidemiological studies which determine prevalence by asking questions, the results will vary depending on the questions and the order in which they are asked. The definition of urinary incontinence given by Brocklehurst *et al.* (1971) was that it was present if the answer to the question, "Does urine ever come away unexpectedly and without your being able to stop it and you get wet?" was "Yes". This definition must apply to all persons with urinary incontinence even if someone else has to answer the question for the patient. This question was followed (Brocklehurst *et al.* 1971) by one to discover stress incontinence: "Does this only happen when you cough, laugh or move?". The resulting prevalence of stress incontinence in women was 12%. By contrast another study (Milne *et al.* 1972) used four questions beginning with one about incontinence related to urgency followed by questions about stress ("Does your urine come away if you cough or sneeze?"), nocturnal, and continuous incontinence. This order of questioning produced a prevalence of stress incontinence of 31% in women. Possibly it is easier to admit to stress incontinence than to say "yes" to a question covering all incontinence.

Some authors have made a useful distinction between temporary and established incontinence, (Willington, 1969; Newman, 1962).

Isaacs and Walkey (1964) classified urinary incontinence by grading according to severity, the grades being none, once daily, more than once daily and double incontinence. Akhtar *et al.* (1973) used four grades, these being occasional accident or stress, nocturnal, continuous and double. Sheldon (1948) differentiated severe grades of incontinence "in which the bladder or the rectum empty themselves of their contents" from mild grades with "voiding of slight amounts of urine in response to a sudden urgency of desire to micturate". He did, however, record as incontinence the involuntary voiding of urine in whatever amount. Hobson and Pemberton (1955) distinguished between "occasional and partial incontinence due to sudden muscular effort" and "regular and complete incontinence". One paper differentiates urge incontinence from stress incontinence (Haydon and Youkilis, 1970), the former being associated with decreased bladder capacity from infection or disease of the central nervous system.

Enough has been said to show the semantic problems associated with the words "urinary incontinence" and to suggest that comparisons between surveys may not be easy. At the same time all patients with urinary incontinence of whatever degree must fit into the definition used by Brocklehurst and his colleagues.

HOSPITAL STUDIES

PREVALENCE IN HOSPITAL SURVEYS

Results from a number of surveys made in hospital are given in Table 1. Prevalence figures vary from 12·9% to 48%. It is impossible to relate these figures to population prevalence, since so many unknown factors of selection and bias operate in the different hospitals and time periods concerned. Totterman (1959) describes a rise in prevalence of urinary incontinence in a hospital for the aged in Helsinki from 12·1% in 1953 to 24·9% in 1957. Presumably this change is the resultant of admissions and survivals during the four years.

The lowest prevalence figures are those given by Willington (1969) but these are for established incontinence persisting after admission. At the time of admission he found urinary incontinence in 35·5% of men and 32·1% of women. These latter figures approach those given by Walkey *et al.* (1967), the only other authors in Table 1 who describe results from consecutive admissions. Willington's figures for established incontinence were 14·2% of all admissions and 41·5% of incontinent admissions. He also reported a history of urinary incontinence in 30·2% of 750 patients visited at home. This author showed the effect of the home environment on the prevalence of urinary incontinence in

TABLE 2.1

PREVALENCE OF INCONTINENCE OF URINE IN HOSPITAL SURVEYS

Author	Year	Women		Men		Type of Patient	Country
		No.	% Incontinent	No.	% Incontinent		
Affleck	1947	552	21·9	236	19·1	Longstay	England
Wilson	1948	33	42·4	35	31·5	Longstay	England
Thomson	1949	398	44·0	316	25·0	Longstay	England
Brocklehurst	1951	183	33·3	416	18·3	Longstay	Scotland
Totterman	1959	707	25·9	178	20·8	Longstay	Finland
Isaacs and Walkey	1964	248	46·0	274	40·1	Longstay	Scotland
Walkey *et al.*	1967	250	47·0	250	48·0	Consecutive Admissions	Scotland
Willington	1969	489	12·9	411	15·8	Consecutive Admissions	England

hospital when he found that the largest proportion of those retained in hospital, the smallest proportion of those resettled in the community, and the largest proportion of those admitted because of incontinence were patients living with relatives.

Isaacs and Walkey (1964) related their prevalence figures to severity. Of their incontinent patients, one quarter were incontinent once daily, one quarter more than once daily, and one half were doubly incontinent.

ASSOCIATED FACTORS IN HOSPITAL STUDIES

1. *Sex and Marital State*

Data about sex distribution vary widely. Totterman reported the same prevalence in men and in women but found greater absolute numbers in women. The study by Willington (1969) produced a male to female ratio of 1:1·07. This author commented on the predominance among patients with urinary incontinence of married men and widowed women. The admission of married men rather than married women was ascribed to the difficulty experienced by ailing wives in washing soiled male clothing. Brocklehurst (1951) reported from hospitals in Glasgow that urinary incontinence was twice as common in women as in men and suggested as the reason the greater prevalence of dementia in older women. Isaacs and Walkey (1964) also writing from Glasgow found similar proportions of incontinence in men and women.

2. *Age*

Two of the studies listed in Table 1 (Thomson, 1949; Willington, 1969) agree in finding no age differences in the distribution of urinary incontinence in elderly people. There was no increase in prevalence in the older groups. Isaacs and Walkey (1964) found that the degree of incontinence was also not related to age.

3. *Infection*

Some authors believe that acute or chronic urinary infection maintains urinary incontinence (Eckerstrom, 1959) or have reported a high prevalence of infection in the urine of incontinent patients, (Totterman, 1959; Eckerstrom, 1955). The latter author describes bacteriuria in 70% of men and 85% of women in 102 persons with urinary incontinence in a hospital in Sweden. However, a careful statistical study from Glasgow showed that although incontinence in hospital patients was more common in persons with than without urinary infection the difference reached statistical significance in women only. The authors regarded the difference as marginally significant and concluded that chronic urinary infection did not exert a major influence in the production of urinary incontinence in the elderly (Walkey *et al.* 1967). These authors used bacteriuria as the criterion of infection. It is possible that acute urinary infections with symptoms are related to incontinence (Wilson, 1948).

4. *Physical Activity*

It has been said that among old people who are confined to bed by illness, 25% forthwith develop incontinence of urine (Eckerstrom, 1955). Becoming bedfast was listed as a predisposing cause of incontinence by Brocklehurst (1951) and by Wilson (1948). This may cause incontinence simply by increasing the difficulty of reaching the water closet in time, although Willington (1969) gave an interesting theory based on the conditioned reflex mechanism and in particular on transmarginal inhibition as described by Pavlov.

Isaacs and Walkey (1964) provided figures relating physical activity to urinary incontinence. Amongst ambulant patients only 11% were graded as having severe incontinence, while 83% of the severe grades of incontinence were non-ambulant. The same authors showed the importance of being able to dress in that 80% of patients who could dress themselves, 50% of those dressed by the nurses and 33% of those confined to bed were continent of urine. Similar relationships emerged between patients' ability to feed themselves and incontinence.

5. *Disease of the Central Nervous System*

This is listed by many authors as the most important predisposing factor whether the disease be cerebrovascular such as stroke or other upper motor neurone lesion, or any of the organic brain syndromes (Affleck, 1947; Wilson, 1948; Thomson, 1949; Isaacs and Walkey, 1964; Willington, 1969; Eckerstrom, 1955; Brocklehurst, 1951). The chronic sick patients studied by Affleck (1947) contained 37·3% with mental symptoms, mainly organic brain syndromes. Eckerstrom (1955) found in 102 patients with urinary incontinence, 17 with dementia, and 21 who had had a cerebrovascular accident. Isaacs and Walkey (1964) reported that 80% of patients in their study with double incontinence had brain damage, while 73% of those without damage were continent. The same authors, using tests of mental impairment, demonstrated statistically significant increases in dementia with increase in the severity of the grade of incontinence.

Brocklehurst (1951) defined the neurogenic bladder as any ab-normally functioning bladder due to some defect in the nervous control. He postulated that some interruption of the upper motor neurone by releasing tonic impulses would lead to a spastic and hyperexcitable bladder. Cystometrograms were made from which it was concluded that an uninhibited bladder would be found in most senile incontinent patients, the causes being mainly cerebrovascular disease or dementia, (Brocklehurst and Dillane, 1966*b*). The same authors made cystometrograms in continent old women and found abnormal tracings in the majority (Brocklehurst and Dillane, 1966*b*). To some extent the neurogenic bladder appears to be the result of ageing, but several authors think a spastic over-active bladder predisposes to incontinence (Eckerstrom, 1959; Totterman, 1959; Wilson, 1948), perhaps particularly if additional neurological disease is present.

6. *Other Factors*

Opinions about prostatic hypertrophy as a cause of incontinence vary. Hayes (1955) regards it as the most important cause in men and Eckerstrom (1955) mentions it, while Wilson (1948) thinks prostatic enlargement is not important as a cause of incontinence. Wilson mentions senile vaginitis in women as being associated with incontinence.

POPULATION STUDIES

PREVALENCE IN POPULATION SURVEYS

Fewer studies of the prevalence of urinary incontinence have been made in the general population than in hospital. Information from population surveys is listed in Table 2.

Since examination of a sample from a population is intended to estimate population prevalence, it is worth mentioning the sampling techniques used in these surveys. Sheldon (1948) used a random sample of elderly men and women obtained from the Wolverhampton register of ration cards. He succeeded in questioning 81·8% of the subjects in the sample. Hobson and Pemberton (1955) also used a random sample, from Food Office Records in Sheffield of elderly persons living alone or with spouse. Their sample was drawn from a larger sample used in a social survey and they examined 65% of the sample they drew. Van Zonneveld (1959) questioned 3000 people of 65 years and over in Groningen in Holland, using 70 medical students as observers. These people formed 25% of the aged in the town but the sampling technique was not described. Sourander (1966) examined a random sample of persons aged 65 years and over, stratified by age, from Turku in Finland. He obtained what is, for a study of the elderly, the high response rate of 84%. Brocklehurst *et al.* (1968) used all persons aged 65 years and over in a London general practice as a sample of old people in southern England and examined 85% of them. Milne *et al.* (1972) examined a simple random sample of persons aged 63 and upwards in a defined area of Edinburgh, using the National Health Service Lists of all the general practitioners in the area (91) as the sampling frame. In this survey the practitioners asked those of their patients who were sampled to take part and the response was 65%. Akhtar *et al.* (1973) used three random samples of persons aged 65 or more, two of which were stratified for age. Two of the samples were from all the old people in the Scottish town of Kilsyth and one was from six general practices in Glasgow. The response rate was 70%.

This description of sampling methods and response rates shows how difficult it is to make comparisons between surveys. Relatively poor response rates in the elderly may not be important since Akhtar (1972) and Milne, Maule and Williamson (1971) were able to show that respondents and non-respondents are similar in many respects. Apart from bias introduced by sampling and refusal, an added difficulty is observer reliability. Milne, Hope and Williamson (1970) showed that the replies made by old people to questions asked by one observer do not show high reproductibility. Akhtar *et al.* (1973) described inter-observer difficulties in population studies of the elderly.

With these facts in mind it is surprising that the surveys listed in Table 2 agree as well as they do. The surveys made by Hobson and Pemberton (1955), Brocklehurst *et al.* (1968) and Milne *et al.* (1972) have recorded much higher prevalence rates for urinary incontinence than have others. This is because these workers have recorded the presence of all incontinence even of the mildest degree. Hobson and Pemberton reported occasional and regular incontinence. The latter was found in 2·6% of men and 7·4% of women. The paper of Milne *et al.* (1972) distinguishes between mild and severe incontinence, the latter including nocturnal and continuous incontinence. Severe incontinence as defined was found in 5% of men and 4·5% of women which are figures comparable with those of the other surveys in Table 2. Sheldon's figures, occupying an intermediate position, are almost all from persons with lesser degrees of incontinence. The figures of Sourander (1966) are for continuous incontinence and Akhtar *et al.* (1973) are reporting persistent incontinence. Van Zonneveld (1959) reports incontinence without qualification. His paper mentions, in describing a survey separate from that shown in Table 2, the prevalence of stress incontinence in older women as varying from 2% to 7% according to age group. These figures are lower than those reported in women by Brocklehurst *et al.* (1968) and Milne *et al.*(1972) which were 12% and 31% respectively. It has already been shown above that such variation in prevalence may be related to the questions used to collect the information. Hobson and Pemberton, without giving actual numbers with stress incontinence, regard uterine prolapse as the main cause of minor degrees of incontinence in elderly women.

The relationship between disability and urinary incontinence was considered by Akhtar *et al.* (1973). They found urinary incontinence to be present in 33% of 27 subjects who were disabled and dependent but in only 3% of subjects who were disabled but not dependent. This result is qualitatively similar to the findings of Isaacs and Walkey (1964) in respect of their patients' ability to walk, dress and feed themselves.

ASSOCIATED FACTORS IN POPULATION STUDIES

1. *Sex*

Urinary incontinence in population surveys shows similar prevalence in men and women (Table 2) except in the studies by Brocklehurst *et al.* and Milne *et al.* The greater prevalence in women in these studies is from the inclusion of stress incontinence in the percentages. Their figures for stress incontinence in men were 2·7% and 5·6% respectively.

2. *Age*

No age differences in the prevalence of urinary incontinence were found by Brocklehurst *et al.* or by Milne *et al.* Although Van Zonneveld does not comment on age differences, the figures in Table 1 in his paper show no age effect.

3. *Infection*

In the studies by Brocklehurst *et al.* and Milne *et al.* no association was found between bacteriuria and urinary incontinence including stress incontinence. By contrast Sourander (1966) found an association between incontinence and infection ($p < 0{\cdot}01$). It is difficult to explain these diametrically opposite findings although it is interesting that Sourander reported a higher prevalence of bacteriuria in women (33%) compared with the other two studies (20% and 11·5%).

4. *Disease of the Central Nervous System*

The expected association between incontinence and disease of the central nervous system is reported by some of the surveys in Table 2. Akhtar *et al.* found 25 of their 27 disabled dependent subjects suffering from a neurological disorder, while 9 of the 27 were incontinent. Milne *et al.* (1972) observed an association between severe incontinence and dementia in both sexes. Brocklehurst *et al.* (1971) found the prevalence of incontinence greater when diminished toy test performance showed the prevalence of dementia to have increased. Hobson and Pemberton recognised the importance of mental and neurological causes in the severe grades of incontinence. Among 21 women with regular incontinence they found 14 with evidence of either dementia or residual hemiplegia, or a combination of them.

TRANSIENT INCONTINENCE

Newman (1962) distinguishes between true and apparent incontinence. He relates the latter type to factors such as precipitancy, polyuria and the taking of hypnotics and the former to causes such as neurological disease, trauma, bladder-neck disturbance and dementia. Willington (1969) found that the prevalence of incontinence in hospital fell from 33·6% on admission to 14·2% at a later date when the incontinence was described as established.

The concept is an important one because if the transient group is not separated from the whole group of incontinent patients, the size of the long term problem is exaggerated. Most geriatric physicians see patients who develop urinary incontinence in the presence of acute urinary tract infection or faecal impaction. Such incontinence will often clear if the infection or impaction is treated. Similarly, incontinence with a toxic confusional state, having a treatable cause, may disappear after treatment. Incontinence associated with difficulty in reaching the lavatory in time, due to poor locomotion from causes such as arthropathy, foot trouble, paralysis, disorders of balance or poor vision, may disappear if appropriate toilet arrangements are made. Although all are familiar with incontinence which is transient and associated with such causes, figures are not available to describe prevalence in detail.

One such cause of incontinence for which figures from population survey are available is precipitancy. This has been estimated using questions such as "Do you have to pass urine in a hurry?" (Brocklehurst *et al.* 1968) or "Do you lose control of your bladder if unable to go to the lavatory as soon as you need to pass urine?" (Milne *et al.* 1972).

TABLE 2.2

PREVALENCE OF INCONTINENCE OR URINE IN POPULATION SURVEYS

Author	Year	Women		Men		Country
		No.	% Incontinent	No.	% Incontinent	
Sheldon	1948	321	12·7	135	7·4	England
Hobson and Pemberton	1955	284	22·9	192	26·0	England
Van Zonneveld	1959	1450	2·2	1486	3·2	Holland
Sourander	1966	203	6·9	197	5·1	Finland
Brocklehurst *et al.*	1968	375	23	182	17	England
Milne *et al.*	1972	272	42	215	25	Scotland
Akhtar *et al.*	1973	490	1·6	319	2·2	Scotland

Brocklehurst *et al.* reported precipitancy in 28% of men and 32% of women while Milne *et al.* found 21% in each sex. Neither study detects a significant difference in prevalence between the sexes. The reported figures in these studies show no statistical relationship between precipitancy and infection. Sheldon (1948) was aware of precipitancy as a predisposing cause of minor incontinence but included precipitancy under the heading of increased frequency of passing urine, so that its prevalence in his survey was not stated. If infection is treated when present and suitable toilet arrangements are made, incontinence due to precipitancy should be minimal.

FAECAL INCONTINENCE

Less information is available about the prevalence of faecal incontinence. Affleck (1947) in his study of the elderly chronic sick in hospital recorded double incontinence in 10·6% of the men and 11·4% of the women. Brocklehurst (1951) found 23% of patients in longstay beds in Glasgow suffering from incontinence and 75% of those with incontinence (which is equivalent to 17% of patients examined), had faecal incontinence. Isaacs and Walkey (1964) reported 24% of men and 21% of women in their hospital survey with double incontinence. They associated double incontinence, as mentioned above, with brain damage and intellectual impairment.

Population studies confirm that faecal incontinence is primarily a problem of geriatric patients in hospital, since no community study which records faecal incontinence reports other than a very low prevalence. Sheldon (1948) found only 3 women which amounted to 0·6% of his sample. Hobson and Pemberton (1955) found 3 men (1·6%) and 5 women (1·7%) with occasional faecal incontinence. Regular faecal incontinence occurred in 2 women (0·7%) and no men. Both reports described faecal incontinence as a factor leading to admission to hospital and hence to a low population prevalence. The Edinburgh longitudinal study (unpublished data) included 2 subjects with faecal incontinence (0·4%) and these were in longstay beds suffering from dementia.

The size of the problem was gauged by Brocklehurst (1972) who estimated that faecal incontinence occurred in 45,000 people in the United Kingdom, i.e. less than 1 per 1000 of the population.

CONCLUSION

The prevalence studies reported in this chapter suggest that between 13% and 48% of older patients in hospital and between 1·6% and

42% of the elderly in the community suffer from incontinence of urine. If severe incontinence alone is considered, the community prevalence over the age of 65 years does not exceed 7%. A symptom so common and of such social and personal importance certainly warrants our best efforts directed towards investigation and treatment. Faecal incontinence, although rare in the community, is of importance second only to incontinence of urine as a problem in long-stay hospitals.

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Mesure de la densité osseuse chez le vieillard

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La mesure de la densité osseuse n'a pas qu'un intérêt académique. Cet axiome est démontré par le fait que le quart des lits orthopédiques à Edimbourg est constamment occupé par des femmes âgées avec fracture du fémur, une condition associée, comme on le sait, avec la déminéralisation de l'os. La mesure précise de la masse osseuse ou des variables qui en dépendent est essentielle pour l'étude des conditions menant à la déminéralisation de l'os. La déminéralisation peut être la conséquence du vieillissement physiologique, de la maladie ou du traitement avec, par exemple, les corticostéroïdes. Tout perfectionnement dans la mesure de la masse osseuse faciliterait non seulement l'étude de l'histoire naturelle de la déminéralisation dans une population donnée, mais le contrôle de l'efficacité du traitement lorsque celui-ci pourra être effectué. Enfin, les mesures permettraient d'explorer l'effet de l'hérédité dans la déminéralisation. Ceux qui étudient la composition du corps éprouvent des difficultés à estimer la masse du squelette et la mesure précise de la masse osseuse permettrait de résoudre également ce problème. Des techniques spéciales sont nécessaires vu que les radiographies standards ne révèlent la perte de la substance osseuse que lorsque celle-ci a atteint le 30% de la norme (16).

Méthodes

Les méthodes utilisées dans la mesure de la masse osseuse sont:

A. *Squelette appendiculaire*

1) densitométrie;
2) mesure de l'absorption d'énergie provenant d'un appareil à rayons X approprié ou d'une source radioactive;
3) anthropométrie;
4) radiations naturelles.

B. *Squelette axial*

1) densitométrie;
2) anthropométrie;
3) autres méthodes.

C. *Activation par les neutrons*

D. *Méthode sonique.*

Ces diverses méthodes seront discutées dans le présent article.

A.1. Densitométrie du squelette appendiculaire

Toutes les méthodes densitométriques reposent sur la radiographie d'un os donné par comparaison avec un étalon approprié. La mesure proprement dite consiste à comparer la densité de l'os radiographié avec celle de l'étalon. Si l'étalon standard est un cône dont la courbe de densité est connue, la densité de l'os peut être exprimée en millimètres, correspondant à l'épaisseur du cône rendant la même densité sur la radiographie. Il s'agit là d'une mesure optique et d'autres calculs sont nécessaires pour exprimer cette densité en grammes de minéral osseux par rapport au volume de l'os. Décrite ainsi cette méthode paraît simple, mais elle est soumise à un grand nombre de variables pouvant fausser les résultats.

Divers matériaux ont été utilisés pour l'établissement de l'étalon tels que les métaux, l'ivoire (18), l'os de bœuf (12), la cendre d'os (39) et diverses solutions chimiques contenues dans un cône en perspex (14, 20). Les métaux les plus communément utilisés sont l'aluminium ou un alliage constitué de 92,5% d'aluminium avec 7,5% de zinc, lequel présente un coefficient d'absorption proche de celui de l'apathite (31). Les étalons de métal sont soit de forme scalaire avec des degrés de densité connue, soit des cônes dont la courbe de densité est connue.

La densitométrie est habituellement effectuée au moyen d'un densitomètre que l'on peut trouver dans le commerce. La mesure densitométrique de la radiographie d'un os donne une courbe dont l'amplitude varie en fonction de la densité des tissus mesurés. La densité optique s'obtient en calculant la surface de cette courbe, soit avec un planimètre, soit au moyen d'un computeur approprié. La densité optique de l'os est alors comparée avec celle de l'étalon. On peut aussi utiliser un gabarit pour la localisation d'une zone d'un os tel que la partie distale du radius dont la densité optique sera mesurée avec un densitomètre EEL sans scan. L'identification de la zone correspondante sur l'étalon permet de trouver la densité de l'os, exprimée en mm d'épaisseur de l'étalon (5,22).

La corrélation entre la denstté de l'os et de l'étalon est influencée par le kilovoltage utilisé pour faire la radiographie ainsi que par l'ouverture du champ. L'augmentation de l'ouverture pour un kilovoltage constant diminue l'épaisseur équivalente de l'étalon, tandis que l'augmentation du kilovoltage pour une ouverture constante du champ l'augmente. La relation densitométrique entre le minéral osseux et l'étalon reste linéaire pour une ouverture de champ de 13 cm et un kilovoltage entre 30-90. Une fois déterminés le kilovoltage et l'ouverture de champ appropriés, il est bon de s'y tenir pour toutes les mesures (30).

La courbe de sensibilité du film compense les changements du temps d'exposition. Ainsi la durée de l'exposition peut être variée sans affecter les résultats (30). La durée d'exposition choisie devrait fournir une densité optique sur le film qui soit adaptée au densitomètre utilisé (20). Cette densité doit être suffisante pour maintenir la densité de la partie la plus mince du cône-étalon au-dessus de la densité optique minimum du film (8). Il faut s'assurer par des tests préliminaires que l'irradiation est également distribuée sur toute la surface du film et que les cassettes utilisées donnent toutes des résultats comparables (20).

Le mieux est de développer les films dans un appareil automatique.

Une des causes importantes de la variation de la densité optique de l'os est l'épaisseur des parties molles. L'absorption des rayons X par l'eau étant comparable à celle des parties molles, cet effet peut être éliminé en plongeant le membre et l'étalon à radiographier dans une bassine contenant de l'eau à une profondeur constante. Cela suppose que tous les membres à radiographier ainsi que l'étalon ont la même épaisseur de parties molles ou de leurs équivalents (15). L'effet de dispersion est également standardisé lorsque l'épaisseur des parties molles ou l'épaisseur de la couche d'eau interposée sont constantes (13). L'effet de dispersion peut être diminué en allongeant la distance entre le membre à radiographier et le film (15) – cette distance devant être de 40 cm dans le cas de l'avant-bras – ou en plaçant un canevas de plomb sous la cassette.

Les dispositions les mieux appropriées ayant été trouvées, il faut s'y tenir. Celles-ci comportent le kilovoltage, l'ouverture du champ, le temps d'exposition, la distance entre le tube à rayons X et le film, la distance entre le membre à radiographier et le film, le type du film, la position de l'étalon et du membre dans la bassine d'eau, les cassettes et la technique de développement du film. On a avancé que les erreurs de la méthode densitométrique s'ajoutent et que par conséquent la densitométrie est moins précise que la mesure de l'épaisseur corticale (8). De telles causes d'erreur peuvent être diminuées en vouant une attention pédante à la standardisation de cette technique.

La méthode densitométrique est utilisée pour les os de la main, le cubitus, le radius, le fémur et le calcaneum.

A.2. Mesure de l'absorption de l'énergie des photons par l'os

Cette technique décrite par *Cameron* et *Sorenson* (4) remplace le rayonnement X à multiples niveaux énergétiques ordinairement utilisé par une source monochromatique de rayons gamma fournie par l'iode-125 ou l'américium-241. La quantité d'énergie absorbée par l'os irradié par une telle source est proportionnelle à la masse de minéral osseux présente. Actuellement on trouve dans le commerce un appareil permettant un balayage par le faisceau de rayons gamma du membre dont on désire mesurer la densité osseuse. Un compteur de scintillations en iodure de sodium permet la mesure de l'absorption de l'énergie des photons. Dans le modèle commercial, l'information provenant du compteur est transmise à un petit computer qui effectue l'intégration de la surface de la courbe d'absorption, surface variant avec la quantité d'os minéral présente. Le computer donne, à partir de cette surface, la quantité d'os minéral. Les mesures effectuées avec l'iode-125 donnent une bonne corrélation entre la masse osseuse du radius et son épaisseur. Les facteurs de correction de l'épaisseur diminuent la variabilité des mesures de la masse osseuse du radius dans une population donnée (33).

En utilisant l'appareil on tient compte de la variation due aux parties molles en entourant le bras avec un sac de caoutchouc contenant de l'eau ou une solution de sulfate de potassium à 2%. Ce sac est comprimé contre une ouverture carrée à travers laquelle le bras est enfilé, ce qui donne une équivalence constante pour les variations dues aux parties molles.

Pour les os relativement minces comme le radius, on utilise avantageusement l'iode-121 comme source de rayons gamma. Pour les os plus épais, on utilise l'américium-241.

La méthode est parfaitement reproductible avec un coefficient de variation compris entre 2% et 3% pour des mesures répétées chez le même sujet (33). Le point idéal pour la mesure de l'épaisseur du cortex osseux est situé à 8 cm de l'extrémité distale du radius. Le point de mesure de la densité de l'os trabéculaire s'effectue à 3 cm de cette même extrémité distale.

Les mesures effectuées d'après cette technique sont comparées aux mesures effectuées sur la cendre d'os de cadavres (34). La corrélation est bonne. Cette technique de mesure de la masse osseuse est la plus satisfaisante lorsque l'os est recouvert de tissus de densité différente.

A.3. Méthodes anthropométriques

(squelette appondiculaire)

Les mesures anthropométriques de la masse osseuse sont basées sur la mesure de l'épaisseur du cortex d'os tels que les phalanges, le radius, le cubitus, le fémur et la clavicule. On obtient des radiographies avec la meilleure définition en exposant le film sans écran. On utilise le plus souvent les métacarpiens et les phalanges.

La plupart utilisent le deuxième métacarpien de la main droite. On en mesure la longueur (L) dont on calcule la moitié. On mesure alors le diamètre du métacarpien à la moitié de sa longueur avec une jauge micrométrique, si possible munie d'un cadran (D), ainsi que le diamètre de la cavité médullaire (d). L'épaisseur corticale est alors donnée par D-d. On a calculé divers indices basés sur ces mesures tels que l'index métacarpien (D-d) x 100/D (3), la surface corticale D^2-d^2 (6, 8) et un index sans dimensions D^2-d^2/D x L (7). Dans les études statistiques ces indices se comportent plus ou moins comme l'indice D-d, le plus simple à calculer.

Ces mesures sont reproductibles (24). La marge interne du cortex n'est pas toujours nette. On peut la voir mieux sous lumière atténuée avec l'aide d'une loupe.

La corrélation entre les mesures de l'épaisseur du cortex et le contenu en cendres de phalanges mesuré post mortem est excellente (6, 8). Un travail récent d'*Exton-Smith* et coll. a montré que la corrélation est meilleure pour l'index D^2-d^2 que pour D-d (6).

La corrélation entre l'épaisseur corticale et la mesure densitométrique du même os est moins bonne (2, 8, 23). Une corrélation inverse a été trouvée entre l'occurrence de fractures de la partie distale de l'avant-bras et les mesures densitométriques de la masse osseuse au poignet (27).

A.4. Radiations naturelles

On a utilisé, pour la mesure de la densité osseuse les radiations spontanées provenant du calcium 47 contenu dans l'os. Après avoir recouvert le membre à mesurer, on utilise un cristal d'iodure de sodium pour compter les radiations provenant du Ca 47 provenant d'un point déterminé de l'olécrâne ou du calcaneum (11). Le Ca 47 représentant une proportion constante du calcium de l'os, il est facile de déduire le contenu en calcium total de l'os examiné.

B.1. Densitométrie du squelette axial

On a utilisé la densitométrie pour mesurer la masse osseuse de la colonne vertébrale, mais cette mesure est plus difficile que pour les extrémités, vu l'épaisseur des tissus interposés. *Nordin* et coll. ont tenté d'éliminer les différences dues aux parties molles en comparant la densité des vertèbres avec celle des disques inter-vertébraux (3, 28). On a utilisé comme étalon une vertèbre provenant d'un homme mort jeune, placée dans la même position que la vertèbre du sujet d'examen, et recouverte de couches de caoutchouc donnant l'équivalent de la densité des parties molles du sujet vivant. Le patient est couché sur le côté. La différence de la densité optique entre la vertèbre et le disque intervertébral du sujet, divisée par la même différence mesurée sur l'étalon fournit un rapport dépendant de la masse osseuse de la vertèbre. Dans la méthode de *Vose* (29) un cône étalon en métal fut exposé entre deux plaques de plexiglass donnant l'équivalent des parties molles du sujet couché sur le côté.

En plus des difficultés spécifiques mentionnées ci-dessus, les mêmes précautions de standardisation que pour la densitométrie du squelette appendiculaire doivent être prises.

B.2. Mesures anthropométriques du squelette axial

Ces méthodes appliquées à la colonne vertébrale s'efforcent de mesurer le degré de déformation des corps vertébraux sur des radiographies de profil de la colonne vertébrale. En raison de la déminéralisation de l'os trabéculaire chez le vieillard, les vertèbres sont déformées en coin. On peut mesurer cette déformation en comparant la hauteur ventrale et dorsale de la vertèbre de profil. Le degré de l'ostéoporose est alors donné par le nombre de vertèbres dont la hauteur ventrale du corps est de deux tiers ou moins de la hauteur dorsale (11). La déformation en coin peut aussi être estimée par la mesure de la longueur de lignes joignant les bords antérieurs et postérieurs de six vertèbres voisines et en exprimant le résultat sous forme de proportion (22). Un autre moyen d'estimation est celle de la déformation en vertèbre de poisson produite par l'expansion du disque intervertébral par suite de la déminéralisation. Cette déformation est présente si la hauteur centrale du corps vertébral représente les deux tiers ou moins de la hauteur postérieure. *Barnett* et *Nordin* (3) utilisent la hauteur centrale pour calculer un index similaire appelé index de biconcavité. D'autres chercheurs ont comparé cet index avec la densité réelle d'une vertèbre mesurée par le principe d'Archimède sans trouver de corrélation (37). La mesure de la hauteur ventrale relative et de la hauteur centrale relative a été utilisée par l'étude de *Framingham* pour calculer le degré d'ostéoporose spinale. La mesure anthropométrique de la masse osseuse des vertèbres donne une certaine mesure du degré d'ostéoporose. S'il n'y a pas de déformation, toutefois, ces mesures ne fournissent pas d'informations sur la variation normale de la masse osseuse.

B.3. Autres méthodes de mesure de la densité du squelette axial

Ces méthodes reposent sur la mesure de la densité optique d'un corps vertébral effectuée sur une radiographie de profil de la colonne sans faire usage d'un densitomètre. Une étude a établi pour les corps vertébraux 4 catégories de densité en reportant celle-ci à la densité des parties molles mesurée sur le même film (32). Le coefficient de reproductibilité chez un observateur atteignit 0,78. Une autre étude utilisa comme étalon 5 vertèbres de cadavres dont le degré d'ostéoporose était connu: la comparaison avec la densité osseuse des vertèbres du sujet vivant s'effectuait à l'œil (35).

Comparaison entre les mesures de la masse osseuse du squelette axial et appendiculaire

La gradation utilisée par l'étude de *Framingham* (17) a été utilisée pour comparer les mesures effectuées sur les extrémités et sur la colonne vertébrale. *Goldschmitt* et coll. ont montré que les mesures effectuées à l'iode-121 sur le radius présentent une bonne corrélation avec le score de l'étude de *Framingham* (11). Une autre étude a récemment montré que la déminéralisation des vertèbres se retrouve dans le radius en effectuant des mesures chez deux groupes de femmes, l'un avec des fractures par tassement des vertèbres (33). *Smith* et *Frame* qui estiment la densité optique des vertèbres par rapport à celle des parties molles ont trouvé une bonne corrélation entre cette estimation et l'épaisseur du cortex du métacarpien (32). D'autres études ont mis en relation le nombre de fractures par tassement des vertèbres avec l'épaisseur corticale mesurée au radius et à l'humérus (19, 21). *Urist* et coll. se basant sur des mesures effectuées sur des biopsies osseuses sont d'avis que la densité des os longs reflète l'ostéoporose du squelette dans son ensemble (36). *Weaver* et *Chalmers*, dans une étude effectuée sur le cadavre ont trouvé une corrélation significative mais non excellente entre le poids des cendres d'os provenant de biopsies de l'os iliaque et la résistance des corps vertébraux aux forces d'écrasement (40). *Barnett* et *Nordin* combinèrent la mesure de l'épaisseur corticale du fémur et d'un métacarpien avec la hauteur centrale des corps vertébraux pour établir un score permettant d'estimer la masse osseuse. Ce score montre une bonne corrélation avec la densité osseuse de biopsies provenant de la crête iliaque (3). Ces diverses études montrent un certain degré de corrélation entre les mesures de la masse osseuse des extrémités et de la colonne vertébrale. Pour d'autres auteurs, ces corrélations sont misérables (11, 22).

C. Activation neutronique

Cette méthode mesure le calcium total du corps dont les 98% sont contenus dans le squelette. Le sujet vivant ou un cadavre sont exposés dans une chambre à irradiation à côté d'un étalon dont la teneur en calcium est connue. L'irradiation s'effectue par un flux de neutrons. Aussitôt après l'irradiation on mesure avec un compteur Geiger la quantité de Ca 49 formé chez le sujet et l'étalon. Cette méthode permet de calculer le calcium total du corps en grammes avec une précision de l'ordre de ±5% (25). La mesure effectuée chez des cadavres qui furent ensuite réduits en cendres dont on mesura le contenu en calcium permit d'introduire un facteur correctif pour la masse corporelle chez les sujets vivants. La masse corporelle joue un rôle important, le flux de neutrons pénétrant plus facilement dans un corps maigre que dans un sujet obèse. Les analyses effectuées sur les cadavres montrent que le calcium total augmente avec le un cinquième du cube de la longueur du squelette (25).

Ces mesures ont été effectuées chez des ostéoporotiques, donnant des valeurs nettement audessous de la normale. La méthode de l'activation par un flux de neutrons pourrait être utilisée pour estimer le calcium total dans divers groupes d'âge de sexe différent, ce qui faciliterait le diagnostic de la déminéralisation et le contrôle de l'évolution de la maladie.

D. Mesures de la masse osseuse par les ultra-sons

Les ondes sonores traversent l'os plus vite que les parties molles. Lorsqu'une onde sonore traverse un membre placé entre deux transducteurs à distance constante l'un de l'autre, le temps de traversée du membre est proportionnel aux vitesses du son dans les tissus qui le composent. Le temps de traversée mesuré chez le sujet est comparé au temps de traversée de l'os seul, ce qui donne une estimation de la masse osseuse (29).

Conclusion

Les méthodes de mesure décrites ci-dessus peuvent être utilisées chez des sujets de tout âge. Aucune n'est contre-indiquée chez le vieillard. La déminéralisation étant une affection du vieillard, les études effectuées grâce aux méthodes ci-dessus seront effectuées de préférence chez le vieillard.

Les études statistiques effectuées montrent que la masse osseuse diminue avec l'âge, la perte la plus importante s'observant chez les femmes (10). Le degré de cette perte de la masse osseuse est estimé par la mesure de l'épaisseur corticale d'os déterminés (7, 10, 22, 27) ou par densitométrie (22). Il est possible que le processus de déminéralisation diffère dans l'os trabéculaire et dans l'os cortical, puisqu'on observe une augmentation de l'épaisseur de la corticale chez le vieillard (7, 10, 22) alors que les mesures densitométriques effectuées à la partie distale du radius ne montrent pas d'augmentation (22). *Meema* et *Meema* supposent que l'augmentation de la porosité de l'os précède la diminution de l'épaisseur corticale (21). Cette hypothèse complique les relations entre l'épaisseur corticale et les mesures densitométriques. Les mesures effectuées avec l'iode-125 montrent que la déminéralisation de l'os trabéculaire est plus marquée que celle de l'os cortical (33).

La valeur moyenne de l'épaisseur corticale mesurée par densitométrie par comparaison avec un étalon de métal diminue avec l'âge dans les études effectuées chez diverses populations âgées, mais la variance des moyennes reste plus ou moins inchangée (23). Ce fait laisse supposer que la déminéralisation s'effectue à la même allure dans les deux sexes (26). Les études longitudinales ne confirment que partiellement cette hypothèse car elles montrent que la déminéralisation ne se produit pas chez tous les sujets (1, 9).

Les données fournies par les études de la masse osseuse chez les vieillards devraient être réexaminées en tenant compte de la masse corporelle afin de pouvoir corriger en fonction de celle-ci les valeurs mesurées (7).

Les méthodes décrites ci-dessus doivent être choisies selon leur convenance. La plus avantageuse, ne coûtant que le prix des films utilisés est la mesure de l'épaisseur corticale des métacarpiens ou des phalanges. Cette technique permet de détecter des changements survenant chez le même sujet en quelques années (9). La mesure de l'absorption des rayons gamma provenant d'une source d'iode-125 (4) a résolu ou éliminé la plupart des problèmes associés à la mesure densitométrique de la masse osseuse. Pour ceux qui peuvent se le procurer, cet appareil est le mieux adapté actuellement à l'étude de la masse osseuse effectuée sur des populations.

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MEASUREMENT OF BONE MASS IN OLDER PEOPLE

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INTRODUCTION

The measurement of bone mass in older people is of more than academic interest. This is demonstrated by the fact that one quarter of the orthopaedic beds in Edinburgh are, at any one time, occupied by elderly women with fracture of the femur, an injury known to be associated with loss of mineral from bone. Accurate measurement of bone mass, or related variables, is essential for the study of the conditions under which bone becomes demineralised. Demineralisation may result from physiological ageing, disease or treatment with, for example steroid drugs. Any increase in the accuracy of measurement would not only permit improved study of the natural history of bone mineral loss in the population, but would also allow the assessment of methods of treatment when these became available. Ultimately such measurement may help in exploring the inheritance patterns of bone mineral loss. Students of body composition find the mass of the skeleton difficult to assess and accurate measurements of bone mass would help to solve this problem also. Special techniques are needed since standard radiographs show changes in bone mass only after loss of 30% of bone mineral (16).

METHODS

Methods used in measuring bone mass are:

A. Appendicular skeleton

1. Densitometric
2. Measurement of the absorption of energy from a suitable X-ray or radio-active source.
3. Anthropometric.
4. Background radiation.

B. Axial Skeleton

1. Densitometric.
2. Anthropometric.
3. Other.

C. Neutron Activation

D. Sonic

The remainder of this paper discusses these methods.

A 1. Densitometry (appendicular)

All densitometric methods depend on radiography of a bone with a suitable standard beside it. Measurements are then made to compare, on the radiograph, the optical density of the bone with that of the standard. If the standard is a wedge of known slope the bone density can be expressed as millimetres of thickness of standard. This density is optical and further computations based on suitable experiment would be needed to convert this to density expressed as grammes of bone mineral per unit volume of bone. Described in this way, the technique sounds simple but it is subject to many causes of variation.

Many materials have been used as standards including metals, ivory (18), beef bone (12), bone ash(39), and chemical solutions in perspex wedges (14, 20). Metals commonly used are aluminium or a mixture of aluminium 92.5% with zinc 7.5% which has an absorption coefficient close to that of apatite (31). Metal wedges are either step wedges with steps of known thickness or plain wedges of known slope.

Densitometry is usually performed using a commercially available densitometer. The densitometric scan across the radiograph of the bone results in a curve varying in height according to the type of soft tissue or bone being scanned. Measurement of the relevant area under the curve, to compute the optical density, may be done simply with a planimeter or by a suitable computer programme. This density is compared with that resulting from scanning the radiograph of the standard. Alternatively a template may be used to identify an area of a bone such as the lower radius on the radiograph and the optical density of this area measured with an EEL densitometer, without scanning. The identification of the site with equivalent optical density on the standard allows expression of bone density in terms of thickness of standard (5, 22).

The relationship between bone and standard is affected by the kilovoltage used in making the radiograph and by the size of the field. Increasing field size at a constant kilovoltage diminishes and increasing kilovoltage at a constant field size increases the equivalent thickness of the standard. The densitometric relationship between bone mineral and standard is linear with a field size of 13 cm and kilovoltage in the range 30-90. When suitable kilovoltage and field size have been determined they should be kept constant (30).

The film response curve compensates for exposure changes. Hence the duration of exposure can be varied without affecting the results (30). The exposure chosen should provide an optical density on the film which suits the densitometer used (20). This density should be sufficient to keep the density of the thinnest part of the wedge above the minimum optical density of X-ray film (8). Preliminary testing should make certain that radiation is evenly distributed over the film and that casettes are used which give comparable results (20). Processing of films is best done automatically.

An important cause of variation in optical density of bone is variation in thickness of soft tissue. Since the absorption of X-rays by water is similar to that of soft tissue, this effect can be largely eliminated by immersing the limb to be X-rayed and the standard in a water bath of constant depth. This means that all limbs X-rayed and the standard have virtually the same thickness of soft tissue or its equivalent (15). A constant thickness of soft tissue or water also standardises the effect of scatter (13). Scatter can be reduced by a long exit distance from limb to film (15), 40 cm in the case of the forearm, and by placing lead canvas under the cassette.

Once suitable conditions have been determined they should be kept constant. These include kilovoltage, field size, exposure, tube-film and limb-film distances, type of film, position of standard and limb in the water bath, cassettes and type of processing. It has been suggested that errors in densitometry may be additive so that densitometry is potentially less accurate than measurements of cortical thickness (8). Such errors can be minimised by an obsessional regard for standardisation of technique.

Sites used in densitometry in the limbs include hand bones, ulna, radius, femur and calcaneus.

A 2. Measurement of photon energy absorbed by bone from a radio active source.

In this technique, described by Cameron and Sorenson (4) the X-ray beam of multiple energy levels is replaced by a monochromatic source of gamma rays usually iodine 125 or americium 241. When such a beam falls on bone, the amount of photon energy absorbed by the bone is proportional to the mass of bone mineral present. An apparatus, now available commercially, has been constructed in which a scanner transports the beam of gamma rays across the limb whose bone mass is to be measured. A sodium iodide scintillation counter estimates the absorption of photon energy. In the commercial model, the output from the counter is fed into a small computer which integrates the area under the absorption curve. This area varies with the amount of bone mineral present. Using suitable factors the computer calculates, from the area, the bone mineral content. Iodine 125 scans show a high correlation between bone mass of the radius and bone width. Correction for bone width reduces the variance of bone mass of the radius in the population (33).

When using the apparatus, allowance is made for variation in soft tissue by encircling the arm with a rubber bag containing water or 2% potassium sulphate solution. This bag is compressed in an aperture of square section through which the arm passes, thus providing a constant soft tissue equivalent.

For smaller bones, such as the radius, iodine 125 is a suitable source of gamma rays. For larger weight-bearing bones, americium 241 is used.

The technique has good repeatability with a coefficient of variation between 2% and 3% in repeated measurements on one person (33). A satisfactory site, mainly cortical bone, is 8 cm proximal to the distal end of the radius.

Measurements made in this way were related to the ash content of the bone scanned in cadavera (34). The scan correlated well with ash content. This method of measurement of bone mass is probably the most satisfactory for use in bones covered by other tissues.

A 3. Anthropmetric methods (appendicular)

Anthropometric estimates of bone mass are based on measurements of the cortical thickness of suitable bones, such as phalanges, radius, ulna, femur and clavicle. The best radiographs for the purpose, with sharp definition, are obtained by exposing films without screens. Metacarpals or phalanges are the bones most commonly measured.

The second right metacarpal is used by many workers. The length (L) is measured and the mid point marked. Using an engineer's vernier caliper, preferably with a dial, the diameter (D) of the metacarpal is measured at the mid point, as is the diameter of the medullary cavity (d). Cortical thickness is then calculated as D - d. Various indices related to this have been used such as the metacarpal index (D - d) x 100/D (3), the cortical area $D^2 - d^2/D \times L$ (7). In population study these indices behave statistically very much as D - d, which is certainly the simplest to compute.

These measurements are satisfactorily reproducible (24). The inner margin of the cortex is not always sharply defined. It can sometimes be more clearly seen with the light dimmed in the viewing box and with a hand lens to inspect the margins of the cortex.

High correlations have been found between cortical measurements on a phalanx and ash content of the phalanx determined after death (6, 38). A recent study by Exton-Smith and his colleagues showed the best correlation with ash content was from $D^2 - d^2$ rather than $D - d$ (6).

Moderate correlations have been reported between cortical thickness and densitometry on the same bone (2, 8, 23). An inverse relationship has been found between lower forearm fractures and densitometric estimates of bone mass at the wrist.(27).

A 4. Background radiation

Background radiation from the naturally occurring isotope calcium 47 has been used in the measurement of bone mass. After suitable shielding a sodium iodide crystal is used to count calcium 47 from such sites as the olecranon or the calcaneus (11). Since calcium 47 forms a constant proportion of natural calcium, the count of calcium 47 varies with the amount of calcium in the bone examined.

B 1. Densitometry (axial)

Densitometry has been used to measure bone mass in the spine but is more difficult in this site than in the limbs because of the greater soft tissue mass and because of gas in the bowel. An attempt was made by Nordin and his co-workers to eliminate soft tissue differences by comparing the density of vertebrae with that of intervertebral discs (3, 28). A spine from a young man obtained at autopsy was used as a standard, with soft tissue equivalent rubber above and below it to place the phantom in the same position as the spine of the subject lying on his side. Difference in optical density between vertebra and disc in the subject, divided by the same computation in the standard gave a ratio presumably dependent on the bone mass of the vertebra. In the method used by Vose (29) a metal calibration wedge was exposed through a stack of plexiglass plates equivalent to the lateral thickness of the patient.

Apart from the special difficulties mentioned above, spinal densitometry requires the same attention to exposure and processing factors as was described in the section on densitometry of the appendicular skeleton.

B 2. Anthropometric methods (axial)

These methods applied to the spine attempt to measure the amount of deformity of vertebral bodies in lateral radiographs of the spine. With the loss of trabecular bone in older people, vertebral bodies may become wedge-shaped. This may be measured by comparing the anterior with the posterior height of vertebral bodies and grading osteoporosis by the number of vertebrae in which the anterior height is 2/3 or less of the posterior height (11). Wedging can also be assessed using a map-measurer to determine the lengths, including disc spaces, of lines drawn through the anterior and posterior borders of six adjoining vertebral bodies and expressing the result as a ratio (22). A further measurement available is that of the codfish deformity produced by the expansion of the intervertebral disc into the demineralised vertebral body. This deformity is said to be present if the central height of a body is 2/3 or less of the posterior height.

Barnett and Nordin (3) used anterior height to calculate a similar index called the index of biconcavity. Other workers compared this index with the actual density of a vertebra measured by the principle of Archimedes and found no relationship (37). Measurements of relative anterior height and relative central height as described above were used in the Framingham study to compute a score for spinal osteoporosis. Anthropometric examination of bone mass in the spine seems to measure the degree of osteoporosis. If no deformity of vertebral bodies is present, no information about normal variation in the bone mass of the spine can be obtained from these measurements.

B 3. Other methods (axial)

These methods depend on assessment of the optical density of vertebral bodies in a lateral radiograph of the spine without using a densitometer. In one study the density of vertebral bodies was scored in four categories by comparison with the density of soft tissue on the same film (32). The coefficient of reproducibility for one observer was 0.78. Another study used 5 different vertebrae, obtained at autopsies, which showed varying known degrees of demineralisation. These were used as standards, on spinal radiographs, with which the optical density of the vertebrae of the subject was compared visually (35).

Comparison of axial and appendicular measurements of bone mass.

The Framingham spinal score for osteoporosis (17) has been used to relate measurements made on the limbs to the state of the spine. Goldsmith and his co-workers showed that iodine 125 scans of the radius correlated well with the Framingham score (11). Another recent study which separated a group of women into those with and those without crush fractures of vertebrae, used iodine 125 scans to show that mineral loss from vertebrae was reflected in the radius (33). Smith and Frame who assessed the optical density of vertebral bodies by direct visual comparison with that of soft tissue found a significant correlation between that assessment and metacarpal cortical thickness (32). Other studies have related crush fractures of vertebrae to cortical thickness in the radius and humerus (19, 21). Urist and his colleagues thought that bone biopsy suggested that long bones reflected osteoporosis in the skeleton as a whole (36). Weaver and Chalmers, in an autopsy study, showed significant but poor correlation between the ash weight of iliac biopsy and resistance of a vertebral body to a crushing force (40). Barnett and Nordin combined cortical thickness measurements on the femur and on a metacarpal with a measure of central vertebral height to obtain a score which estimated bone mass. This score showed a significant correlation with iliac crest biopsy (3). These various studies show some measure of agreement between bone mass measurements in the limbs and those in the spine. Other studies have found poor correlations between such measurements (11, 22).

C. Neutron Activation

In this method total body calcium, at least 98% of which is in the skeleton, is measured. The living subject, or a cadaver, is exposed in an irradiation chamber, together with a calcium standard of known composition, to a neutron flux. Immediately after irradiation the subject and the standard are counted in a whole body counter to estimate the quantityof induced calcium 49. With these results it is possible to calculate total body calcium in grammes with an accuracy of +- 5% (25). Examination of cadavera in this way, followed by direct estimation of total body calcium by ashing the whole cadaver, introduced a correction for body size into the estimation in living subjects. Body size is important because the neutron flux penetrates smaller bodies to a greater degree than in larger bodies. Cadaveric analysis showed that total body calcium increases as 1/5 the cube of the skeletal length (25).

Measurement of total body calcium has been performed in persons who have demineralisising bone disease. In these patients measured totals were well below predicted values. Neutron activation could be used to determine normal values of total body calcium in various age groups of each sex, to assist in the diagnosis of wasting disease of bone and to follow the progress of such disease.

D. Sonic measurement of bone mass

Sound has greater velocity in bone compared with soft tissue. When a burst of sound passes through a limb between two transducers which are a constant distance apart, the transit time through the limb is proportional to the velocities of sound in the tissues. The actual time recorded compared with that recorded in bone alone can be used to measure bone mass in the limb in a column of unit area in the path of the sonic beam (29).

CONCLUSION

The methods described are applicable to persons of any age. None is unsuitable for use in the elderly. Since demineralisation is largely associated with ageing, studies using any of these methods tend to be made on older people.

Cross-sectional studies show bone mass decreasing as age increases, the apparent loss being greater in women (10). This loss is found using cortical thickness (7, 10, 22, 27) or densitometry (22). The process of loss of bone mineral may differ in trabecular and cortical bone since cortical thickness in cross-sectional study increases in the oldest men (7, 10, 22) but densitometry on the lower radius does not show this increase (22). Meema and Meema have offered a hypothesis in which increased porosity of cortical bone precedes loss of cortical thickness (21). This would complicate the relationship between cortical thickness and densitometry. The rate of bone mineral loss with age was greater in trabecular than in cortical bone using iodine 125 scanning (33).

The mean values of cortical thickness and of metal equivalent in densitometry decrease with increasing age in cross-sectional studies of the elderly, but the variance of the means remains much the same (23). This suggests that all persons in both sexes lose bone at much the same rate (26). Longitudinal studies only partly confirm this since they reveal some subjects in whom bone loss does not occur (1, 9).

Data in studies of bone mass in older people should be examined to assess the effect of body size on the results and to correct for this if necessary (7).

The methods described vary in their suitability. The cheapest method, whose cost is only that of hand films, is measurement of metacarpal or phalangeal cortical thickness. This technique is quite capable of showing longitudinal change in a short period of years (9). The measurement of absorption of gamma rays from an iodine 125 source (4) has solved or eliminated many of the problems associated with bone densitometry. For those who can afford it, this apparatus is probably the best tool available at present for the study of bone mass in the population.

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