Diet and physical activity as determinants of nutritional status in elderly women

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Diet and physical activity as determinants of nutritional status in elderly women

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Aan mijn ouders en mijn oma

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Stellingen

1. Overgewicht kan op hogere leeftijd leiden tot verminderde lichamelijke activiteit.
(dit proefschrift)

2. Inactiviteit bij ouderen leidt doorgaans niet tot ernstige voedingstekorten.
(dit proefschrift)

3. De beste manier om de voedingstoestand van ouderen in de gaten te houden is hen regelmatig op de weegschaal te zetten.
(dit proefschrift)

4. Er zijn geen ethisch verantwoorde methodes voor het bepalen van de lichaamssamenstelling bij ouderen.
(o.a. dit proefschrift)

5. Het geven van dieetadviezen aan ouderen is zinloos als daarmee afbreuk wordt gedaan aan het eetplezier.

6. Het beeld dat onder jongeren bestaat over ouderen is meestal gegrond op de bekendheid met de grootouders. Het beeld dat ouderen hebben over de jeugd in het algemeen is afkomstig uit de plaatselijke pers. Eigen kleinkinderen vormen meestal de gunstige uitzondering op de regel.

7. Hoe lang ik zal leven, ligt niet in mijn macht. Dat ik echter, zolang ik leef, ook daadwerkelijk leef, dat ligt aan mijzelf.
Seneca.

8. There exists a paradox between the efforts made to reduce the injuries caused by biological aging and the attention paid to the injuries imposed by social aging.
Dean, D. Lancet (1992);339:1403-1404

9. Eenmaal zal je doodgaan, niet omdat je ziek bent, maar omdat je leeft.
Seneca.

10. De aantrekkelijkheid van de titel van een publikatie bepaalt voor een groot deel de belangstelling van de potentiële lezer.

11. Om oud en wijs te worden is promoveren geen vereiste.

Proefschrift L.E. Voorrips
Diet and physical activity as determinants of nutritional status in elderly women.
Wageningen, 3 november 1992.

Abstract

Diet and physical activity as determinants of nutritional status in elderly women.

Thesis, Department of Human Nutrition, Wageningen Agricultural University, Wageningen, the Netherlands, 3 November 1992.

Laura E. Voorrips.

The purpose of the studies described in this thesis was to examine the relationship between physical activity, dietary intake and nutritional status in elderly women.
Background of the study was a lack of knowledge about the existence of nutritionally unfavourable pathways associated to the age-associated decrease in physical activity, leading to either overweight or nutrient deficiencies.
A physical activity questionnaire was adapted and validated for use in elderly people and applied to perform a cross-sectional study in independently living apparently healthy women aged 60 to 80 years. Comparison revealed a marked weight difference, body weight being substantially higher in sedentary elderly women compared to women with a high level of physical activity. In retrospect, analysis of both body weights and physical activities showed that the weight difference was already prevalent at the age of 25 whereas no differences could be detected in former levels of physical activity. It was suggested that the currently low level of physical activity was more a result rather than a cause of a high body weight. Using a battery of tests to assess physical fitness it was shown that flexibility and endurance were associated to level of physical activity. Data were confirmed in findings on subjective fitness. Measurement of energy expenditure at rest and during standardised activities revealed that energy costs of walking on a treadmill were markedly higher in elderly than in middle-aged women.
Conclusions of the study were that women with a higher body weight might be more likely to reduce physical activity with ageing. An explanation is that the age-dependent increase of energy costs of moving around makes the performance of physical activity unpleasant, especially in women with a high body weight.

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Voorwoord

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Een belangrijke bijdrage aan de plezierige werksfeer is geleverd door de grote groep AIO's en OIO's die onze vakgroep rijk is. Het goed onderling overleg maakt dat we ons samen sterk voelen om de problemen rondom het "AIO-schap" te kunnen oplossen.

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Chapter 1

Introduction.

In most Western societies, the number of elderly people is increasing, both absolutely and expressed as a percentage of the total number of inhabitants. In 1980, 9.3% of the residents of the Netherlands was aged 65 to 79 years and 2.2% was aged 80 years or older. In 1991 those numbers were increased to 10 and 2.9% respectively[1]. It is expected that these figures will rise to about 11.0 to 11.3% for age 65 to 79 and to about 3.6 to 4.0% for age 80 and over, in 2010. The number of elderly women outweighs that of men. For the age 65 to 79 the female/male sex ratio is 1.31, for the age group of 80 years and older this ratio is 2.22[1].

This demographic revolution requires adaptation of amongst others a nutrition and health policy which must be based on sound scientific information. Studying the elderly people in these fields, however, gives rise to some specific problems and these will be discussed first.

Chronological versus biological age

Ageing is a multifactorial process which alters structures and reduces function of cells and tissues of many organ systems[2]. Generally it is characterized by a diminished ability to regulate the internal environment (impaired homeostasis) and by a reduced probability of survival[3]. The consequences of impaired homeostasis are an unstable equilibrium that easily can be disturbed due to stress generating events.

A wide variability exists between the rates of ageing in individuals. This has led to the concept and use of "biological age(ing)" versus "chronological age(ing)". Chronological age is the age based on calendar time[4]. In the first decades of life chronological age is a main determinant of physiological and social development. With increasing age, this relationship attenuates and the variability in development widens. Chronological age ends up to be a rather insensitive measure of ageing. Biological age, on the other hand, defines the ageing status based on functional capacity. In a chronological age group, the man or woman who differs least in functional properties from the status observed in young individuals has the lowest biological age[4]. In certain aspects of ageing research, biological age could be a more preferable base to select participants than chronological age. However, the establishment of biological age will always be a problem, as no uniform measure is available so far[4]. For the use of biological parameters to assess ageing, adequate reference values should be available to evaluate the process of ageing. The dilemma arises that in medical science "normal" and "optimal" ageing are difficult to define.

The discrimination between effects of ageing per se and effects resulting from disease is extremely difficult and often not clear at all. In general, it can be stated that changes that occur with ageing in almost all persons and of which the possibilities of medical or other interventions are not known, can be considered as normal ageing (e.g. changes in the arterial wall, in the cartilages of large joints etc.)[4]. As presented by Shock, different body functions show a very diverse rate of decline with age[5,6]. This illustrates the problem of purchasing a valid test to assess biological ageing. For some aspects of ageing research, unhealthy people could be excluded from the study population, to allow study of effects of "true ageing". For studies on the effects of menopause-related changes, years after menopause could be used instead of, or in addition to, chronological age. In general, for most purposes the use of chronological age can be preferred over the use of biological age as long as definite and well described methods to assess biological age are not available.

Using chronological age, elderly can be divided in age groups. A segmentation that is commonly used is described by Shephard[3], classifying in middle age (age 40 to 65), old age (age 65 to 75), very old age (age 75 to 85) and extreme old age (age 85 and over).

Elderly volunteers as subjects

Studying elderly people is always subject to a certain selection bias. First of all, necessarily elderly volunteers have lived long enough to allow participation in ageing studies, referred to as selective survival[7]. More than in studies in younger people, elderly volunteers are part of a self-selected group who have distinguished themselves by actively participating in a research study in their old age[8]. As diversity in physiological functioning widens with increasing age, selective participation is more severe in the elderly than in the young[9]. This may cause serious problems in studies where representative samples on population basis are required or where results are to be extrapolated into the general population. In studies on physical activity, it is expected that those subjects will participate who consider themselves as physically fit or who expect some benefit out of participation. This results in participants with either above-average health or people anxious about their health. Such problems are more serious in older than in younger subjects, since the proportion of volunteers diminishes progressively with age[3].

Comparing elderly and younger subjects' performance on physical tests reveals specific problems. It is difficult to persuade elderly people to do particular exercises as they are often anxious to fall or to extent measurements up to exhaustion. Also, when they are motivated, they are often not used to the exercise or equipment[3]. Another problem evolving in comparisons of elderly and younger subjects as regards to their physical activity is that due to the relatively sedentary nature of most older people, cross-sectional differences will always exist in physical activity level of elderly and younger subjects[10].

Another factor affecting the choice of methodology is the impaired short-term memory in elderly subjects. In food consumption studies, the relatively simple 24 hour recall method gives problems when applied in the elderly. Methods requiring long term memory and that are based on habitual intake, such as the one month-dietary history however, are easier to perform in the elderly than in the young because of their strong reliance on life long habits[11].

Longitudinal versus cross-sectional study design

The problem of selective participation is partly responsible for the discrepancy observed between cross-sectional and longitudinal studies on ageing[9]. In longitudinal studies, subjects serve as their own controls. Confounding by hidden factors such as heredity can be controlled[9]. However, cohort effects or time effects can influence interpretation of results. Furthermore, longitudinal studies are expensive, have a long duration and are subject to loss of participants. Subjects generally have to be higher motivated to participate than in cross-sectional studies. An example of a longitudinal study involving

Dutch participants is the Zutphen-cohort of elderly men, participating in the Seven Countries Study[12,13].

Another approach is the use of a mixed longitudinal design. On base level, people are recruited at different ages (cross-sectional part) and followed at intervals (longitudinal part). Using this design, the effect of ageing can be discriminated from cohort- and time effects. It has in common with the longitudinal design that it is expensive and requires highly motivated individuals. This design is used in the Baltimore Longitudinal Study on Ageing. The European study on nutrition and health in the elderly (Euronut-SENECA) has been a cross-sectional study that in most participating research centers will be extended to become mixed-longitudinal[14]. The Dutch data in this study are collected in Culemborg[15].

The process of ageing and its relationship with physical activity and nutrition

The decrease in functioning of various organ system which is referred to as ageing, is subject to influences from heredity, disease, and factors such as physical activity and nutrition.

A commonly observed phenomenon in ageing is a gradual conformation to a more sedentary lifestyle. Partly the decrease in physical activity is resulting from a decline in job responsibilities due to retirement. As work activity in Western societies is much less nowadays than it once has been, the decrease in physical activity following on retirement will be less pronounced although the daily routine of going out to work is disturbed. The conformation to a more sedentary life style also is a result from cultural habits. The sedentary existence in old age has been considered the reward for a life time of hard work[16].

Along with the decline in physical activity and energy expenditure a gradual decline in energy intake has been observed. In a cross-sectional analysis of data of the Baltimore Longitudinal Study on Ageing[17] (BLSA), it was shown that energy intake in men aged 20 to 93 years declined linearly from 11.3 MJ/day at age 30 to 8.8 MJ/day at age 80. Comparable changes have been reported in the Zutphen cohort[12]. In Dutch harbour employees before and after retirement (with a time interval of 12 to 14 years), Bakkum *et al* reported a reduction in daily energy intake of 4.3 MJ per day[18] which can be ascribed primarily to the loss of working activity. The adjustment of energy intake to reduced levels of energy expenditure is a favourable phenomenon in view of maintenance of energy balance and prevention of obesity. However, a decrease in energy intake easily is accompanied by a decreased intake in micronutrients. The requirements of most nutrients probably are not changed with ageing[19].

Changes that occur with ageing also can have an effect on both physical activity and nutrition. For example, a reason for a decline in physical activity can be the muscular and joint deterioration that makes movements more difficult[20]. Likewise, changes occurring with aging can affect the entire process of preparation of food, consumption and digestion in the body.

On the following pages, relevant changes occurring with ageing and directly related to physical activity and/or nutrition will be described. Where suitable, effects of physical activity and nutrition will be discussed.

Ageing and body composition

Obvious changes with ageing occur in body composition: the accumulation of fat and the substantial loss of fat-free mass (muscle mass and bone mineral). Increase in body weight with ageing is common and considered "normal"[9].

In sedentary populations the gain in weight will be mostly fat, although in later age this weight gain will be masked by decrease in bone mineral and muscle tissues[9]. In addition, a redistribution of adipose tissue takes place, as more fat is stored intra-abdominally[21]. Chronic exercise can reduce fat accumulation with age, and older people can have body compositions comparable to younger people when physical activity is continued throughout lifespan[22,23]. In a cross-sectional study body composition of male master athletes was compared to younger athletes and untrained men[23]. Body composition of master athletes was comparable to younger athletes, whereas the visually matched older sedentary individuals were fatter. De Vries[24] found a small but significant decrease in the body fatness of 112 men aged 51 to 87 years, following six weeks of regular exercise involving calisthenics, stretching, walk-jogging, and some aquatic sports. Continuation of the program for 42 weeks produced no further change. In an observational longitudinal study a mean increase of 3% of body fat was observed in 73 manual workers from one year before to one year after retirement[25]. Muscle mass was decreased by 1%. The change proved to be dependent on the actual change in physical activity. Analysis of a subsample revealed that muscle mass further decreased in the following five years.

The decrease in fat free mass observed with ageing can be ascribed for the bigger part to the loss of skeletal muscle. Muscle mass loss is estimated to be 40% between ages 20 and 70 as assessed by reduction in urinary output of muscle-derived metabolites creatinine and 3-methylhistidine[26,27], ^{40}K loss[28,29], and autopsy findings[30]. The latter findings also revealed that internal organs of people over the age of 70 weigh 9 to 18% less than the similar visceral organs of young adults[30]. Sidney *et al* found that a year of endurance training in 65-year old men increased their whole-body potassium by 4%[22]. In a study on skeletal muscle changes with regular exercise, Suominen *et al*[31] studied 26 men and women aged 69 years in Finland. In eight weeks, the subjects participated in 5 one-hour exercise sessions per week. Muscle biopts showed enzyme changes indicating an increased capacity for aerobic metabolism in skeletal muscle following exercise regimen.

Bone mass and bone composition change with age. In men bone loss is ± 0.4% per year starting at age 50, whereas the loss in women is higher and starts earlier. After menopause bone loss is increased 5-fold. The decrease in bone loss results in a high rate of bone fractures of primarily hip, spine and wrist in older compared to younger women[9]. Decreased hormone levels may be one important factor in the bone loss as osteoblast activity is increased when oestrogen is administered. Inactivity is considered to be a key factor in bone loss due to loss in mechanical forces and compressional stress applied to bones. The role of physical activity has been studied frequently in both observational and intervention studies. Volume and density of bone in the dominant arm of long term (over 4 decades) tennis players were greater than in the non-dominant hand[32,33]. Moderate physical activity has proved to be protective for bone loss in cross-sectional studies[34-36] and in longitudinal studies[22,37]. Several prospective studies demonstrate that postmenopausal women who exercise regularly gain bone mass[38-43]. No consistent data are available about the duration and intensity of physical activity needed. Physical activity that involves weight bearing and isometric stress, especially walking and strength training seem best to increase muscle and bone mass. The lifelong weight-bearing of an obese body leads to bones with a higher density[44].

Nutritional components that are known to have an impact on bone loss are calcium, phosphorus, protein, fluoride, fibre and vitamin D (derived from diet and skin)[45] and will be discussed later.

Ageing and energy expenditure

In most societies, daily energy expenditure decreases with ageing. Energy expenditure can be divided in basal metabolic rate (BMR), dietary induced thermogenesis (DIT) and energy expended due to physical activity[46]. The reduction of energy intake with ageing goes along with decreased needs due to a reduction in basal metabolic rate and in energy spent on physical activity.

It has been observed that BMR tends to decline with ageing, explained by a decrease in fat free mass (FFM). The effect of physical activity on BMR has been studied primarily in younger subjects, leading to conflicting results but generally to a higher BMR in active individuals, even when expressed per kg of fat free mass[46]. In elderly men BMR was 6% higher in active men compared to inactive men[47], even when controlled for fat free mass. In another study however, BMR tended to be higher in active elderly men compared to sedentary controls but no differences were seen when expressed per unit of body potassium[48]. Physical activity intervention with a 12 weeks exercise program at 70% of the maximal oxygen uptake (VO_{2max}) did not significantly increase BMR in older men[49].

The effect of ageing on DIT is subject to debate, but mainly a decrease is observed[50]. Physical activity appears to increase DIT in elderly men[48].

Declining physical activity accounts for a further decrease in total daily energy expenditure.

Whereas for a beneficial effect of physical activity on the process of ageing generally a certain threshold is required, it is clear that energy expenditure will be elevated at any level of activity above lying in bed.

As mentioned before, energy intake generally is adjusted to a decreased expenditure. In the seventh and eighth decade the reduction in energy intake is more pronounced, possibly due to disabilities limiting the physical activity of the ageing person[45]. Studies in nursing homes generally confirm decreased intakes with low physical activity. The decrease in energy needs in most elderly subjects however is incompatible with the unchanged requirements of most micronutrients. For vitamins that function directly in energy metabolism (e.g. thiamin), the recommended level is slightly less for older people because of their reduced energy needs[45].

In animal models dietary restriction has shown to expand life span. Also, dietary restriction might postpone physiological changes generally observed with ageing. Famous in this respect are the studies of McCay *et al* in the 1930's[51]. Most of these studies are performed in rodents and implications for humans are not clear.

Age related functional changes with ageing that are directly related to physical activity

Maximal oxygen uptake (VO_{2max}): In general the greatest age decrements are found in performances such as maximum work output that require the coordinated responses of a number of different organ systems. The neuromuscular responses involved in producing an integrated response are less effective in the old than in the young subjects[6].

Functional aerobic capacity defines the functional limit of the circulatory system to deliver oxygen to meet the greatly increased aerobic metabolic requirements of skeletal muscles during strenuous dynamic exercise. Additional energy requirements in excess of this limit are met temporary by anaerobic metabolism[2]. The measurement of functional aerobic capacity is performed by determination of the oxygen consumption during maximal possible dynamic exercise (VO_{2max}). VO_{2max} is the best single indicator of physical working capacity. It equals the product of maximal cardiac output and maximal arteriovenous oxygen difference. Cross-sectional studies reveal that VO_{2max} declines progressively with age starting after a peak in adolescence[2]. In cross-sectional studies, the age-related decline in VO_{2max} in men is 0.40 to 0.50 ml/kg.min/year, whereas the decrease in women is about 0.20 to 0.35 ml/kg.min/year[52,53]. Due to selective survival and participation in cross-sectional studies, the annual decline observed in longitudinal studies is larger than in cross-sectional studies[10,52,54]. The reduction in VO_{2max} observed with ageing could result from lesser physiological conditioning or detraining[10,23] and could be attributed to a decrease in cardiac output and possible lower arterio-venous difference[10].

In elderly subjects the measurement of maximal performance is difficult to achieve and not without risk[9]. The efforts of elderly people are not limited by the power of the heart and lungs but by factors like dyspnea, fear of overexertion, muscular weakness, poor motivation and the appearance of electrocardiographic abnormalities[55]. Therefore, prediction tests on submaximal levels are more abundantly used in the elderly.

The decline of VO_{2max} in physically active healthy elderly is less than in sedentary healthy elderly[2,9,23,52]. Some studies have examined the effects of an exercise program on cardiorespiratory fitness[49,56-58]. In a study of Cunningham *et al*, a one year training program showed a significant increase in VO_{2max} in 100 exercising men aged 55 to 65 years, compared to an equal number of controls[57]. Seals *et al* found that 6 months of high intensity training produced significantly larger gains in VO_{2max} than were produced in the previous 6 months of light intensity training[58]. Badenhop *et al*[56] found similar changes in VO_{2max} in high and low intensity groups after a 9-week exercise program. In a longitudinal study in 15 physically active men aged 45 to 65 years, a training schedule of 3.6 hours per week at 70-84% of maximal heart rate still resulted in a decrease of VO_{2max} of 12% over 20 years[59]. This suggests a progressive physiological deterioration despite exercise training. In elderly who initiate training late in life, a key effect of physical training to increase VO_{2max} could be modulated through an increased muscle mass, with a resultant increase in arterial-venous O_2 difference[58].

Cardiovascular functioning: Studies which have investigated an effect of age on cardiac performance fail to demonstrate a unique age effect on resting cardiac output[60]. In subjects who are free from coronary disease and maintain the activities of daily living, cardiac output (heart rate, stroke volume) are not markedly affected by age. In studies where subjects are less intensively screened, small decreases are found in resting heart rate and stroke volume, resulting in lower resting cardiac output[61].

During physical activity however, more substantial age-related changes can be seen. The absolute level of cardiac output has been shown to be lower in the elderly at submaximal levels. This is attributable to a lower stroke volume, probably resulting from a decreased sympathetic response in the aged[62]. Maximum heart rate is reduced in the elderly, thus further resulting in a reduced cardiac output and VO_{2max}[63]. However, as mentioned before, factors such as muscle weakness, shortness of breath, and fear of excessive exertion can cause premature termination of a maximal test. Also in highly trained endurance athletes this decrease is observed[9,23].

Respiratory system: Some characteristics of pulmonary function decline in the elderly, but the extent to which this influences physical working capacity in healthy individuals is not certain. The vital capacity declines with age, with no apparent change in the total lung capacity, and the residual volume is increased. Dyspnea during prolonged exercise may well be associated with respiratory muscle fatigue resulting from sustained relatively high ventilation or an increased muscle weakness with age[64].

Strength: Strength (both isometric and dynamic) has a peak in the third decade, followed by a plateau until age 50 and a subsequent decrease[9]. The decrease is dependent on the muscle groups tested, as the loss in strength in leg muscles may be higher than the loss in arm muscles[9,53]. The hand dynamometer is an easy method to measure isometric strength, but caution must paid to generalisation to the whole body. The decrease in grip strength shows to be less in women than in men, probably due to a lower peak strength because of less occupational use of hands. Loss of occupation is an important confounding factor in the relation between strength and ageing[9].

The loss of strength probably may be caused by a loss in muscle mass, or a decrease in strength per unit of muscle mass[65]. The loss of muscle volume may be due to a reduced fibre size, particularly in fast-twitch (type II) fibres. Also, the total amount of fibres could be decreased[9].

Resistance training may increase strength in the elderly, but to a lesser account than in younger individuals. Frontera *et al* showed sizable increases in both strength and muscle areas in men 60 to 72 years old after a 12-week program of strength training[66]. Eight weeks of high-intensity resistance training in nine nonagenarians resulted in a meaningful mean strength gain of 174 ± 31%[67]. Thus, the trainability of skeletal muscle in response to an isometric stimulus persists even into old age. Since many activities of daily living, such as rising from a chair or climbing stairs, depend on muscular strength, such training has the potential to enhance the daily functional capacity of older individuals. No increase in strength has been found in cardiorespiratory exercise training[9].

Elderly are more vulnerable to muscle and tendon rupture[3]. Possible contributing factors are muscle stiffness due to fatigue, slow relaxation of antagonists, loss of elastic tissue and alterations in collagen structure, loss of joint flexibility, and decrease in blood supply of tendons.

Reaction time: Only a few studies of reaction and movement time have included elderly subjects with different levels of physical activity. Spirduso[68] and Spirduso and Clifford[69] compared active and sedentary older (mean age 57 years) and younger (mean age 24 years) male subjects on simple and discrimination reaction and movement time. Active groups reacted and moved faster than the nonactive. The old active group was slower than the young active group but faster than the young inactive group. The older, non-active group was slowest in all variables. The results suggest that regular physical activity preserves reaction and movement times. The average decline attributed to age was 8% in the active group and 22% in the sedentary groups.

Recently, results have been published of a three-year exercise intervention in sedentary women aged 57 to 85 years. Improved reaction time indicated that exercise is effective in reversing or at least slowing certain age-related declines in motor performance and in speed of cognitive processing[70].

Age related changes that are directly related to nutrition

With ageing, changes take place that can affect food consumption and nutritional requirements of elderly people on every phase of the food intake and food digestion level.

Food consumption: Several factors such as impaired ability to move around, impaired visual functioning, hand tremor and limited finances can lead to problems with the buying and preparation of food. Loneliness can result in an indifference to eating. Ignorance of the basic facts of nutrition can cause problems especially for men who never have cooked being especially vulnerable when they are widowed.

The oral cavity: Impaired functions of smell and taste can cause either a decreased appetite or increased seasoning or addition of salt to the food[71]. The threshold for perception increases slightly whereas above threshold the ability to identify tastes and odours is reduced[72]. Smell however would be affected to a greater extent than taste[73]. Decreased saliva production reduces the ability to swallow and increases the risk for dental caries[74]. A reduction in saliva production can also be a side effect of certain drugs that are frequently prescribed for elderly people such as diuretics[71]. Most elderly have lost their teeth and use complete removable dentures. Ill-fitting dentures, e.g. due to reduced gum and jaw-bone, reduce both chewing ability and social confidence to eat with others[71]. The above mentioned changes can lead to a an adjusted food pattern, potentially causing nutritional problems[75].

The digestive system: In the digestive system, some changes take place that either increase or decrease the requirements of particular nutrients. The most prominent change in the digestive system takes place in the stomach[74]. Gastric atrophy and atrophic gastritis increase significantly with age, resulting in a decreased secretion of gastric acid and intrinsic factor[19] and an increased risk for bacterial overgrowth of the small intestine. A reduced secretion of hydrochloric acid leads to impaired protein digestion[71] and can influence the bioavailability of calcium, iron, folate, vitamin B_6 and vitamin B_{12}. A reduction in intrinsic factor results in lack of binding with ingested vitamin B_{12} which is normally absorbed in the ileum. Bacterial overgrowth may lead to gas formation due to carbohydrate maldigestion[71]. However, bacteria can favourable compensate the impaired bioavailability of folate and vitamin B_6[74].

In the small intestine, absorption of fat, protein and carbohydrates appears to be essentially unaffected by age in healthy elderly subjects, as long as no extreme loads are administered[74]. Calcium absorption is significantly decreased in the elderly, potentially due to decreased gastric acid secretion, decreased skin synthesis of pre-vitamin D, decreased renal activation of 25-OH-hydroxyvitamin D and perhaps end-organ resistance to 1,25-OH-dihydroxyvitamin D[74]. For most other micronutrients such as iron and copper no impaired absorption is evident. After administration of a test dose, vitamin A levels are higher in elderly than in younger subjects due to the slower clearing of intestinal lipoproteins in the elderly. As elderly people have higher vitamin A stores, safety level is sooner reached than in younger subjects[74].

A reduced renal function and an impaired ability to concentrate urine in addition to a reduced sensation of thirst can lead to dehydration. Finally, alterations in gastrointestinal motility may cause constipation or diarrhoea[74]. The prevalence of constipation increases substantially after age 65 and contributes significantly to morbidity[74]. Maintenance of physical activity, increased water intake and a higher fibre intake can overcome this problem. There is often an insufficient intake of water due to an impaired sensation of thirst. The concentrated food within the digestive system extracts fluid from the gut wall into the lumen to enable absorption to proceed[71].

Nutritional requirements: A lot of countries have developed standard intakes (allowances) of nutrients that are set high enough to protect almost all of the population against deficiency. Since the nutrient needs of adults are based mainly on studies made on young adults, many of the allowances for older adults are largely estimated by extrapolation. In the Dutch Recommended Dietary Allowances, adults are classified into three age groups: age 22 to 50, age 50 to 65, and 65 years and over[76]. Since the latter categories cover an extensive period of continuous bodily changes, which individually take place at very different rates, the single allowance for each nutrient can only be a gross approximation. In addition, many older people have some chronic disorder for which the Recommended Dietary Allowances make no provision.

Another effect of the ageing process on nutrient requirements can be caused by the simultaneous use of multiple medication. Many drugs commonly used by the elderly may have major effects in appetite, taste, and smell. Drugs can have an adverse effect on both consumption and digestion of food. Drug-nutrient interactions can lead to increased or reduced nutrient requirements and to side effects such as nausea and diarrhoea[77].

Chronic diseases, physical activity and nutrition

Ageing and coronary heart disease

Cardiovascular disease is the most common cause of death among people of 65 years and over[1]. Epidemiologic studies have revealed that physical inactivity is a risk factor for cardiovascular disease. A recent review showed a median risk ratio of 1.9, comparable to the ratios of other risk factors such as systolic blood pressure, smoking, or hypercholesterolemia[53]. Important studies that demonstrated the beneficial effect of physical activity were published by Paffenbarger *et al.* They followed 16936 alumni for 6-10 years and revealed a 64% reduction in nonfatal and fatal myocard infarction in men expending more than 8.4 MJ (2000 kcals) per week in exercise (walking, stair-climbing, and sports) compared to men with lower expenditures. The reduction found in men of 65 to 74 years was comparable to that in younger. Strenuous sports but also walking and stair climbing were associated with the reduced risk. The energy expenditure of 8.4 MJ per week for walking would require a walking distance of 34 kilometers per week or 5 kilometers per day, a level achievable for most elderly[53]. After 12 to 16 years of follow-up, risk for all-cause mortality in alumni aged 60 to 84 with high activity was half the risk of alumni at lower levels of activity. Younger alumni at the highest activity level had 25% less risk than those at the lowest level, indicating that the effect of physical activity is more clear in the elderly than in younger people[78]. Habitual postcollege exercise, not students' sports play, predicts low coronary heart disease risk. Sedentary students becoming active alumni acquire low risk[79]. The effect of physical activity on coronary heart disease is independent of contrary life-style elements such as smoking, obesity, weight gain, hypertension, and adversal parental history[79]. Studies in San Francisco longshoremen[80], male office workers in the Civil Service[81,82] and results from the Honolulu Heart Study[83] confirm that involvement in vigorous sports or work activity results in a reduction in coronary heart disease incidence. Also the Framingham study has reported similar associations between exercise and cardiovascular disease. The decrease in relative risk was most pronounced in subjects over age 60[84].

Experimental studies showing the effect of exercise intervention on morbidity and mortality of coronary heart disease are scarcely available. Recently, Posner *et al* showed in a pilot study beneficial effects of a moderate exercise program on occurrence rates of new cardiovascular diagnoses and time to onset of these diagnoses in previously sedentary men aged 60 to 86[85]. Intervention was performed for two years. Exercise showed a protective effect primarily against the development of clinically significant arrhythmias, but not against the development of other cardiovascular conditions including angina and myocardial infarction. Other studies are generally limited to the effect of physical activity on the separate risk factors for coronary heart disease.

Diet is presumed to play a major role in atherogenesis because of its direct influence on blood pressure and blood lipids. Through obesity, diet has an influence on the factors mentioned before, and on glucose tolerance. It has been shown that the importance of these risk factors does not change essentially with ageing. The relative effect might be diminished, but absolute figures at least remain constant due to the growing population of elderly people[86-89]. The potency of diet to have influence on these risk factors in the elderly however is not very clear yet. It is assumed that in principle the influence will be the same as observed in younger individuals.

Blood Pressure: Hypertension is one of the main risk factors for the development of coronary heart disease. In older people the systolic blood pressure is a better predictor for cardiovascular disease than the diastolic pressure. Several studies have suggested that increased levels of physical activity and exercise are associated with lower levels of blood pressure, changes being more marked in individuals with hypertension[24,90,91]. The effect seems to be presumably present in the systolic pressure. In these studies however, it is difficult to exclude a habituation effect, as experimental subjects always have had more contact with the investigators and the laboratory than control subjects. Most studies on the effect of the lowering of blood pressure in the elderly use drugs[92-95] or a combination of drugs and sodium restriction[96] to attain the required reduction. These studies show a reduction in mortality due to coronary heart disease but not of total mortality.

A meta-analysis of 13 randomised trials by Grobbee and Hofman led to the conclusion that sodium-restriction can lower blood pressure with a more important effect with increasing age[97]. The overall effect however was small and restricted to systolic blood pressure.

Blood lipids: Ageing is often associated with a rise in fasting plasma total and low-density (LDL) cholesterol from the third to the sixth decade followed by a decline[53]. The ratio HDL/total cholesterol falls by 30 to 50% during the same period before plateauing. Triglycerides tend to rise across the age span. There is an increased variability in lipid levels with ageing, so that some elderly people have levels comparable to younger people. The effect of physical activity on lipoprotein levels was subject to a number of studies. Generally, a clear increase in HDL was found with increasing physical activity. Data on total cholesterol and LDL cholesterol are less obvious[20,98,99].

In master athletes, HDL, triglycerides and LDL are comparable to younger athletes, whereas sedentary contemporaries have less favourable ratios[100]. This suggests that physical conditioning and maintenance of low body fat may prevent some of the age-related deterioration in lipoprotein metabolism. The increase in HDL might be dependent on the base level of fitness and the intensity level of the activity performed[20,101].

Dietary components that have effect on lipoprotein levels, at least in adults, are excess of energy, saturated fats and dietary cholesterol. Data on the influence of these nutrients in the elderly, however, are sparse[89]. Not many studies are available where the long term effect of cholesterol lowering by means of dietary intervention is studied in the elderly[102]. Most studies used drugs only[103] or a combination of drugs and diet modification[104-106]. These studies have shown that cholesterol lowering in elderly subjects leads to reduced mortality due to coronary heart disease but not in total mortality.

Glucose tolerance: In older individuals a slight increase (1 mg/decade) is observed in fasting blood glucose[53]. This slight increase is accompanied by a vast increase (10 mg/decade) of blood glucose 2 hours after administration of a glucose load, accompanied by an increase in insulin, illustrating a decreased sensitivity to insulin. These age-related changes in glucose tolerance may result in non-insulin-dependent diabetes mellitus (NIDDM), which is a risk factor for cardiovascular disease. Exercise[107] and weight loss[108] intervention may improve sensitivity to insulin.

Ageing and cancer

Cancer is the second death cause in the elderly and a major health problem among elderly in developed countries. Most types of cancer are characterized by a long induction period. As carcinogenesis is a multistage process with an irreversible initiation phase, it must be asked whether the elderly, who have been exposed to initiating agents for a long period of time, will reduce their cancer risk by reducing their dietary consumption of mutagenic carcinogens[109]. Several nutritional agents such as fibre, vitamin C, calcium and a low-fat diet have been described to slow the promotion phase of several types of cancer, and might be of value in the elderly[109].

The effect of physical activity on cancer is less clear than its effect on coronary heart disease or all-cause disease. A re-analysis of studies in four populations considering coronary heart disease showed little definite effect on incidence of cancer[110]. The reason for this can be that cancer is a matrix of diseases differing in etiology, site, timing, symptoms, and course.

Ageing and osteoporosis

Osteoporosis affects 25 to 30 percent of women over 65 and is characterized by bone loss leading to fractures. Three main methods for prevention are physical activity, nutrition and oestrogen replacement. The effect of physical activity on bone mass has been discussed in the section on "ageing and body composition". The role of calcium in the diet seems obvious as 40 percent of the bone mineral consists of calcium[20]. However, studies on the preventive effect of calcium reveal contradictory results[111,112]. In general, no additional benefit can be expected from dietary calcium above the level required to sustain calcium balance[111]. Other dietary factors associated with the prevention of osteoporosis are vitamin D (either from the diet or synthesised by the skin under influence of sunlight)[113], fluoride, fibre, phosphorus and protein. A high body mass index has been shown to be protective for bone loss.

Ageing and psychological well-being

The main purpose of present-day gerontology is to improve the well-being and quality of life of the elderly more than to extent the life-span. The way to do this is to postpone the symptomatic onset of chronic disease, or compression of morbidity[2,114].

The term "quality of life" has frequently been used but is very difficult to define. The meaning differs from person to person and is dependent on circumstances[115]. Despite this difficulty in definition, it is assumed that quality of life is mainly dependent on physical and mental health. Secondary, but important aspects influencing the quality of life are economical situation and social environment.

Considering the aspect of quality of life immediately leads to the importance of psychological well-being in the elderly. In a population-based study with an age-range of 18 to 83 years participation in physical activity was associated to improved psychological well-being[116]. Part of this association was through improved subjective physical health. Data were controlled for potentially confounding factors including sociodemographic characteristics and overweight. Studies investigating the effect of exercise on stress in the elderly are very limited. Sidney and Shephard[117] found a decrease in anxiety in men and women 60 years of age and older following 14 weeks of aerobic conditioning. However, a comparison of psychological well-being in 13 physically active and 12 inactive healthy young old to very old women revealed only a trend towards less depression and fatigue among the active subjects[118]. Habitual moderate exercise showed not to be associated with an increase in psychological well-being.

For very elderly people, additional benefits may come from a reduced anxiety to fall due to floor exercises, and emotional benefit may be derived from exercising in pairs, one of the rare opportunities presented to many elderly people for socially acceptable, but non-clinical touching[119].

For many elderly people the daily routine of food consumption has an important impact on the quality of life. As mentioned before, loneliness and depressions can lead to loss of appetite and interest in food. Attention should be paid to this aspect whenever dietary measures are taken to increase physical health of elderly subjects.

The interaction of nutrition, physical activity and ageing

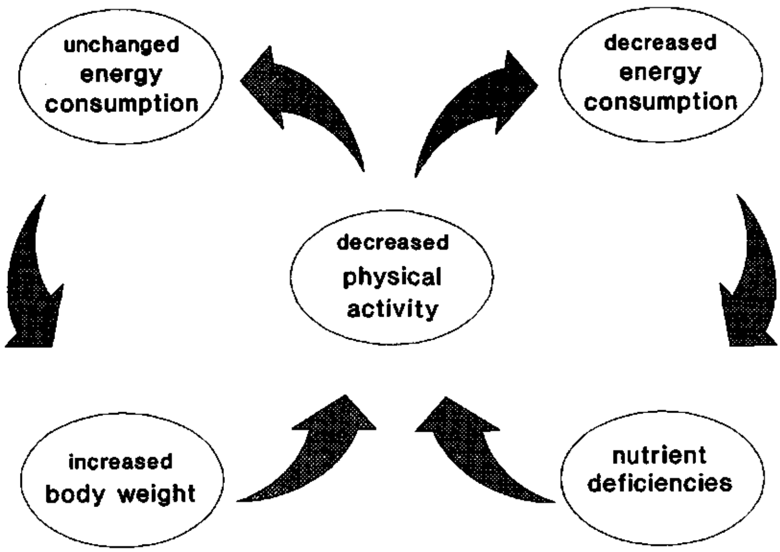
As delineated above, physical activity has an impact on nutrition by modulating the requirements of mainly energy. Energy intake and energy expenditure must be strongly regulated to prevent weight loss or weight gain. With the generally observed decrease in energy expenditure with ageing[17], less energy will have to be provided by the food. However, as requirements for most other nutrients are not basically influenced by the ageing process, the nutrient density of the foods consumed in relatively small quantities by old people must be consistently high[120]. Two main pathways of undesirable regulation are about to take place, as depicted in Figure 1. One possibility is, that the adjustment of energy intake to reduced energy expenditure takes place, but is not accompanied by an increase in nutrient density. Nutrient deficiencies may develop, which might in turn result in a further decrease in physical activity due to disease and listlessness. A second, unfavourable possibility is a lack of adjustment of energy intake to reduced energy expenditure level, which could lead to a positive energy balance, resulting in a gain in body weight or fat mass. This again could lead to a further decrease of physical activity due to overweight. Both pathways result in a vicious circle leading to less physical activity and impairments.

The maintenance or the obtaining of a higher physical activity level with ageing could overcome the depicted unfavourable pathways. A higher energy expenditure allows a higher energy consumption that facilitates the meeting of micronutrient requirements without the need to increase nutrient density. On the other hand, increased energy expenditure allows a higher energy consumption without risk of weight gain and development of obesity and associated impairments. Although it has been described that middle-aged runners develop an energy intake that is 40 to 60% greater than sedentary men and women of the same age[121], there is not much information available in the change in food intake produced by an active life-style or an exercise program in elderly subjects. Debry *et al*[122] showed that elderly living in rural areas had higher energy intakes than elderly in urban settings, due to greater physical demands. Very low energy intakes were found less among elderly people who are physically active. This illustrates the potential beneficial effect of physical activity on energy and nutrient supply.

Assessment of physical activity in elderly subjects

Many different methods have been used to assess physical activity. They can be divided in direct measurements of energy expenditure, classification according to job, questionnaires or interviews, prospective diaries, physiological markers, observations, mechanical and electronic monitors, and dietary measures. For application in epidemiologic research, instruments must be valid, reliable, inexpensive and practical while not affecting behaviour. Surveys or questionnaires are most practical in large-scale studies[123]. For the use of methods to assess physical activity in elderly subjects, additional criteria must be met. Generally, most techniques are more difficult to apply to the elderly than to young adults[3]. Writing difficulties due to arthritic hands, and problems

Figure 1. Two unfavourable pathways hypothesing the occurrence of vicious circles in nutritional problems arising with an age-related reduction in physical activity



with impaired eye-sight require interview-administered methods. Job classification can not be applied due to retirement. Heart rate recording is complicated because pendulous skinfolds may cause electrodes to become detached long before heart rate recording is completed. Also, the relationship between heart rate and energy expenditure is less clear in the elderly. Weakness of short term memory can result in problems with physical activity recalls. Questionnaires with a longer time of reference should assess habitual physical activity instead.

Habitual physical activity

In general, a lower percentage of elderly people is participating in vigorous exercise than younger subjects. Only a limited amount of data is available regarding the participation in physical activity of the elderly in the Netherlands. As published by the Dutch Centre for Statistics, 27% of the men and 24% of the women aged 65 and over and living alone do actively participate in physical activity. For households consisting of more people these figures are 36 and 24% respectively. In men and women between 18 and 64 years of age these figures lay between 60 and 80%[1].

In a study in a sample of 863 Dutch elderly men aged 65 to 85 years, living in Zutphen (The Netherlands), cross-sectional analysis revealed a median total of reported physical activity of about 1 hour and 20 minutes per day. Only 6% reported not to participate in physical activity at all. With higher age, less time was spent in sports, hobbies and work, whereas time spent on walking, bicycling and gardening did differ less[124].

In a recent study on 526 apparently healthy men and women aged 65 to 80 years from different parts of the Netherlands, participation in sports activity was more than 6 hours per week in 21% of men and 14% of women. No sport activity was reported by 48% of the men and 54% of the women[125].

Assessment of dietary intake in the elderly

The estimation of dietary intake in the elderly causes specific problems. Methods relying on the use of short term memory, such as 24 hour recalls, are less usable. Weighed records can be a problem owing to writing difficulties. To overcome memory problems, a dietary history in combination with a food frequency list of foods commonly available (a modified diet history) may result in a reliable estimate[126].

Food consumption data in the Netherlands

Recently food consumption data of elderly subjects have become available from several studies in the Netherlands[12,14,127,128]. Data were collected using the dietary history method[12,14,127] or a two day 24 hour record[128]. The data are summarized in Table 1. In the study by CIVO-TNO the study design consisted of a two-stage cluster sample of 538 apparently healthy independently living Caucasian elderly men and women stratified on region, urbanization and age group. The age range was 65 to 79 years and the response rate 53%[127].

Table 1. Food consumption data of elderly men and women in The Netherlands.

	men				women		
	TNO n=269	Zutphen n=315	VCP n=227	SENECA n=114	TNO n=269	VCP n=261	SENECA n=124
Energy (MJ)	10.1	9.4	10.3	10.3	7.9	7.9	7.8
Protein (g)	82		81	85	70	68	70
Fat total (g)	106		114	113	81	87	85
SF	47		48	49	36	38	38
MUFA	41		44	44	31	32	33
PUFA	18		19	20	14	14	14
Carbohydrates (g)	251		249	255	202	194	204
Alcohol (g)	10		16	12	1	6	3
Cholesterol (mg)	355	344	343	338	290	289	277
% energy from:							
protein	13.7	14.6	13.5	13.9	15.1	15.0	14.9
fat	40.4	39.9	41.3	41.3	39.6	40.7	40.5
carbohydrates	41.6	41.4	40.6	41.6	43.1	42.0	43.5
alcohol	3.6	4.1	4.7	3.2	0.5	2.2	1.0
Thiamin (mg)	1.07	1.02	1.16	1.24	0.93	0.97	0.94
Riboflavin (mg)	1.70	1.76	1.67	1.73	1.51	1.45	1.52
Vitamin B6 (mg)	1.38	1.27	1.52	1.71	1.15	1.26	1.33
Vitamin C (mg)	94	97	83	122	101	93	124
Retinol (mg)	1.07	1.11	1.04	1.04	0.95	0.90	0.89
Calcium (mg)	1130	1121	1052	1180	1010	943	1038
Iron (mg)	13.1	12.7	13.0	13.2	11.3	11.3	11.1

TNO: Study on food consumption and nutritional status of apparently healthy, independently living elderly people aged 65 to 80 (127).
Zutphen: Kromhout et al, 1990, men aged 65 to 85 (12).
VCP: Voedselconsumptiepeiling 1987-1988, men and women aged 65 and over (128).
SENECA: Men and women aged 70 to 75 from Culemborg, the Dutch participant in the Euronut-SENECA study (14).

SF: saturated fat; MUFA: mono-unsaturated fat; PUFA: poly-unsaturated fat.

The study performed in Zutphen is the Dutch contribution to the Seven Countries Study, a longitudinal study of chronic disease risk factors. In 1960, 1088 out of 2400 men aged 40 to 59 were selected for participation. Initial response rate was 84%. In Table 1 dietary intake data are presented of the data collected in 1985. Data refer to the 315 men that did participate in the dietary surveys in 1960, 1965, 1970 and 1985[12].
The participants of the "Voedselconsumptiepeiling 1987-1988" are a representative sample of the independently living, Dutch speaking population of The Netherlands, aged 1 to 74 years. The response rate was 81% and data were collected for 5898 people.
The Dutch data of the Euronut-SENECA study are collected in the town of Culemborg[15]. The 238 men and women were aged 70 to 75 years and a random sample of all people of that age living in Culemborg. Participation rate was 37%.
The average data are highly comparable and show a high percentage of (saturated) fat intake, but do not reveal major deficient intakes in mineral or vitamin supply. The question arises whether this also accounts for elderly with low energy intakes and if there is a relationship between energy and vitamin and mineral intake on the one hand and physical activity on the other hand.

The thesis

In this thesis the relationship is studied between dietary intake, nutritional status and physical activity of elderly people. As the sex ratio increases above age 65 in favour of women, who are contradictory enough studied less than men, the study is focused on the female sex.
The first part of the thesis involves an observational study to investigate the relationship between dietary intake, nutritional status and physical activity in a sample of elderly women *(chapter 3)*. The purpose of the study was to evaluate the existence of unfavourable pathways associated to physical inactivity and leading to nutritional problems, as illustrated in Figure 1. A cross-sectional design was chosen to compare voluntary recruited physically active and sedentary individuals. This design might elucidate the strongness of the relationship without the methodological problems of a longitudinal study where a decrease in activity with ageing can both be voluntary and a result from disease. For the study, subjects either high or low in physical activity were

recruited. No special attempt was made to enrol subjects into extremes of physical activity (eg master athletes), as the resulting differences between sedentary individuals and master athletes would not have resulted in increased knowledge about the importance of changing physical activity levels in the majority of elderly.

It was extensively presented to potential subjects that their physical activity level should not have changed recently (the last 5 years) and it was stressed that physical inactivity was voluntary and not allowed to be a result from disease.

To start the study, a questionnaire was designed, validated and checked on reproducibility, to assess physical activity and enable the classification of groups with different activity levels *(chapter 2)*.

The design of the study was such that after the cross-sectional evaluation decisions had to be made about further parts of the study. These parts included assessment of body weight and physical activity in retrospect *(chapter 4)*, the evaluation of several aspects of physical and subjective fitness *(chapter 5)* and the measurement of energy expenditure during rest and standardised activities *(chapter 6)*.

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Chapter 2

A physical activity questionnaire for the elderly.

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Abstract

A validated physical activity questionnaire for young adults was adapted and validated for use in free living, apparently healthy people, aged 63 to 80 years. Test-retest reliability of the questionnaire on 29 participants was 0.89 as determined by Spearman's correlation coefficient. Further classification by tertiles of activity resulted in 72 % of the participants being correctly classified and 0 % grossly misclassified on two separate occasions. In a similar group of 31 subjects, classifications based on questionnaire activity scores were compared with classifications obtained by repeated 24-hour activity recalls and pedometer measurements, showing Spearman's correlations of 0.78 and 0.73, for both methods, respectively. Seventy-one and 67 % of the subjects, respectively, were classified in the same activity tertile for both methods. It is concluded that the questionnaire provides a reliable and valid method for classifying elderly subjects into categories of high, medium, and low physical activity.

Introduction

As the number of elderly people is increasing, recent research is focusing now on how to obtain a better quality of life at older ages[1,2]. In an attempt to identify factors that influence the quality of life in the elderly, the general health status and especially mobility seem to be important. Two factors that probably have an impact on both physical and mental health are physical activity and nutritional status, acting separately as well as in combination[1,2]. To study the interaction between physical activity and nutritional status, it is necessary to assess habitual physical activity. Many methods for the assessment of physical activity are described in the literature[3,4]. However, so far no standardized techniques have been proposed. Also, no special methods have been designed to meet the problems arising while working with elderly people. Some special

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arrangements should be made, because of loss of occupational activities, weakness of short-term memory, poor eyesight or writing difficulties in elderly subjects[5,6].

In epidemiologic research an activity questionnaire is the most practical and widely used approach to assess physical activity[5,7]. Because of the weakness of short-term memory, the reference time interval in a questionnaire for elderly people should not be too short. Owing to eventual poor eyesight and arthritic hands, an oral questionnaire by personal interview may solve the problems to be expected in a written questionnaire.

For this purpose an interview questionnaire, which is based on the activity questionnaire as described by Baecke *et al*[8], with a reference time period of one year was developed and adapted for use in elderly individuals. In the present study test-retest reliability of the adapted questionnaire was investigated. To classify people as high, moderate, or low in daily physical activity, classification was made in tertiles.

To check the relative validity of the questionnaire, the individual tertile scores were compared with tertile scores obtained with two independent methods to assess physical activity: a repeated 24-hour physical activity recall and measurements with a pedometer. The aim of the study was to evaluate the potency of the questionnaire to classify apparently healthy elderly people in a consistent way into extremes of the distribution of physical activity.

Subjects and methods

Subjects

To obtain a study population with a broad range of physical activity, 90 independently living apparently healthy elderly subjects, aged 63 to 80 years, were recruited from sport clubs, associations of elderly people and by advertisements in Wageningen and environs. Sixty of them, 26 men and 34 women, could participate in this study because of being available during the whole study period. This methodological study did not require a representative sample of the population of elderly people. All participants were randomly assigned to either of two study groups, but for practical reasons couples were always assigned together randomly to one group. This resulted in two groups: group A for the reliability study (n=29) and group B for the study of relative validity (n=31). Written informed consent was obtained from all the subjects.

Questionnaire

The adapted questionnaire is based on the activity questionnaire of Baecke *et al*[8], which was validated in young adults. Some adaptations were made to make the questionnaire applicable for use with elderly people. One of the main points was that the questionnaire was completed by the interviewer during a personal interview, whereas the Baecke questionnaire is self-administered. As household activities in the elderly become relatively important, owing to loss of occupational activities[9], additional questions on this topic were introduced. The questionnaire consisted of scores in household activities, sporting activities, and other physically active leisure time activities, altogether resulting in an activity score. After adaptation and before use of the questionnaire in this study, expected difficulties in interpreting and answering the questions were discussed in an independent focus group of elderly people.

In the questionnaire the respondents are asked to report habitual physical activities of the last year. Items on household activities are questions with four to five possible ratings, ranging from very active to inactive. Sports and other activities are asked as type of activity, hours per week spent on it, and period of the year in which the activity is normally performed. All activities are classified according to work posture and movements. An intensity code, originally based on Bink *et al*[10] based on net energetic costs of activities, was used to classify each activity. The questionnaire takes about 30 minutes to complete.

Reliability

The reliability of the questionnaire was assessed by a test-retest design. The questionnaire was administered twice by the same interviewer, with a time interval of 20 days. Possible test-effects were tested by paired Student's *t*-test. Spearman's rank order correlation coefficients were calculated. Participants were classified into tertiles of activity score, and between-class Kendall's tau-b correlation coefficients were calculated[11].

Relative validity

The activity scores as obtained by questionnaire were compared with the results of a repeated 24-hour activity recall and a pedometer score. The 24-hour activity recalls were performed three times at the subject's home, on two randomly chosen weekdays and one weekend day in a three week's period. Activities were recorded in periods of ten minutes. Net energy costs of activities were used, classified according to work stature and movements as formulated by Bink *et al*[9]. The recall score was calculated by multiplying the amount of minutes spent on each activity with the net energy cost (total energy expenditure without resting energy expenditure) per minute of each activity. The recall score is presented as the mean net energetic cost per day. As an objective type of measurement, a pedometer (Fitty, Kasper and Richter, Uttenreuth, Germany) was used. The pedometer registers movements of the body in the vertical direction. A pedometer score was obtained over three consecutive days (two weekdays and one weekend day). The use of the pedometer was explained to the participants when the instrument was given, and also written information was handed out. A fixed step width of 0.75 m was used to calculate the amount of movements (counts) made from the displayed distance walked. The pedometer score is presented as the mean amount of counts per day.

Spearman's rank order correlation coefficients were calculated. Also, subjects were classified according to tertiles on questionnaire, recall, and pedometer score, and Kendall's tau-b was calculated[11]. Results are presented as means ± standard deviation. For all calculations the SAS System was used[12].

Results

Subjects

Table 1 gives some physical characteristics of the participants in the two groups.

Reliability

In group A (n=29) the questionnaire was administered twice with an interval of 20 days. Table 2 shows mean, SD, minimum and maximum value, and tertile cut-off points of the test and retest procedure and the calculated differences between the two occasions. There was no significant difference between the two scores, the 95% confidence interval being between -1.3 and 0.6. Spearman's correlation coefficient between first and second interview was 0.89.

Figure 1 shows the plot of the test and retest activity scores with tertile cut-off points. Twenty-one participants (72 %) were classified in the same tertile at both occasions. Gross misclassification, i.e., two scores in the opposite tertiles, did not occur. Using tertile classification, Kendall's tau-b correlation coefficient had a value of 0.74.

Relative validity

To determine the relative validity, the questionnaire was completed by all 31 participants (group B). Mean calculated activity score was 13.6 ± 6.8 with a minimum value of 1.2

Table 1. Some physical characteristics of the participants in the two groups (mean ± SD).

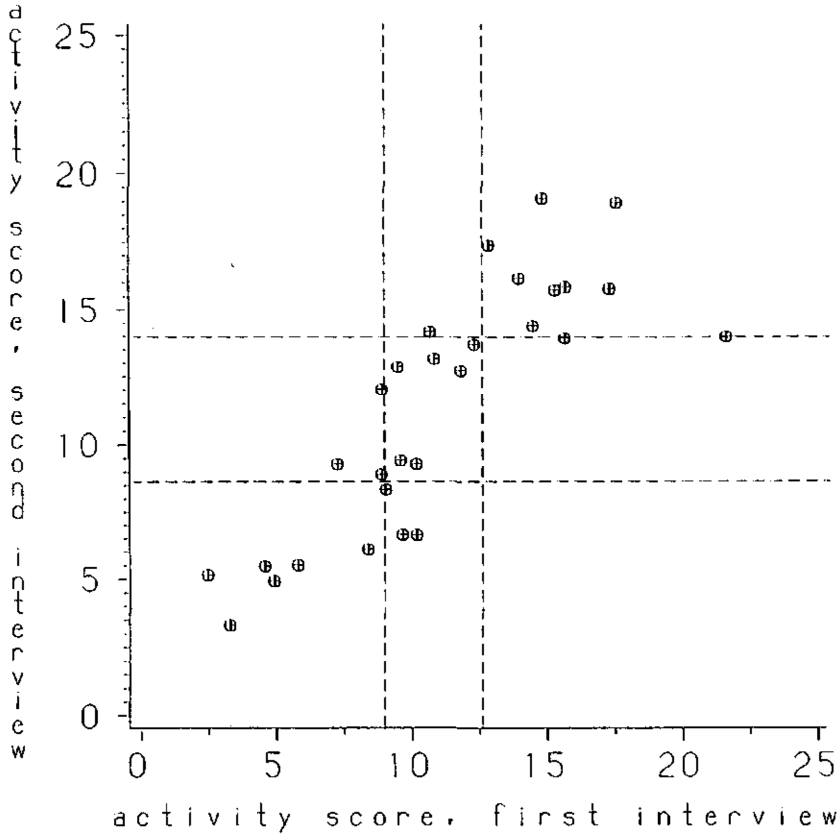
	Group A		Group B	
	men (n=12)	women (n=17)	men (n=14)	women (n=17)
Age (y)	70 ± 4	71 ± 5	73 ± 7	69 ± 5
Body weight (kg)	75 ± 9	70 ± 7	75 ± 8	67 ± 9
Body height (m)	1.75 ± 0.10	1.64 ± 0.04	1.73 ± 0.08	1.62 ± 0.06
Body mass index (kg/m^2)	24.3 ± 1.9	26.1 ± 2.6	25.1 ± 1.9	25.6 ± 3.1

Table 2. Test and retest results of the physical activity questionnaire in 29 elderly men and women aged 63 - 80 years.

	First measurement	Second measurement	Difference*
Mean	11.0	11.4	-0.4
SD	4.6	4.6	2.6
minimum value	2.5	3.3	
maximum value	21.7	19.1	

* difference = first score - second score.

Figure 1. Test-retest reproducibility of the activity questionnaire tested in a group of 29 elderly people. Scores on two occasions, time interval 20 days. Cut-off points 9.0 and 12.6 (first interview) and 8.6 and 14.0 (second interview). Spearman's correlation coefficient 0.89.



and a maximum value of 31.4. The group was divided into tertiles of activity score, with cut-off points of 9.4 and 16.5, respectively.

The physical activity recall was completed by all 31 subjects. The daily mean recall activity score was 4225 ± 1093 kJ/day (1010 ± 261 kcal/day). Minimum value was 2481 kJ/day (593 kcal/day); maximum value was 7106 kJ/day (1699 kcal/day). Tertile cut-off points were 3718 and 5023 kJ/day, (889 and 1141 kcal/day) respectively. Spearman's correlation coefficient of recall versus questionnaire scores was 0.78. In Figure 2 the relation between 24-hour recall scores and activity scores is shown, together with tertile cut-off points. Twenty-two out of 31 participants (71 %) were classified consistently in the same tertile. Gross misclassification, defined as two scores in opposite tertile, occurred in only one case. Calculated Kendall's tau-b based on tertile scores was 0.66. A pedometer score was obtained in 30 subjects. The mean amount of counts per day was

Figure 2. Relative validity of the activity questionnaire compared with the recall score, measured in 31 elderly people. Cut-off points questionnaire: 9.4 and 16.5, cut-off points recall score: 3718 and 5023 kJ/day.

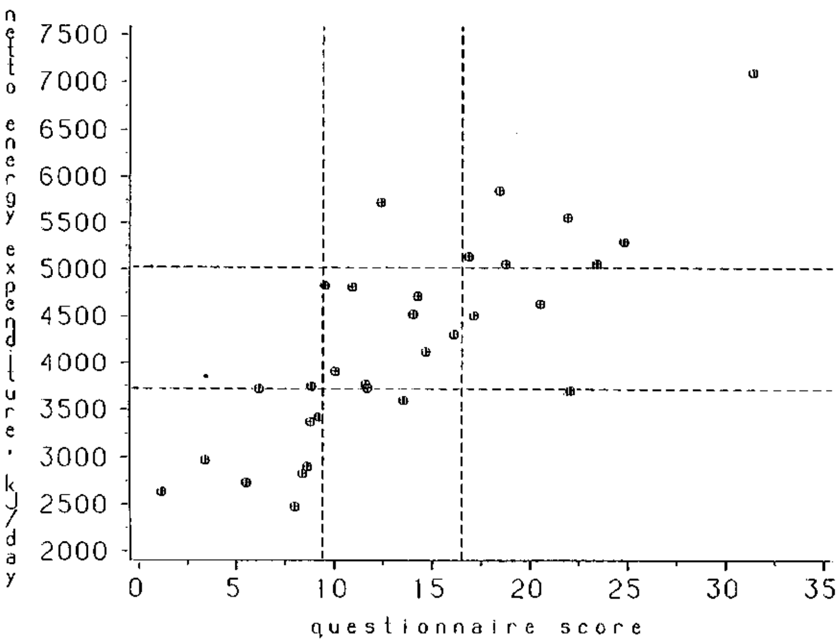
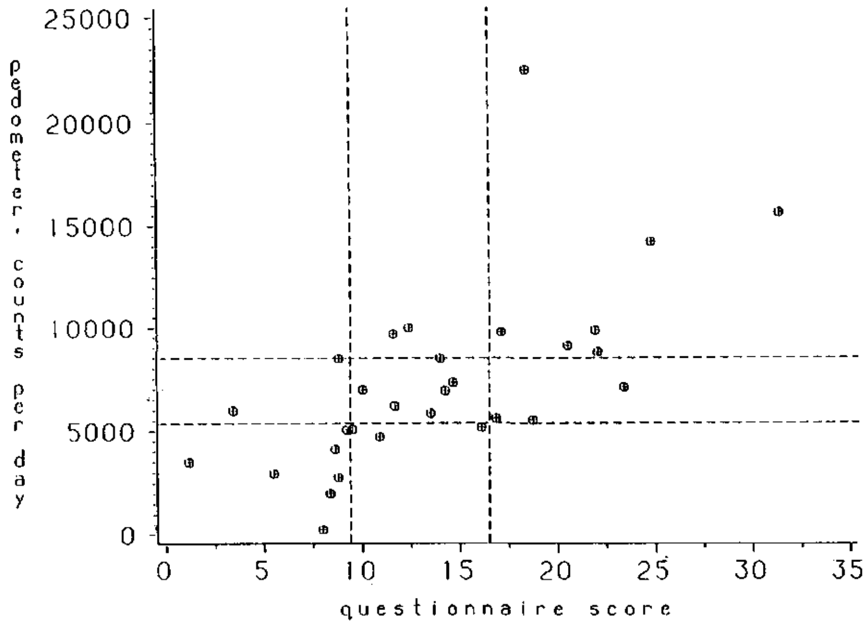


Figure 3. Relative validity of the activity questionnaire compared with the pedometer score, measured in 30 elderly people. Cut-off points questionnaire: 9.4 and 16.5, cut-off points pedometer: 5378 and 8489 counts/day.



7335 ± 4369 with a minimum value of 267 and a maximum value of 22489 counts per day. Spearman's correlation coefficient between pedometer scores and questionnaire scores was 0.72.

The participants were divided into tertiles based on pedometer scores, cut-off points being 5378 and 8489 counts, respectively. In Figure 3, the plot of mean amounts of counts per day versus activity score, with cut-off points, is shown. Twenty participants (67 %) were classified into the same tertile based on pedometer scores and questionnaire results. Kendall's tau-b was 0.68. Gross misclassification did not occur.

Discussion

The tested questionnaire was developed to enable discrimination between physical active and inactive, healthy, independently living elderly people for a study on dietary intake and nutritional status. Therefore, this study focuses mainly on the reliability and relative validity of the classification of elderly into extremes on the scale of activity.

As stated earlier, the assessment of physical activity is probably more difficult to perform in elderly people than in younger adults. One main problem is, that total energy expenditure of these subjects consists of a major part of household activities with a minor energy expenditure. Therefore heart rate measurements are inadequate for use in elderly subjects. Also, the pendulous skinfolds of the elderly may cause detaching of the electrodes long before an intended 24-hour recall has been completed[6].

Reliability

Data on short-term and long-term reliability of activity questionnaires in literature are scarce. Test-retest reliability of the Baecke questionnaire[8], with a time interval of three months, shows 0.88, 0.81, and 0.74 correlation coefficients for work index, sport index and leisure time index, respectively. The test-retest reliability of the Paffenbarger Survey[9], as measured in 14 postmenopausal women with a time interval of 4 weeks, was 0.76 for the caloric index.

Over an interval of 20 days, the developed questionnaire had a Spearman's rank correlation coefficient of 0.89. The test-retest reliability of this questionnaire seems therefore at least comparable with the above mentioned values. The largest difference found in a test-retest period of 20 days was a score of 22 in the first and 14 in the second interview. However, both scores resulted in classification into the high activity group. No significant test effect was observed (Table 2) and no gross misclassification occurred (Figure 1).

Analysing quartiles instead of tertiles resulted in 28 (97 %) of the participants assigned to the same quartile or one quartile apart. One participant (3 %) was classified two quartiles apart.

Relative validity

It is important to notice that both methods used to validate the questionnaire are not "gold standards" to assess physical activity. The 24-hour physical activity recall was chosen as a reference method because it is relatively reliable, cheap, and does not influence daily life too much[3]. A disadvantage is, however, that decrease of short-term memory, as is often reported in the elderly[5,6] can influence the results. The pedometer only measures movements in a vertical direction by the whole body (as, e.g., occurs during walking) but movements on for instance a bicycle cannot be measured correctly. Also, the pedometer cannot be used during swimming. Both cycling and swimming are activities that often were performed by the study population. Furthermore, both reference methods had a reference period of only three days, whereas the questionnaire refers to activities of the last year. Therefore, a comparison between questionnaire scores and results of the two reference methods is difficult, and the comparison can only be used to signal a possible trend. However, the Spearman's correlation coefficient between the questionnaire and the two reference methods was 0.78 and 0.72 for the physical activity recall and the pedometer, respectively, indicating a reasonable relative validity. Also, except in one case, gross misclassification did not occur. A comparison of different methods, described by Cauley *et al*[9] showed far lower correlation coefficients. Subdividing in quartiles instead of tertiles comparing pedometer and questionnaire data resulted in 29 (93 %) of the participants being classified in the same quartile or one quartile apart. Two participants (7 %) were classified two quartiles apart. Comparing 24-hour recalls and the questionnaire, these numbers were 97 % and 3 % respectively.

The more active people in the research population spend several hours per week in vigorous activities such as swimming, cycling, gardening and gymnastics. Most of them do the housework themselves. The less active people perform vigorous activities less than 15 minutes per day, walk less stairs and generally do not do the heavy housework.

The good agreement in both tertile and quartile classification shows that the tested questionnaire provides a reliable and valid method to classify apparently healthy elderly people into extremes of physical activity.

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Appendix

Questionnaire, codes and method of calculation of scores on habitual physical activity in elderly people.

Household activities.

1) Do you do the light household work? (dusting, washing dishes, repairing clothes etc.)?

   0. Never (< once a month) |_|
   1. Sometimes (only when partner or help is not available)
   2. Mostly (sometimes assisted by partner or help)
   3. Always (alone or together with partner)

2) Do you do the heavy housework? (washing floors and windows, carrying trash disposal bags, etc.)?

   0. Never (< once a month) |_|
   1. Sometimes (only when partner or help is not available
   2. Mostly (sometimes assisted by partner or help)
   3. Always (alone or together with partner)

3) For how many persons do you keep house? |_|
   (including yourself; fill in "0" if you answered "never" in Q1 and Q2.)

4) How many rooms do you keep clean, including kitchen, bedroom, garage, cellar, bathroom, ceiling, etc.? (Fill in "0" if you answered "never" in Q1 and Q2.)

   0. Never do housekeeping |_|
   1. 1 - 6 rooms
   2. 7 - 9 rooms
   3. 10 or more rooms

5) If any rooms, on how many floors? |_|
   (fill in "0" if you answered "never" in Q4.)

6) Do you prepare warm meals yourself, or do you assist in preparing?

   0. Never |_|
   1. Sometimes (once or twice a week)
   2. Mostly (three to five times a week)
   3. Always (more than 5 times a week)

7) How many flights of stairs do you walk up per day?
(one flight of stairs is 10 steps.)

0. I never walk stairs |_|
1. 1-5
2. 6-10
3. More than 10

8) If you go somewhere in your hometown, what kind of transportation do you use?

0. I never go out |_|
1. Car
2. Public transportation
3. Bicycle
4. Walking

9) How often do you go out for shopping?

0. Never or less than once a week |_|
1. Once a week
2. Twice to four times a week
3. Every day

10) If you go out for shopping, what kind of transportation do you use?

0. I never go out for shopping |_|
1. Car
2. Public transportation
3. Bicycle
4. Walking

Household score = (Q1+Q2+...+Q10)/10

Sport activities

Do you play a sport?

Sport 1:	name		
	intensity (code)	_____	(1a)
	hours per week (code)	_____	(1b)
	period of the year (code)	_____	(1c)

Sport 2:	name		
	intensity (code)	____	(2a)
	hours per week (code)	____	(2b)
	period of the year (code)	____	(2c)

Sport-score: $\sum_{i=1}^{2} (ia * ib * ic)$

Leisure time activities

Do you have other physical active activities?

Activity 1:	name		
	intensity (code)	____	(1a)
	hours per week (code)	____	(1b)
	period of the year (code)	____	(1c)

Activity 2 till 6: as activity 1.

Leisure time activity score: $\sum_{j=1}^{6} (ja * jb * jc)$

Questionnaire score = household score + sport score + leisure time activity score.

Codes:

Intensity code [1]:

0:	lying, unloaded	code 0.028
1:	sitting, unloaded	code 0.146
2:	sitting, movements hand or arm	code 0.297
3:	sitting, body movements	code 0.703
4:	standing, unloaded	code 0.174
5:	standing, movements hand or arm	code 0.307
6:	standing, body movements, walking	code 0.890
7:	walking, movements arm or hands	code 1.368
8:	walking, body movements, cycling, swimming	code 1.890

Hours per week:

1.	less than one hour/week:	code 0.5
2.	[1,2> hours per week	code 1.5
3.	[2,3> hours per week	code 2.5
4.	[3,4> hours per week	code 3.5
5.	[4,5> hours per week	code 4.5
6.	[5,6> hours per week	code 5.5
7.	[6,7> hours per week	code 6.5
8.	[7,8> hours per week	code 7.5
9.	more than 8 hours per week	code 8.5

Months a year:

1:	less than one month per year	code 0.04
2:	1-3 months	code 0.17
3:	4-6 months	code 0.42
4:	7-9 months	code 0.67
5:	more than 9 months per year	code 0.92

[1] unitless intensity code, originally based on energy costs.

Chapter 3

Are physically active elderly women in a better nutritional condition than their sedentary peers?

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Abstract

The generally observed decrease in physical activity with age has its influence on energy requirements and to a lesser extent on micronutrient requirements of the elderly. In this study it was hypothesized that physically active people can more easily obtain their recommended nutrient intake without becoming overweight, because of their increased energy needs. Nutritional intake, body composition and vitamin status were assessed in two groups of women aged 60-79 years. The groups showed large differences in pattern and level of physical activity as estimated by a previously described questionnaire. Dietary intake was assessed by dietary history. Body composition was assessed using anthropometric measures and bioelectrical impedance. Blood levels of haematological parameters, blood lipids and several vitamins were measured. Differences in food consumption were not statistically significant. However, the more physically active women tended to have a food pattern more in line with dietary allowances according to the Dutch guidelines. At the same body height the physically active and sedentary women had body weights of 64.9 ± 10.9 and 77.1 ± 12.0 kg (mean ± SD), respectively ($p < 0.001$). Percentage of body fat was higher in the sedentary women. Blood levels did not differ significantly between both groups of women except for higher ß-carotene in the active women.

Introduction

Energy expenditure decreases with age, due to both a change in body composition and reduced physical activity[1]. However, it is assumed that apparently healthy elderly people have the same requirements for most of the vitamins and minerals as younger people[2]. The most frequently described exception is vitamin A as result of increased absorption and decreased clearance[3]. The decrease in energy expenditure of elderly people will lead to decreased energy intake if obesity is to be avoided. A diet lower in energy may result in a lower uptake of micronutrients if nutrient density stays equal. This may lead to nutritional deficiencies. Maintenance of physical activity in old age may prevent the decrease of energy requirement and therefore facilitates the intake of sufficient amounts of micronutrients.

Studies have been performed in older people at the extremes of physical activity, in athletes and in inactive people living in institutions[4-8]. In this study the relation between physical activity, dietary intake and nutritional status was studied in apparently healthy, independently living elderly women aged 60-79 years of age. Two groups were compared with a different pattern of physical activity, selected by a new and validated physical activity questionnaire[9]. Energy and nutrient intake, and aspects of nutritional status were compared between relatively physically active and sedentary women.

Subjects and methods

Subjects

Subjects were selected by means of a physical activity questionnaire especially developed and validated for use in elderly subjects[9]. The questionnaire resulted in an activity score based on sports, leisure time physical activity and household activities. One hundred free-living women aged 60 to 80 years were recruited at different meeting places for the elderly and by door-to-door recruitment. Subjects were apparently healthy, based on both a medical questionnaire and subjective evaluation. The meeting places were selected to find subjects with a large range of physical activity. Based on results of the physical activity questionnaire the upper and lower 30 subjects were selected to participate in this study comparing food intake and nutritional status. All participants live in the city and environment of Wageningen, located in the central-eastern part of the Netherlands.

Dietary Intake

Dietary intake was assessed by a modified dietary history method as used and validated in the Euronut "Nutrition and the Elderly" study[10]. This method uses a structured quantitative food questionnaire which asks about the meals consumed in the last month as well as between meal snacks. Amounts were recorded in household measures. Portion sizes most frequently used were checked by weighing on an electronic weighing scale (Sartorius 1020) to the nearest gram. Preceding the questionnaire the participants recorded their food consumption on one weekend day and one working day. This estimated record was used to make them more aware of the food they were eating and to give the interviewer information about meal patterns. Interviewers were postgraduate students in Human Nutrition and blinded to the activity level of participants. Energy and nutrient consumption was calculated using the computerized Dutch Food Composition Table[11].

Anthropometry and body composition

Body weight was measured to the nearest 0.5 kg after an overnight fast, with the participant dressed in underwear only, using a spring balance (SECA). Height was measured to the nearest 1 mm by means of a wall-mounted device. No senile kyphosis was reported. From height and weight the body mass index (BMI, kg/m^2) was calculated. Fat-free mass and body fat percentage were calculated from BMI[12]. Skinfold thicknesses at biceps and triceps were measured in triplicate to the nearest 0.2 mm using a Holtain skinfold calliper (Holtain Ltd, Crymmych, UK). Body density was estimated from the sum of biceps and triceps skinfolds using linear regression equations[13]. Body fat was then calculated from body density using Siri's equation[14]. Bioelectrical impedance was measured with a body-composition analyser (type BIA 101, RJL systems, Detroit, MI) with the subject in a supine position. Fat free mass and percentage body fat were calculated using an age-specific formula[15]. Assistants were blinded to the activity level of participants.

Biochemical measurements

Blood was taken after an overnight fast. Haemoglobin and haematocrit were measured using a Coulter Counter (Cell-dyn 1600, Sequoia Turner) at the laboratory of the Wageningen "Gelderse Vallei" hospital. Serum was stored at -80°C and analysed enzymatically for total and high density lipoprotein (HDL) cholesterol, and triglycerides[16,17]. Vitamin analyses were carried out by Hoffmann-La Roche in Basel, Switzerland. Activation coefficients of thiamin, riboflavin and vitamin B_6 were measured in ACD-stabilized blood[18]. Stimulation of erythrocyte transketolase (ETK) by thiamin pyrophosphate was used as a measure for thiamin status. For riboflavin, erythrocyte glutathione reductase (EGR) was stimulated with flavin adenosine dinucleotide (FAD). Pyridoxal-5'-phosphate (PLP) stimulation of glutamate oxaloacetate aminotransferase (EGOT) and measurement of plasma levels of pyridoxal-5'-phosphate were used as a measure of the B_6 status. For ETK, EGR and EGOT the activation coefficient α is calculated of the ratio between enzyme activity after and before stimulation with coenzyme.

Plasma folate and vitamin B_{12} were measured in plasma using solid-phase radio-assays (No Boil Dualcount, Diagnostic Products Corporation DPC, Los Angeles, USA). Vitamins A, E and ß-carotene were analysed using HPLC[19]. Cut-off points for risk on vitamin deficiencies were provided by Hoffmann-La Roche.

Statistics

Data were analysed using the SAS system[20]. The results are expressed as mean values with standard deviations (SD). Student's unpaired two-sided *t*-test was used to evaluate differences in continuous variables among the groups. In case of a skewed distribution (intakes of cholesterol, vitamin A, vitamin C) a natural logarithm transformation of each value was carried out. For alcohol consumption the non-parametric Wilcoxon test was used. Differences with a p value less than 0.05 were considered statistically significant.

Results

Subjects

The activity score resulting from the activity questionnaire ranged from 2 to 32. Subjects at the upper end of the scale with an activity score higher than 17 were labelled the "physically active group". Subjects at the lower end of the scale, with an activity score below 9, were labelled the "sedentary group". Subjects of the physically active group reported that they were involved in activities such as gymnastics, dancing, badminton, rowing, walking and cycling for several hours per week. The sedentary group participated in several of the above-mentioned activities, but mostly for less than 15 minutes per day. No women in both groups were employed at the time of measurement.

Twenty-five out of thirty physically active women who were invited actually participated and twenty-three of thirty invited sedentary elderly women. Reasons for not participating were loss of interest (eight subjects), holidays during the research periods (three subjects), or death in one case. Data on age, marital status and educational level are provided in Table 1. There was no significant age difference. Marital status was almost similar to the Dutch average in the same age group, and educational level somewhat higher[21].

Table 1. Age, marital status and educational level of two groups of women aged 60 - 79 years with different levels of physical activity.

	Active Mean ± SD (n=25)	Sedentary Mean ± SD (n=23)
Age (y)	69.7 ± 4.1	71.2 ± 3.9
Marital status:		
- Unmarried	2	3
- Married	12	11
- Divorced	2	0
- Widowed	9	9
Educational level:		
- Primary school only	7	5
- Lower vocational education or advanced elementary education	5	6
- Intermediate vocational education secondary education	7	4
- Higher vocational education or university degree	6	8

Dietary intake

Intakes of energy, nutrients and of nutrients expressed as percentages of energy are presented in Table 2. Two active and four sedentary subjects told us to have a slimming diet. In dietary intake no statistical differences were detected with the exception of dietary fibre when expressed per MJ of energy consumed. The percentage of energy consumed as fat was lower in the physically active subjects (35.9 % and 37.6 % for physically active and sedentary subjects, respectively) and the percentage of energy consumed as protein and carbohydrates was higher. However, these differences were not statistically significant. Using the Dutch Recommended Dietary Allowances for women aged 65 and over, 15 of the women had intakes of vitamin A below RDA (< 800 retinol equivalents per day) and 27 had intakes of thiamin below RDA (< 1.0 mg/day). Eleven women were below RDA for riboflavin and vitamin B_6 respectively (< 1.3 and < 1.3 mg/day). Four women had intakes of vitamin C below the RDA of 70 mg/day. No women had intakes of total iron below RDA of 8 mg/day and nine had calcium intakes below the RDA of 800 mg/day[22].

Table 2. Daily intake of energy and nutrients in two groups of women aged 60 - 79 years with different levels of physical activity.

	Active Mean ± SD (n=25)	Sedentary Mean ± SD (n=23)
Energy (MJ)	6.9 ± 1.4	7.4 ± 1.6
Energy/kg body weight (kJ/kg)	109 ± 30	98 ± 23
Protein (g)	68.2 ± 11.71	68.0 ± 16.5
Fat (g)	67.0 ± 22.1	75.3 ± 23.4
Carbohydrates (g)	182.6 ± 39.2	193.5 ± 47.5
Alcohol (g)	5.0 ± 7.6	8.0 ± 12.5
Fat (% energy)	35.9 ± 5.8	37.6 ± 7.1
Protein (% energy)	17.2 ± 4.3	15.4 ± 2.6
Carbohydrates (% energy)	44.7 ± 4.0	43.8 ± 7.4
Alcohol (% energy)	2.2 ± 3.5	3.2 ± 5.0
Dietary fibre/energy (g/MJ)	3.6 ± 0.9	2.9 ± 0.8*
Dietary fibre (g)	24.0 ± 5.7	21.3 ± 5.1
Water (g)	2332 ± 632	2101 ± 394
Calcium (mg)	1050 ± 292	1082 ± 306
Iron (mg)	12.7 ± 2.4	12.1 ± 2.8
Vitamin A (mg)	1.0 ± 0.6	1.1 ± 0.5
Thiamin (mg)	1.0 ± 0.6	1.0 ± 0.2
Riboflavin (mg)	1.7 ± 0.4	1.7 ± 0.5
Pyridoxine (mg)	1.2 ± 0.2	1.1 ± 0.3
Vitamin C (mg)	128 ± 57	113 ± 39

*: $p < 0.05$.

Table 3. Anthropometrical data on two groups of women aged 60 - 79 years with different levels of physical activity.

	Active Mean ± SD (n=25)	Sedentary Mean ± SD (n=23)
Body height (m)	1.62 ± 0.06	1.63 ± 0.06
Body weight (kg)	64.9 ± 10.9	77.1 ± 12.0*
BMI (kg/m^2)	24.7 ± 4.5	29.1 ± 5.3*
Skinfolds:		
- biceps (mm)	10.0 ± 3.5	11.9 ± 3.8*
- triceps (mm)	19.6 ± 5.0	21.2 ± 4.0
Impedance (Ω)	581 ± 69	560 ± 67
Body fat (%)		
- from skinfolds	35.7 ± 4.1	37.5 ± 3.3
- from BMI	43.2 ± 3.0	46.2 ± 2.3*
- from impedance	47.4 ± 7.1	54.1 ± 4.8*

* $p < 0.05$.

Anthropometry and body composition

The body weight was 12 kg higher in the sedentary women, a statistically significant difference. There was no significant difference in body height. The results of anthropometry and the measurement of the bioelectrical impedance are presented in Table 3. Body fat percentage as calculated from BMI and bioelectrical impedance was significantly higher in the sedentary group. Using skinfolds however, the difference between the groups was not statistically different.

Biochemical measurements.

Among the biochemical tests no significant differences were detected between the groups. Haematological data and data of blood lipids are presented in Table 4. Haematological measurements were within the normal range for elderly subjects.

Parameters of vitamin status are presented in Table 5. One subject used mega doses of dietary supplements, resulting in extremely high values especially for plasma pyridoxal phosphate (1694 nmol/l, whereas the group mean of the remaining subjects is 20 nmol/l). Vitamin data of this subject are not included in the analyses. The physically active group had a significant higher level of ß-carotene. The ETK activation coefficient was high for seven women ($\alpha > 1.18$). EGR and EGOT activation coefficients were high for 0 and 38 of the participants (α > 1.52 and α > 1.8, respectively). Plasma pyridoxal-5'-phosphate was below 30 nmol/l in 41 out of 47 subjects. Plasma folate was not below 7 nmol/l in this study, and cobalamin was below 150 pmol/l in four women. Low plasma values were found for both retinol and ß-carotene in one subject (retinol < 1.0 μmol/l and < 0.30 μmol/l respectively). Vitamin E levels were never below 15 mmol/l.

Table 4. Haematological measurements, serum total and HDL cholesterol, and triglycerides in women aged 60 - 79 years with different levels of physical activity.

	Active Mean ± SD (n=25)	Sedentary Mean ± SD (n=23)
Haemoglobin (mmol/l)	8.5 ± 0.6	8.6 ± 0.5
Haematocrit (%)	42 ± 3	42 ± 3
MCV (fl)	91.8 ± 4.2	92.0 ± 4.6
MCH (fmol)	1.87 ± 0.09	1.88 ± 0.08
MCHC (mmol/l)	20.4 ± 0.3	20.4 ± 0.2
Serum total cholesterol (mmol/l)	6.9 ± 1.1	6.7 ± 1.0
HDL cholesterol (mmol/l)	1.4 ± 0.3	1.5 ± 0.4
Triglycerides (mmol/l)	1.3 ± 0.5	1.3 ± 0.5

*: $p < 0.05$.
MCV: mean corpuscular volume
MCH: mean corpuscular hemoglobin
MCHC: mean corpuscular hemoglobin concentration

Discussion

In this study two groups of elderly women with a different pattern of daily physical activity were compared for dietary intake and nutritional status. The groups studied were not representative of the Dutch population as the education level was higher and self-reported health was better in both groups. This is possibly due to the way of recruitment and the presence of the University and research institutes in Wageningen. However, for the aim of the study, e.g. a comparison of two groups, this is not a problem.

Table 5. Vitamin status in two groups of women aged 60 - 79 years with different levels of physical activity.

	Active Mean ± SD (n=25)	Sedentary Mean ± SD (n=22)
α-erythrocyte transketolase[a]	1.10 ± 0.09	1.12 ± 0.07
α-erythrocyte glutathione reductase[a]	1.19 ± 0.09	1.17 ± 0.11
α-glutamate oxaloacetate aminotransferase[a]	1.77 ± 0.20	1.69 ± 0.17
pyridoxal 5'-phosphate (nmol/l)	19.0 ± 9.7	21.9 ± 16.1
vitamin B-12 (pmol/l)	324 ± 106	322 ± 134
folate (nmol/l)	22.0 ± 8.4	20.9 ± 8.0
retinol (μmol/l)	1.99 ± 0.41	2.02 ± 0.39
ß-carotene (μmol/l)	0.99 ± 0.59	0.67 ± 0.22*
vitamin E (μmol/l)	32.1 ± 8.3	30.0 ± 5.5

a: activation coefficient α: ratio of enzyme activity stimulated with coenzyme and enzyme activity without stimulation with coenzyme.

*: $p < 0.05$

The nutrient intake of both groups hardly showed any differences, with the exception of intake of dietary fibre expressed per MJ of energy consumed. This difference in dietary fibre per MJ of energy between physically active and inactive elderly women has previously been reported by Segebartt *et al*[23]. In general, the food pattern of the more physically active group tended to conform more to the Dietary Guidelines of the Netherlands Nutrition Council[22]. The whole group, however, had a lower fat and higher carbohydrate intake than in a recent nationwide random sample of Dutch elderly people, studied as part of the Dutch Nutrition Surveillance System[24]. The energy intake was not statistically different between the groups. Expressed per kg of body weight, the energy intakes for the physically active and sedentary women were 108.9 ± 30.1 and 98.3 ± 23.3 kJ/kg, respectively. This is in good agreement with the intake of 113 kJ/kg body weight in a combined sample of men and women in the same age category, published recently[25]. Data for women separately will be lower because of the higher fat percentage in women. Comparison of daily use of food groups showed a trend for active women to eat more vegetables, fruits, legumes and non-alcoholic drinks, whereas the sedentary women had a higher consumption of milk, meat and alcoholic drinks. Compared with the results of the Dutch Nutrition Surveillance System the present sample showed a slightly lower consumption of visible fats and bread and a higher consumption of vegetables and fruits (active women only)[24].

The hypothesis that sedentary women eat less and would have inadequate intakes of some nutrients was rejected for our study group. However, there was a marked difference in body weight between the groups. Although a difference could be expected and has been described in literature[26], its size was surprising. In the sedentary group, one outlier had a body weight of 110 kg. Even with this subject omitted, the weight difference between the groups was 10.7 kg, still highly significant. Löwik also observed differences in body weight between physically active and sedentary elderly people, the difference found in a representative group of elderly Dutch women being about 5 kg. Physical activity was assessed approximately by asking about the type and frequency of sport activity only[26].

The haematological and biochemical values were much the same between our two groups. Therefore the conclusion may be drawn that despite the large difference in body weight between the sedentary and active elderly women the more or less equal dietary intake did not lead to differences in blood lipids and blood vitamins levels. Supplement use was higher in the less active people and this could have overshadowed a between-group difference.

Physical activity is known to affect HDL cholesterol and triglycerides in elderly people[27-31]. In this study however, no differences could be detected between the groups. The above-mentioned studies were carried out with people in the extremes of physical activity or by studying the changes in blood lipids during exercise training. Surprisingly the large difference in activity level in the group studied may not be large enough to have an impact on blood lipid levels.

The more physically active elderly women had a higher level of circulating ß-carotene. This difference has been reported earlier[32]. Mensink and Arab studied dietary intake and nutritional status in physically active and less active elderly women. Differences in intake were found for iodine, calcium and vitamin B_2, each being higher in the physically active group. However, no statistically significant differences were found in body weight or body

mass index in this study. A weak point was that the assessment of physical activity was only based upon one question about the performance of sport activity.
At the start of the study we hypothesized that an age-related decrease in physical activity could lead to either a low intake of micronutrients because of decreased energy needs, or to obesity due to higher energy intake than energy expenditure. Based on our results we suggest that the second option is the most probable, although the physically active elderly women also tended to have a healthier food consumption pattern than sedentary women. It is important to note that from our data it cannot be concluded whether the high body weight is a result of reduced activity or that activity is reduced because of the higher body weight. This question has still to be answered.

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Chapter 4

History of body weight and physical activity of elderly women differing in current physical activity.

Laura E. Voorrips, Jolanda H.H. Meijers, Petra Sol, Jacob C. Seidell and Wija A. van Staveren

Abstract

Development of overweight and physical activity during life was studied retrospectively in a group of physically active and a group of sedentary elderly women. The two groups of elderly women were selected based on a validated physical activity questionnaire. A previous study on their current dietary intake and nutritional status showed a 12 kg higher body weight in the sedentary group compared to the physically active group, whereas body height did not differ. In order to study the relationship between development of overweight and physical activity in these elderly women, a retrospective study was carried out in 45 subjects. Information about former physical activity was collected by means of detailed structured interview. Information about body shape and fatness, expressed as "weight index", was obtained using silhouettes and subjective rating of obesity of subjects compared with peers. Classification of obesity was checked by old photographs rated by interviewers, sizes of clothing and recalled body weight and height. Information was collected about the situation at age 12, 25, 40 and 55 yrs whereas the mean current age is 71.

Weight index was statistically significant different between the active and sedentary group from age 25 onwards ($p < 0.05$). Photographs proved to be useful for a valid and objective categorization. No differences were found in physical activity scores between the groups at age 12, 25, 40 and 55 yrs. It is concluded that the current difference in body shape and fatness between physically active and inactive elderly women was already present at age 25 and persisted throughout their adult life. The current low physical activity is possibly a result rather than a cause of higher body weight in old age.

Introduction

A decline in physical activity is generally observed with ageing. This, together with a decline in fat free mass with ageing, results in a reduced need for energy provided by the diet[1]. On the one hand, a low energy intake may result in a lower intake of micronutrients. This might have consequences as it is suggested that the daily requirement for most micronutrients do not decrease with ageing[2]. On the other hand,

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a reduced energy expenditure without adjusted energy intake may lead to overweight. This is a known risk factor for diseases as coronary heart disease and diabetes. In elderly people obesity results in a high incidence of complications as osteoarthritis of the weight-bearing joints[3,4].

In a previous study[5], two groups of apparently healthy elderly women were selected based on physical activity as assessed by a validated questionnaire[6]. Women in the upper and lower tertile of physical activity were selected to participate, whereas women in the middle tertile were not. Comparing the two groups, no differences were found in dietary intake. However, a statistically highly significant difference in body weight and body mass index was found[5]. Having equal body height, the difference in mean body weight between the groups was more than 12 kg, being higher in the sedentary group. To answer the question whether the higher body weight resulted from, or was the cause of, reduced physical activity, retrospective data on the same population were needed. Because hard retrospective data on height, weight and physical activity were unavailable from records, we tried to obtain information on body shape, fatness and physical activity earlier in life using several retrospective methods.

Methods to assess former body weight or fatness have previously been reported in the literature. The data on body weight were connected to important life events[7] or to predefined ages[8]. Also, data were collected on maximum or minimum body weight at fixed age[9], during adulthood in total[8], or in ten year time intervals[10,11].

We are not aware of any publication presenting methods for the retrospective assessment of physical activity.

The purpose of our study was to investigate whether the present between group differences in body shape or fatness, and physical activity in elderly women had existed earlier in life.

Subjects and methods

Subjects

In an earlier study, 23 sedentary and 25 physically more active elderly women were selected based on a validated physical activity questionnaire[5,6]. These women were invited to participate in the present study. The physically active participants spent several hours per week in cycling, walking, dancing and sports, whereas the physically less active participants had a more sedentary life style. Of the 48 subjects from the first study[5], two did not participate in the present study because of illness and one was not any more interested in the study. The remaining 45 participants were aged 71.4 ± 4.1 years (range 64.2 - 79.5 yrs).

Study design

To make data comparable between subjects and to reduce the amount of data we focused on 4 stages in life that are generally well remembered. The connection of body weight to important happenings in life makes it easier for participants to remember body weights, but more difficult to compare individuals, as these events may occur at different ages. We decided to choose specific ages that could be connected to life events. The required ages had to be equally distributed over the life cycle and should be marking points as much as possible. We selected the age of 12, 25, 40 and 55 to be questioned about, whereas the actual mean age of the participants is 71 yrs. In our Western society these ages could be linked to important points in life. At the age of 12 one is still a child, but old enough to remember important things like changing schools and important religious happenings. The age of 25 is easy to remember because around that time often marriage or birth of the first child takes place. Furthermore, people on university level start to work at this age. At the age of 40, most families make their final decisions about the place to live and work for the rest of their lives, and at the age of 55 people change to a life without children.

Questionnaire

The interviews were performed by two trained students in Human Nutrition. As a help to both the interviewer and the subject, a time table was used on which information about age, important happenings in life (eg birth of children, death of husband or child), and subsequent residences was written. Interviews were done by the two interviewers together, one asking questions and one recording the data on the time schedule. Interviews lasted one to four hours. Both the interviewers were blinded to the physical activity level of the participants, and the participants did not know that they had been classified in different groups of activity levels. Questions about the situation at age 12, 25, 40 and 55 yrs were introduced by some general questions about school teachers, housing, and family situation at that particular age, the intention being to help the subjects to remember the specific situation. In case of pregnancy or occurrence of the World War II " Dutch Hunger Winter" (1944/1945) at the given age, questions were answered about the situation one year ahead or before, because data would be affected more or less severely by these circumstances.

Questions about physical activity at a certain age were subdivided in activities at school, at home, at work, at sports and during leisure time. Each of these subscores consisted of a list of items distinguishing for the particular setting. Each item was rated 1 to 5, depending on the contribution to physical activity. For instance, going by foot or by bicycle to school is rated 5, being brought by car is rated as 1.

The items of interest during school time were the means of transport to school, the distance to school and the number of months the school was visited in that particular year. To assess activity at work, questions were included about the type and intensity of work, the number of hours worked per week, the number of months worked in that particular year, and the means of transport and the distance to home. Household activity was assessed as the number of hours worked per day, the number of persons to care for, the number of rooms to be cleaned, and the presence and activity of help. At the age of 40 and 55 questions were added about the availability of household electrical equipment to relieve the household task. At age 12, household tasks were completely different and questions were changed accordingly. At all ages, different tasks were again rated 1 to 5 based on activity level. To assess sport activity, participants were asked about the type, and frequency the sport activity was performed. Sports were rated 1 to 5 for intensity level. Intensity and time spent were multiplied and the sum of different sport activities was calculated. Leisure time activity consisted of type of activity, time spent on it, intensity, type of transport used, distance to activity. Every answer was coded in a 5 point scale. Coding of intensity of all activities was based on energy costs, derived from literature[12]. During the interview, remembrance of activities in household, leisure time and sports was supported by cards with all possible answers.

Subscores were weighed to make equal contributions to the total. To calculate the "total activity score", the separate weighed subscores were added. Comparisons between groups can be made age by age but not longitudinally, as the questions used are not equal on all ages due to different types of activities and environmental changes. Data on current physical activity can not be compared to retrospective data, as a different, more specific, questionnaire was used for current data.

Weight Index

Since we expected difficulties in memory in our participants, the reported body weight and height would give an incomplete and less reliable dataset. Therefore, we decided to use a "weight index" as the best predictive value for former body shape and fatness. The weight index consisted of scores on front and side view of a range of silhouettes combined with a self judgement of the subjects comparing ones body shape and fatness with others of the same age. Side-view silhouettes were derived from Morris and Rona[13] and redrawn for girls aged 12 yrs. Front view silhouettes were used from Van Deursen and Deurenberg[14]. They used silhouettes in 12 to 17 year old children to assess body shape. Morris and Rona[13] used their side-view silhouettes for assessment of obesity in bedridden patients aged 65 and over. Silhouettes were rated 1 (low Body Mass Index (BMI)) to 5 (high BMI). Comparing oneself to peers results in 5 points for people considering themselves fatter, 3 points for as fat as, and 1 point for thinner than peers. The weight index was obtained by summation of the three parts (both silhouettes and comparison to peers).

Sizes of clothing, photographs, body weight and height

Sizes of clothing were asked for ages 25 and over, using the Dutch system of clothing sizes.

The subjects were asked to present photo albums. The interviewers looked for photographs from the subjects at different ages which showed their body shape adequately. Photographs were rated 1 to 5 by the interviewers together (1 for low BMI, 5 for high BMI) after leaving the house of the subject. For the present age, the body shape was rated in the same way.

Body weight and height at the ages of interest were asked starting at age 25, and BMI was calculated.

Weight index, sizes of clothing and height and weight were asked directly following the questions of physical activity of the particular age. Photographs were shown at the end of the interview.

Statistics

Data were analysed using the SAS system[15]. The results are expressed as mean values with standard deviations (SD). In case of normality of the data, Student's unpaired two-sided t-test was used to evaluate differences among the groups. Otherwise, the non-parametric test of Wilcoxon was used. Differences with a p value of less than 0.05 were considered statistically significant. The Spearman rank correlation coefficient was used to validate the weight index to the sizes of clothing, photographs, and reported BMI.

Results

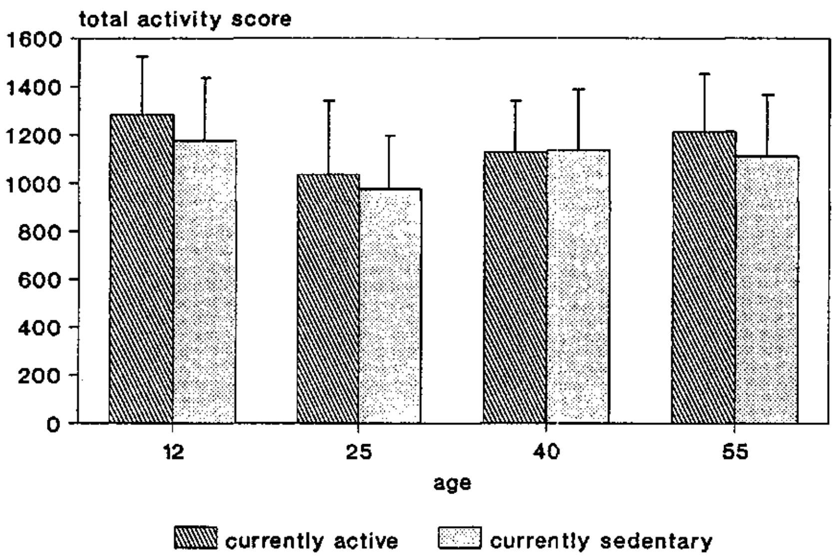
Physical activity

Complete data were collected of 45 subjects. The total activity score at the different ages is presented in Table 1 and visualised in Figure 1. No statistically significant differences could be detected between the two groups at the various ages. Analysing the physical activity scores at school, work, house, sports and leisure time separately, did not reveal any statistically significant differences either.

Weight index

At every age-period, two out of 41 participants were not able to indicate their best-fitting silhouettes. For each age-period however, these were different subjects. Results of the weight index are presented in Table 1 and visualised in Figure 2. At the age of 12 the weight index for the sedentary group was 6.3 ± 2.8 and 5.7 ± 2.7 in the active group (mean ± SD). At the age of 25 these data were 8.2 ± 2.5 and 5.5 ± 2.1 respectively, with a p-value < 0.001. At the age of 40, the sedentary and active groups had weight indices of 9.5 ± 2.5 and 6.9 ± 2.4 respectively, with a p-value < 0.002. At the age of 55 these data were 10.4 ± 2.1 and 6.9 ± 2.5 ($p<0.001$). At the present mean age of 71 these data were 10.5 ± 2.8 and 7.8 ± 3.5 for both groups, with a p-value of < 0.01. The weight index reached statistical difference between the groups starting at age 25.

Figure 1. Physical activity score at different ages of 21 currently sedentary and 24 currently physically active elderly women, based on a detailed questionnaire. Means and standard deviations.

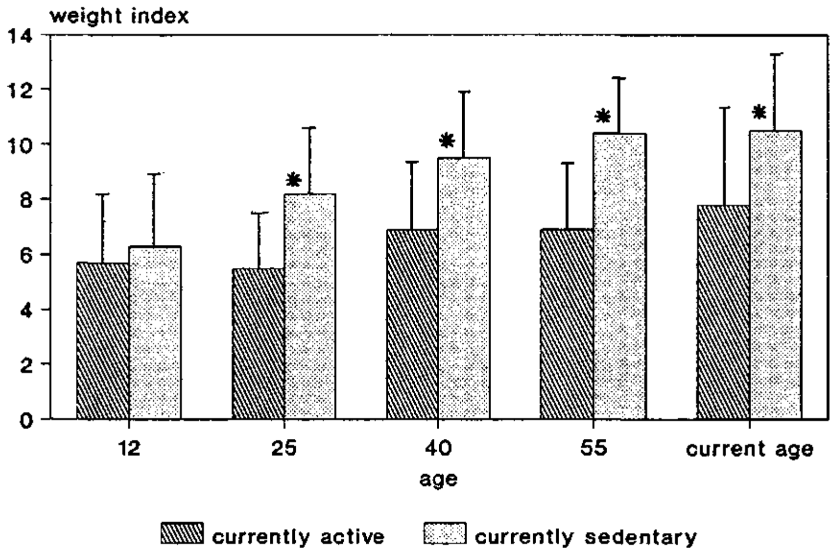


Sizes of clothing, photographs, body weight and height

Sizes of clothing were provided by 38 participants for age 25, by 43 participants for age 40, and by all participants for age 55 and current age respectively. Clothing sizes were different between the groups starting at age 25. Spearman rank correlation coefficient of weight index versus clothing size was 0.56, 0.75, 0.71 and 0.79 ($p<0.05$) for ages 25 to current age respectively.

Photographs were shown by 37 out of 45 participants (age 12 and age 40), 39 participants (age 55) and 41 participants (age 25) respectively. The photographs were rated higher in the sedentary group at age 25, 40, 55 and at the present age ($p<0.05$). Results are presented in Figure 3 and Table 1. Spearman rank correlation coefficients of weight index versus photoscore was 0.25 (not significant) for age 12, and 0.51, 0.52, 0.50 and 0.76 ($p<0.05$) for age 25, 40, 55 and the present age. To evaluate the accuracy of photo scores, cross tables were made against weight score. As the weight index has a range of 1 to 15, and the photoscore of 1 to 5, the weight indices were recoded to a 1 to 5 scale.

Figure 2. Weight Index at different ages, based on rating of two silhouettes and a comparison of body shape with peers, of two groups of elderly women differing in present physical activity. Means and standard deviations.



Number of sedentary/active women age 12, 25 and 55: 19/24, age 40: 20/23, current age: 21/24.

*: $p < 0.05$.

Table 1. Activity score, weight index, photo score, clothing measures, and reported and measured body weight, height and body mass index of elderly women differing in current physical activity, means ± SD. Measurements of body weight and height are performed nine months before. (NS): Not statistically significant different.

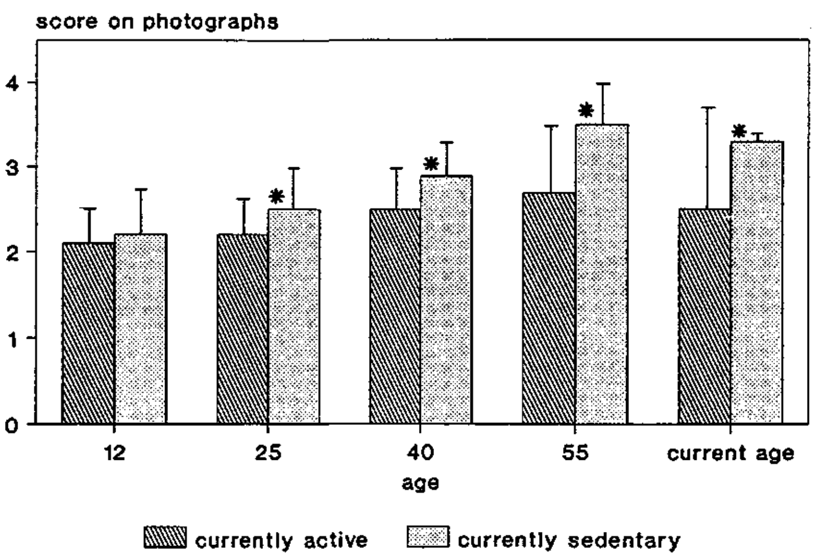
	age 12 y		age 25 y		age 40 y		age 55 y		current age	
	active	less active	active	less active	active	less active	active	less active	active	less active
activity score	1284 ± 251	1179 ± 261 (NS)	1037 ± 305	975 ± 227 (NS)	1127 ± 229	1136 ± 259 (NS)	1213 ± 256	1111 ± 271 (NS)	--	--
n	(24)	(21)	(24)	(21)	(24)	(21)	(24)	(21)		
weight index	5.7 ± 2.7	6.3 ± 2.8 (NS)	5.5 ± 2.1	8.2 ± 2.5	6.9 ± 2.4	9.5 ± 2.5	6.9 ± 2.5	10.4 ± 2.1	7.8 ± 3.5	10.5 ± 2.8
n	(24)	(19)	(24)	(19)	(23)	(20)	(24)	(19)	(24)	(21)
photo score	2.1 ± 0.5	2.2 ± 0.5 (NS)	2.2 ± 0.4	2.5 ± 0.5	2.5 ± 0.5	2.9 ± 0.4	2.7 ± 0.8	3.5 ± 0.5	2.5 ± 0.8	3.3 ± 1.0
n	(18)	(19)	(21)	(20)	(19)	(18)	(22)	(17)	(23)	(21)
clothing measure	–	–	39 ± 2	41 ± 2	41 ± 2	43 ± 2	41 ± 2	44 ± 3	42 ± 3	45 ± 3
n			(21)	(17)	(23)	(20)	(24)	(21)	(24)	(21)
reported weight	–	–	56 ± 6	65 ± 13	60 ± 6	70 ± 9	62 ± 6	75 ± 10	63 ± 10	77 ± 11
n			(20)	(13)	(21)	(15)	(22)	(20)	(24)	(21)
weight measured	–	–	–	–	–	–	–	–	64 ± 10	78 ± 12
n									(24)	(21)
reported height	–	–	166 ± 7	168 ± 7 (NS)	166 ± 7	168 ± 7 (NS)	166 ± 7	168 ± 7 (NS)	164 ± 7	165 ± 7 (NS)
n			(20)	(13)	(21)	(15)	(22)	(20)	(24)	(21)
height measured	–	–	–	–	–	–	–	–	162 ± 6	163 ± 7 (NS)
n									(24)	(21)
BMI	–	–	20.4 ± 2.1	22.8 ± 3.6 (NS)	21.6 ± 2.1	24.7 ± 3.0	22.6 ± 2.8	26.6 ± 3.4	23.6 ± 4.3	28.3 ± 4.5
n			(20)	(13)	(21)	(15)	(22)	(20)	(24)	(21)
BMI measured	–	–	–	–	–	–	–	–	24.5 ± 4.4	29.6 ± 5.2
n									(24)	(21)

Comparing weight index and photoscore resulted to 91 to 95% of the people being classified either identically or only one class apart on two methods at all ages. One subject at age 12 and one at age 25 were classified three classes apart, and gross misclassification (four classes apart) did not occur.

Body weight and height could be reported by 33, 36, 42, and 45 of the participants at ages 25, 40, 55 and present age respectively. Reported body weight was statistically significant different starting at the age of 25, calculated BMI was significantly different starting at age 40, and borderline significant ($p=0.06$) for age 25. Spearman rank correlation coefficients of weight index and reported BMI were 0.68, 0.77, 0.79 and 0.80 ($p<0.05$) for the ages of interest.

Spearman rank correlation coefficient of current reported BMI against clothing measures and photoscores was 0.79 and 0.80 respectively.

Figure 3. Score on photographs showing body shape at different ages of two groups of elderly women differing in present physical activity.



Number of sedentary/active women at age 12: 19/18, age 25: 20/21, age 40: 18/19, age 55: 17/22, current age: 21/23.

*: $p < 0.05$.

Discussion

In this study retrospective data were collected about body shape and fatness, and physical activity of elderly women. The use of a time schedule on important life events proved to be useful in keeping both subjects and interviewers to the required points in life. The association of important life events to the four ages of interest (eg, 12, 25, 40 and 55 years of age) proved to be well chosen.

No differences between study groups were found for physical activity earlier in life. Assessment of physical activity retrospectively is extremely difficult, especially in age groups were only some of them ever participated in registered sport activities. Therefore, we decided to use an item-type questionnaire covering most of the physical activities at different settings. Validation of physical activity earlier in life is only partly possible when subjects have performed sporting activities that have been registered, as in the Harvard Alumni Study[16]. Also, spouses or siblings could provide some additional information. However, with all this information its validity remains unclear. In addition, collecting this type of information is extremely time consuming and therefore it is not applicable to research in larger groups. In our present study, the retrospective physical activity questionnaire was pretested in a panel which showed that most activities performed earlier in life were covered. Although we are uncertain about the validity of the data on physical activity questioned retrospectively, we think that large differences should have been detectable with the method used.

To calculate a total activity score, subscores were weighed to make equal contributions to the total. It can be argued that the score on sport activity should have more influence on the total, as in general it is the best predictor for total physical activity. However, the practice of sports has not been commonly available until recently, and will not have contributed much to the total activity of these women. Also, it would have been difficult to find a correct weighing factor for sports activity. In fact, this would not have altered the conclusions, as not any subscore was different between the two groups.

In our study the weight index was compared with information derived from photographs, clothing sizes, and body weight and height. We decided to use weight index as the most reliable basis to compare groups. As expected, it was easier for people to indicate silhouettes than to give their exact weight and height at a certain age. The weight index was different between the groups with current high and low physical activity starting at the age of 25. A difference in body size was confirmed by data on clothing sizes and body weight and height. In our study, results of these three methods assessing obesity status led to the conclusion that participants are quite consistent in their self rating of adult body size. Since appropriate photographs are a rather objective retrospective indication of body shape or fatness, it was very useful that photographs for all age categories were available. Most of the subjects were able to show photographs at the ages of interest (37, 41, 37 and 39 out of 45 women at the particular ages respectively). Spearman rank correlation coefficients of photographs versus weight index were 0.50 at the age of 25, 40 and 55 years. On group level, photographs can be helpful in assigning obesity status retrospectively, except for data in childhood. The score assigned to a photograph however will be interviewer dependent and they should be trained very well when this method is used by several interviewers in the same study. In our study, all interviews and rating of photographs were performed by the same two interviewers, so interviewer bias was excluded.

The validity of reported body weight, height and clothing measures depends on a reasonable accuracy of the participants. The accuracy of self-reported weight and height is often discussed in literature[17-20]. Generally, overweight people tend to underestimate body weight, whereas underweight people tend to overestimate (flat slope syndrome). The underestimation of body weight in heavier women is more prominent in younger women than in older women[17]. Women tend to overestimate height[17]. In our study, the subject's body weight and height was measured 9 months preceding the interview (table 1). The Pearson correlation coefficient between reported body weight and measured body weight was 0.92 ($p<0.05$). The reported weight was 1.1 ± 2.5 kg lower than the measured weight ($p<0.05$). Reported height was 2.1 ± 2.7 cm higher than measured previously ($p<0.05$). However, underestimation of weight and overestimation of height was not significantly correlated to body mass index.

The detailed retrospective analysis revealed two important aspects. In the first place, both groups showed significant differences in body size and body weight at all time of the retrospective study. This was confirmed by the use of clothing sizes, reported body weight and height, and photographs. In the second place, we could not observe in retrospective view significant differences in physical activity. This may indicate that reduction in physical activity in our group of elderly women took place relatively recently. It is unlikely that one group of the elderly women increased physical activity recently. We may speculate that elderly women with a relatively higher body weight do decrease physical activity more than their peers do with a relatively lower body weight. Further it might even be possible that the observed reduction in physical activity contributes to additional weight gain causing the very large difference in body weight between the physically active and sedentary women.

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Chapter 5

How fit are elderly women differing in habitual physical activity as assessed by physical activity questionnaire?

Laura E. Voorrips, Koen A.P.M. Lemmink, Marieke J.G. van Heuvelen, Petrus Bult, and Wija A. van Staveren

Abstract

Fifty elderly women (age 71.5 ± 4.2 yrs, mean ± SD) participated in a battery of tests assessing several aspects of physical fitness. The women were selected based on tertiles of habitual physical activity as determined by a validated questionnaire. The tests comprised the following measurements: peak expiratory flow, flexibility of shoulder joint, flexibility of hip and spine, balance, reaction time, grip strength, manual dexterity, and endurance. Additionally, data were collected on height, body weight and systolic and diastolic blood pressure. A questionnaire was used to evaluate subjective fitness and general health. Results indicated that physically more active elderly women tend to have better results on most tests. With a lower body weight and body mass index, flexibility of the hip and spine, as assessed using a sit-and reach test, and endurance on a walk test were statistically significantly better in the more active women. Test results are confirmed by subjective evaluation by the participants.

Introduction

Advancing age generally is accompanied by a progressive decline in physical activity[1]. Together with changes in basal metabolic rate this results in a decreased energy expenditure. A reduced energy need has major implications for nutritional requirements, as energy intake should be adapted to expenditure without affecting micronutrient intake. To investigate the existence of nutritional problems related to physical inactivity a study was performed on food consumption and nutritional status of two groups of apparently healthy elderly women differing in level of habitual physical activity[2]. Participants were selected based on a validated physical activity questionnaire[3]. The study showed that the main observed difference between the two groups was a difference in body weight of 12 kg, being higher in the less active group. In retrospective view the study showed that the

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less active group had a higher body weight starting before age 25 whereas no important differences in former physical activity could be detected[4]. One explanation could be that the observed currently low physical activity of the elderly women was a result of the high body weight, more than that the high body weight was a result of recently reduced physical activity.

The higher body weight in sedentary elderly women has evoked the question whether the present difference in habitual physical activity is associated to other differences in body functions affecting activities of daily living. It is well documented that physical activity in old age can help to sustain muscle mass[5,6] or bone density[7] and several aspects of physical fitness such as maximal oxygen uptake capacity[8], motor performance[9], grip strength[10], reaction time[11-13] and flexibility[14].

To investigate whether the women participating in the earlier mentioned studies (who were originally selected based upon an activity questionnaire) showed differences in overall physical fitness, a battery of tests was used. This battery included tests for several aspects of physical fitness and was developed for elderly people[15] and tested for reliability and validity in healthy elderly volunteers. The battery included measurements of peak expiratory flow, flexibility of shoulder joint, flexibility of hip and spine, balance, reaction time, grip strength, manual dexterity, and endurance during walking. Additionally, data were collected of height, body weight and systolic and diastolic blood pressure. It was hypothesized that differences between the activity groups would exist on those functions known to be related to physical activity. As all participants were independently living, performing household activities and other activities of daily living, no differences were expected on reaction time and manual dexterity. Depending on the physical activities performed by the participants, differences were expected on endurance, flexibility, grip strength, balance and subjective health and fitness.

Subjects and methods

Subjects

Free living and apparently healthy elderly were selected based on a validated physical activity questionnaire[2,3]. Physically active and sedentary women participated in former parts of the study[2,4] and were invited to participate in the present study. The physically active participants spent several hours per week in cycling, walking, dancing and sports, whereas the physically less active participants had a sedentary life-style. For the present study also the women of the original middle group of physical activity[2] were invited to participate. In total 50 women actually took part in the study.

Study design

Participants were sent written information about the study and could indicate to be a volunteer by mail. Before the measurements took place, the participants once more completed the questionnaire about daily physical activity[3] which was used for their selection one year before, as well as a questionnaire about self-perceived physical health and fitness. On the day of the measurements the participants were seen by a physician to discuss possible problems on particular tests. The tests in the battery were performed in the same order by all participants.

Battery of tests of physical fitness

The battery of tests was developed for elderly people by the Department of Human Movement Sciences of the University of Groningen, The Netherlands. Criteria for tests to be included were, that they could be performed by people aged 55 years and over and they should be relevant as a measure of the independency of elderly people (e.g. derived from activities of daily living). Finally, they were developed for operation by minimally trained personnel and had to be inexpensive, easily portable instruments. The tests were all checked on reliability and validity during fitness manifestations for elderly[15].

In the sequence the tests were used, the following items were tested:

1. Blood pressure: blood pressure was measured using an automatic sphygmomanometer (COPAL UA-251, Japan).

2. Grip strength: as a measure of muscular strength in the upper limbs, grip strength was measured using a hand dynamometer (Takei Kiki Kogyo TK 1201, Japan) in both the dominant and non-dominant hand. The best score out of three trials was recorded. Strength was expressed in kilogram force (kgf).
3. As a measure of the function of the large airways, the peak expiratory flow was measured (Wright, England). This is the maximum rate of flow of air expelled during a forced expiration. The maximum of three trials was reported.
4. In order to measure manual dexterity, an adapted version of the Minnesota test[16] was used. Forty stones on a board had to be replaced in the right order from one end of the board to the other end. The number of seconds needed was recorded.
5. Flexibility of hip and spine was measured using a sit-and-reach test. The maximum shift (cm) out of three trials was recorded.
6. Body weight and height were measured without shoes. Weight was assessed to the nearest 0.5 kg using a beam scale. Body height was measured to the nearest 0.5 cm. Body mass index (BMI) was calculated by dividing weight (kg) by the height (m) squared (kg/m^2).
7. In order to assess flexibility of the shoulder joint the shift of a handgrip on a rope was recorded when the subject moved her arms stretched from the frontal side over the head to the dorsal side of the body. During this movement the arms had to be kept as close as possible to each other. The shift of the handgrip on the rope and the measured arm length resulted in an angle α. A small value for α indicates a high flexibility. The best score of three trials was recorded.
8. Reaction time was scored as the time (ms) needed to press a button in respons to a light pulse. The median out of 15 trials was recorded.
9. Balance was measured with the subject standing on an imbalanced board. The number of seconds out of 30 that the board did not touch the ground was recorded. The best score of three trials was recorded.
10. Endurance for walking was measured in a walk test. Participants had to walk over a rectangle course of 25 m trajects at increasing velocity of 4, 5, 6, and 7 kilometres per hour for three minutes each. The number of 25 m trajects completed before drop-out was recorded.

Subjective health and fitness

In a questionnaire administered to the participants before the day of measurement the subjective rating of the participants was questioned for the various items to be measured (eg.endurance etc.). Participants had to rate themselves against women of the same age and health, and had to compare their functional abilities to ten years ago. Also, participants were asked to give themselves an evaluation between 1 (very poor) and 10 (excellent) for their self-perceived fitness. This scoring system is common in the Dutch scholar system.

Statistics

Data were analysed using the SAS Institute programs[17,18]. The results are expressed as mean values ± standard deviations (SD). One-way analysis of variance with Tukey correction for multiple comparisons was used to evaluate group effects. In case of non-normality analysis of variance was used based on ranks. Pearson correlation coefficients were calculated and analysis of covariance was used to adjust for differences in body weight between the groups. P values less than 0.05 are considered to indicate statistical significance.

Results

Habitual physical activity

Habitual physical activity of the participants did not change substantially compared to the first assessment by questionnaire.

Measurements of physical fitness.

Physical characteristics and results on the several tests of the test battery are summarized in Table 1. Group effects were found for body weight, BMI, and endurance and flexibility of hip and spine, differences between the highest and lowest activity group being statistically significant. Paired Student t-test revealed that grip strength in the dominant hand was 1.9 ± 2.7 kgf higher than in the non-dominant hand ($p<0.05$). For blood

Table 1. Characteristics and physical fitness of elderly women with different levels of habitual physical activity.

	sedentary $\bar{x} \pm SD$ (n=16)	moderate activety $\bar{x} \pm SD$ (n=15)	high activety $\bar{x} \pm SD$ (n=19)	P
Age (yrs)	72.1 ± 4.3	71.9 ± 3.9	70.8 ± 4.4	0.63
Height (cm)	163 ± 6	162 ± 7	162 ± 6	0.71
Weight (kg)	81 ± 11[a]	69 ± 13[b]	65 ± 9[b]	< 0.05
BMI (kg/m^2)	30.5 ± 5.3[a]	26.5 ± 4.4[b]	24.9 ± 3.8[b]	< 0.05
Blood pressure (mm Hg)				
Systolic	162 ± 27	154 ± 33	145 ± 20	0.17
Diastolic	87 ± 11	84 ± 14	78 ± 10	0.10
Lung function				
Peak-flow (l/min)	306 ± 117	353 ± 90	361 ± 92	0.25
Reaction time (ms)	247 ± 71	230 ± 33	235 ± 39	0.63
Grip strength (kgf)				
Dominant hand	26.9 ± 4.1	26.2 ± 4.4	25.6 ± 4.1	0.67
Non-dominant hand	25.6 ± 3.6	24.7 ± 4.6	22.9 ± 5.5	0.23
Flexibility				
Hip and spine (cm)	22.9 ± 8.9[a]	30.1 ± 11.6[a,b]	35.2 ± 8.7[b]	< 0.05
Shoulder (angle, °)	41.3 ± 3.9	40.8 ± 5.3	39.3 ± 7.2	0.56
Manual dexterity (s)	46.8 ± 4.2	46.1 ± 4.6	45.9 ± 5.0	0.42
Balance (s)	26 ± 2	25 ± 2	27 ± 2	0.06
Walking (25 m trajects)	12.1 ± 8.9[a]	22.0 ± 9.9[b]	26.6 ± 10.1[b]	< 0.05

P: P-value for group effect (analysis of variance).

a,b: groups with the same character are not significantly different from each other.

pressure (both systolic and diastolic), peak expiratory flow and balance the physically active group tended to show more favourable results, but differences were not statistically significant.

Subjective fitness and health

Subjective evaluation of fitness and health of the three groups of participants is visualised in Figure 1. In general a trend was seen in the subjective ratings of participants. The more active women reported better on almost all aspects of physical fitness. This group effect was most notable on flexibility, endurance and balance, aspects of fitness where results were discriminating in the test battery. The subjective evaluation of various items compared with abilities ten years ago did show no trend at all. The personal report mark for physical fitness was lower in the more inactive women. In general the subjective ratings appeared to follow measured data quite well.

Discussion

Measurement of physical fitness

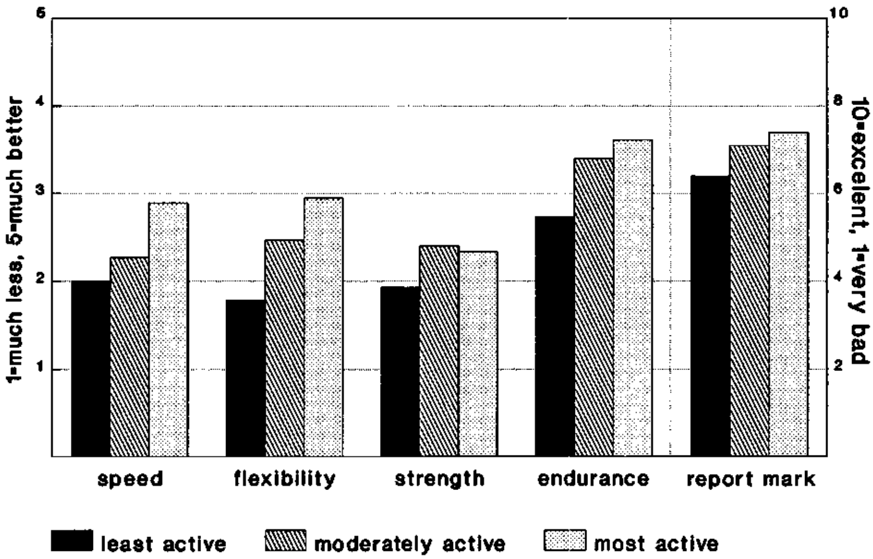
In this study, three groups of elderly women differing in physical activity assessed by questionnaire were tested for objective measures of physical fitness. To do this, tests were chosen that were safe for use in elderly people in a non-laboratory setting. In the literature the test most frequently used to measure physical fitness is the measurement of VO_{2max}[19-22]. VO_{2max} defines the functional limits of the cardiovascular system, which is only one aspect of fitness. As physical fitness should better be defined as a set of attributes that are either health- or skill-related[23], more different tests are required. Since actual measurement of VO_{2max} has risks when applied outside the laboratory, it was replaced by a more mild measure of endurance.

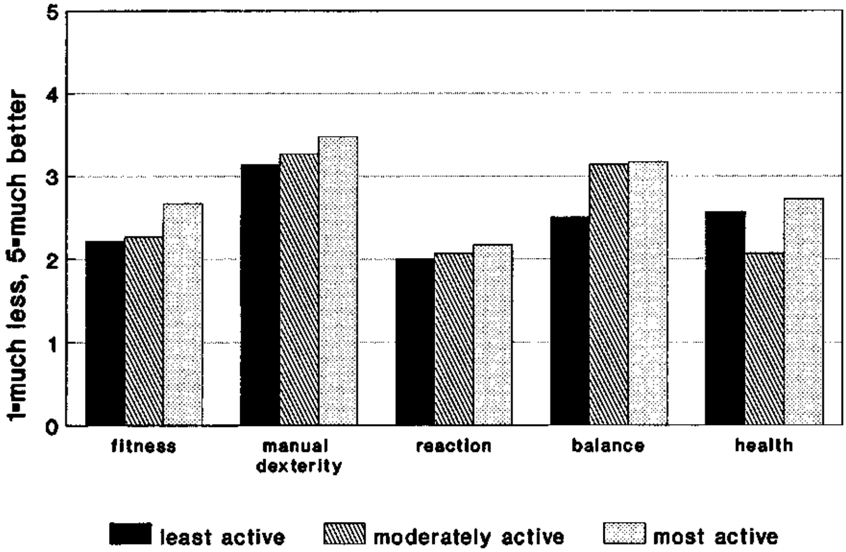
The tests revealed statistically significant differences between the three study groups on body weight and body mass index, flexibility of hip and spine, and endurance. Borderline significance was observed in diastolic blood pressure and balance. Due to small numbers and high variation between subjects, significance was not reached for several test items. A general trend was observed for better test results with higher levels of physical activity. However, as body weight differed markedly between the groups, this might have biased test results. A significant Pearson correlation coefficient between body weight and test results was found for diastolic and systolic pressure (0.30 and 0.29 respectively), flexibility of hip and spine (-0.36) and shoulder (0.28), grip strength (0.30 and 0.36 for the dominant and non-dominant hand respectively) and endurance (-0.40). This indicates that people with a higher body weight have higher blood pressures and grip strengths, whereas flexibility of shoulder and hip and spine is decreased as well as balance and endurance. Adjustment for body weight however did not affect most group differences. One exception was balance resulting in a statistically significant difference between the intermediate and high activity group.

Analysis of the walking test data were carried out with and without exclusion of participants who normally walk with the help of a stick (3 women in the most inactive group, 1 in the most active group). These women were not able to walk comfortably at a speed of 4 km per hour. Elimination resulted in better test results especially for the least active group, with a borderline significant difference between the groups ($p = 0.06$). Only four participants could walk the entire distance including the 7 km/hr speed, so the test discriminates well over the groups.

In general, most results were not unexpected. No between group difference was seen in grip strength, even after adjustment for the difference in body weight. Both body height and body weight were positively correlated to grip strength, which is in agreement with results from others[10]. Also, no significant group effect could be detected on flexibility of the shoulder joint. This was not expected as the active women do participate in swimming or gymnastics, and flexibility can be importantly improved with exercise training[14,24]. Probably, the activities of daily living performed by the other two groups sufficiently support the flexibility of the shoulder joint. A positive effect of physical activity on reaction time has been reported[11-13]. In these studies, the active (male) participants had exercise levels that were substantially higher than those of participants in the present study. In our study the difference in physical activity between the study groups is probably not sufficiently large to have an effect on reaction time. In a study from Rikli and Busch[9] older and younger women differing in habitual physical activity were compared as regards their reaction time, balance, sit and reach flexibility, shoulder flexibility, and grip strength. They revealed that the more active women were significantly better on all tests except on grip strength. No data were available on body weight. A lower blood pressure as a result from physical activity has been described in literature[25].

Figure 1. Subjective evaluation of various aspects of physical fitness of elderly women differing in habitual physical activity.





Subjective fitness and health

The subjective rating that elderly women gave to their own level of physical fitness appeared to be well associated to the values measured. Subjective health and fitness could give a satisfactory indication of objective fitness. More active elderly women value their general health better than less active women. The use of self-ratings of health among low-income elderly (n=3402) in the USA has shown significant correlations to measures of objective health status and were delineated to be of economical means of gaining information about the health of the elderly[26]. The subjective state of health was found to be correlated to 5 year survival in two different studies[27,28].

The report mark for subjective fitness was negatively correlated to body weight (r=-0.44). Kreitler and Kreitler (reference number 29, as cited by Shephard[30]), suggested that the inactivity in old age distorted body image, old people perceiving their bodies as heavier and broader than they actually were, and physical tasks as harder to perform. Distortion of body image, fear of activity, feelings of clumsiness and insecurity-augmented inactivity can create a vicious cycle, especially among older, institutionalised people. In the present study, the currently inactive women have markedly higher body weights than the active women[2], and also in retrospect weight differences were detected in the absence of differences in physical activity[4]. Therefore, a similar vicious circle might be present in the older, inactive women of our study.

Life satisfaction and quality of life are important issues in present-day gerontologic research. Therefore subjective fitness and health evaluation must be considered as valuable determinants that are well associated to physical fitness.

In conclusion the present study shows that elderly women with a higher habitual physical activity as assessed by questionnaire have better results on tests of endurance and flexibility of hip and spine. Subjective rating by the participants is in agreement with the measured differences in physical fitness.

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Chapter 6

Energy expenditure at rest and during standardised activities: a comparison between elderly and middle-aged women.

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Abstract

Age-specific data on energy costs of standardised activities are required to estimate energy expenditure in elderly subjects based on the factorial method. In 33 elderly women aged 72 ± 4 y (mean ± SD) and 30 middle-aged women (42 ± 1 y) energy expenditure was assessed by indirect calorimetry using a ventilated hood system. Energy expenditure was measured at rest, and during sitting, sitting with standardised arm activity and walking on a treadmill at 3 km/hr. Body composition was assessed using several methods, including densitometry. Energy expenditure at rest was 3.51 ± 0.36 kJ/min and 3.43 ± 0.38 kJ/min for the middle-aged and older women respectively, and did not differ significantly between the two groups. Energy expenditure during sitting and sitting with standardised arm activity did not differ significantly between the groups, although energy expenditure expressed as ratio to resting metabolic rate (physical activity ratio, PAR) of sitting with arm activity tended to be higher in the elderly. Walking energy expenditure was significantly higher in the elderly women (16.4 ± 3.7 kJ/min compared to 12.6 ± 2.3 kJ/min in the middle-aged women). The PAR of walking was 4.8 ± 0.8 in the elderly and 3.6 ± 0.5 in the middle-aged women. These data suggest that elderly women walk less efficiently. As PARs are frequently used to estimate daily energy expenditure, it is important to note that additional age-specific data might be required.

Introduction

Generally it is assumed that energy expenditure decreases with age. Total daily energy expenditure is the sum of basal metabolic rate (BMR), the postprandial rise in energy expenditure, and energy expended due to physical activity[1]. The lower total energy expenditure observed in the elderly is ascribed primarily to a lower BMR as is observed in several cross-sectional and some longitudinal studies[2-8]. A decrease in BMR may be the result of changes in body composition, especially the reduction in active cell mass, but could also be caused by ageing per se[3,9]. Secondly, a decline in total daily energy expenditure may result from reduced physical activity. This may cause a further decrease

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in muscle mass, but reduced physical activity may also be in itself a result of reduced muscle mass (physical impairments)[6]. However, energy expended during physical activity might also change with age due to an altered mechanical efficiency or body weight[10]. The influence of ageing on the dietary induced thermogenesis is still subject to debate[1,7,8,11]. It is often assumed that the energy intake of elderly exceeds expenditure resulting in the generally observed weight gain with ageing[12].

Data on energy expenditure at rest and during several activities are a useful tool to estimate daily energy expenditure and energy requirements. Several tables are available with data on energy costs of activities, often expressed as ratio to BMR (physical activity ratio, PAR)[13-15]. In elderly people data on energy expenditure are limited, especially data on energy expenditure in situations other than rest, and they usually involve only male subjects[6,8-11].

In Western societies the most prevalent activities in the elderly are lying, sitting with or without arm activity, and walking. In the present study, energy expenditure was measured at rest, during sitting with and without standardised arm activity and during treadmill walking at a fixed speed. The measurements were performed in elderly women. To evaluate the need for age-specific reference data, a group of middle-aged women was included for comparison. To cope with the problems of assessment of body composition in the elderly[16-18] several methods were used simultaneously.

Subjects and methods

Subjects

Thirty-three elderly women (aged 72 ± 4 y, mean ± SD) and thirty middle-aged women (aged 42 ± 1 y) participated in this study. For a previous study the elderly women had been recruited based on physical activity level measured by questionnaire[19]. Women in the highest and lowest tertile of the physical activity distribution participated in a study on nutritional condition and weight history study[20,21]. For the present study, the elderly women were originating from all levels of physical activity. The thirty middle-aged women participated ten years ago as a control group in a study on food consumption.

Subjects were apparently healthy and did not use any medication known to influence energy metabolism. All subjects lived in the city of Wageningen and surroundings. The protocol of the study was approved by the Medical Ethical Committee of the Department of Human Nutrition. All women gave their informed consent.

Study design

During a home visit subjects were prepared for the study and equipment by an oral explanation and the presentation of photographs. To avoid effects of the menstrual cycle on resting metabolic rate (RMR), measurements in the middle-aged women were performed in the follicular phase of the menstrual cycle[22,23]. After an overnight fast participants were transported to the department by car. They were instructed to avoid any strenuous physical activity during the morning before the measurements. After at least 10 minutes rest RMR was measured during 45 minutes at standardised conditions (12-14 hours post-absorptive state, supine position, awake, with environmental temperature of 20-22 ° C, watching video tapes). As no definite evidence of complete physical or emotional rest could be given, required for measurement of basal metabolic rate[24], the expression 'resting metabolic rate' is used. Measurement of RMR was followed by assessment of energy expenditure sitting on a kitchen chair for 20 minutes, and sitting with standardised arm movements for 15 minutes. Standardised arm activity was performed by moving a ball over a 30 cm distance horizontally, in front of the subjects at hip level, with a speed of 50 movements per minute, 7.5 minutes with each hand. Sitting measurements were followed by walking at a fixed speed of 3 km per hour on a treadmill (Enraf Nonius, Delft, The Netherlands) for 10 minutes, being a comfortable speed for elderly subjects[25]. All measurements were preceded by a period of at least 10 minutes of the same activity, long enough to achieve a steady state in gas exchanges. Between measurement of RMR and the first sitting measurements a small breakfast had to be provided to all subjects to enable the subjects (especially the elderly) to complete the rest of the protocol.

Energy expenditure

Energy expenditure was assessed by indirect calorimetry using a ventilated-hood system as described in detail by Weststrate *et al*[26]. A transparent perspex ventilated hood was placed over the subjects head and secured around the neck. The airflow circulating through the hood was measured by a thermal mass flowmeter (Model 5821N, Brooks, Veenendaal, The Netherlands). Sampling of the hoods outlet air was performed continuously. Samples were analysed for oxygen by a paramagnetic O_2 analyser (Servomex, 1100, Zoetermeer, The Netherlands) and carbondioxide by an infrared CO_2 analyser (Servomex Series 1400, Zoetermeer, The Netherlands). Analysers were calibrated before the session using dried gas mixtures with known O_2 and CO_2 contents. Measurement of flow rate and O_2 and CO_2 concentrations were integrated over 2-minute intervals. Air was transported through the hood at 38 l/min at rest, and during sitting and sitting with arm activity. During walking air flow was increased to 130 l/min. Energy expenditure was calculated from consumed O_2 and expired CO_2 using the equations described by Jéquier *et al*[27]. The Haldane correction was used to correct for differences in volumes of inflowing and outflowing air[27]. Movements of the subjects at rest were recorded using a load cell (TKA-200A, Tokyo Sokki Kenkyujo Co Ltd, Tokyo, Japan) under the bed. Data of RMR with registered movement were deleted from analyses. Periodical ethanol combustion was used as a reference to which all measurements were standardised.

Data on energy expenditure are expressed as kJ/min. Energy expenditure of activities other than resting are expressed as ratio to RMR (physical activity ratio, PAR) as well.

Body composition

Participants were dressed in swimming clothes. Body weight was measured to the nearest 0.05 kg (Berkel ED-60T, Rotterdam, The Netherlands) after voiding. Body height was assessed to the nearest 1 mm using a wall-mounted device and the Body Mass Index (BMI, kg/m^2) was calculated by dividing body weight (kg) by body height (m) squared. Fat-free mass (FFM) was calculated from BMI using an age and fat specific prediction equation[28]. Waist circumference was measured midway between the lower rib margin and the iliac crest; hip circumference was measured at trochanter level. The ratio of waist to hip circumference was calculated.

Skinfold thicknesses were measured in triplicate to the nearest 1 mm using a Holtain calliper (Holtain, Crymmych, UK) at triceps, biceps, subscapular and supra-iliac sites. Body density was calculated from the sum of four skinfolds using the prediction equations of Durnin and Womersley[29].

Biolectrical Impedance was measured to the nearest 1 Ω at 800 mA and 50 kHz with an RJL impedance analyser (type BIA101, RJL Systems, Detroit MI, USA) with electrode attachments at left hand and foot as described by Lukaski *et al*[31]. Fat free-mass from bio-electrical impedance was calculated using the fat-specific prediction equations from Segal *et al*[32].

Body weight under water was measured to the nearest 0.05 kg (Sartorius 3826 MP81, Göttingen, Germany). Body density was calculated from weight in air and weight under water, after correction for simultaneously measured residual lung volume by helium dilution.

Body fat percentage was calculated using Siri's equation[30].

To evaluate the impact of body composition on energy expenditure, data obtained using densitometry are considered as criterion method.

Statistics

Data were analysed using the SAS Institute programs[33,34]. The results are expressed as mean values ± standard deviations (SD). Student's unpaired two-sided *t*-test was used to evaluate differences in continuous variables between the two age groups. One-way analysis of variance with Tuckey correction for multiple comparisons was used to evaluate differences in body composition methods within the groups. Pearson's correlation coefficients are used to assess the relationship between energy expenditure and physical characteristics. P values less than 0.05 are considered to indicate statistical significance.

Results

Subjects

All subjects completed the measurements of energy expenditure at rest and during sitting on a chair. Measurement of energy expenditure during sitting with arm movements was not possible in two elderly women due to muscular problems, measurements during walking caused physical problems in three other elderly women. All subjects completed anthropometric and bioelectrical impedance measurements. Five elderly women and one middle-aged woman did not complete under water weighing, due to fear, shortness of breath or hyperventilation.

Table 1. Physical characteristics of middle-aged and elderly women (mean ± SD).

	middle-aged (n=30)	elderly (n=33)
Age (y)	41.7 ± 0.8	71.8 ± 3.9*
Weight (kg)	65.3 ± 9.9	68.1 ± 9.3
Height (m)	1.68 ± 0.07	1.62 ± 0.06*
BMI (kg/m^2)	23.1 ± 3.2	26.1 ± 3.2*
waist/hip ratio	0.81 ± 0.05	0.87 ± 0.06*
BF densitometry (%)	32.5 ± 5.9†	45.5 ± 7.0‡*
FM densitometry (kg)	21.7 ± 6.6†	31.4 ± 7.3‡*
FFM densitometry (kg)	43.8 ± 4.9†	37.0 ± 5.5‡*
FFM impedance (kg)	44.7 ± 4.4	41.5 ± 4.0*
FFM skinfolds (kg)	43.8 ± 5.1	44.0 ± 4.6
FFM BMI (kg)	44.1 ± 4.5	38.9 ± 4.0*

* p-value of difference between elderly and middle-aged subjects < 0.05

† n=29, ‡ n=28

BF: Body fat percentage, FFM: fat-free mass, FM: fat mass

Body composition

Physical characteristics of the elderly and middle-aged women are presented in Table 1. The elderly women had a significantly lower body height than the middle-aged women. Body weight was slightly higher in the elderly women, but the difference was not statistically significant. BMI and percentage of body fat were higher in the elderly women. FFM based on densitometry, bioelectrical impedance and BMI was lower in the elderly women, whereas no difference could be detected when FFM was calculated from skinfolds. Within the group of elderly women, FFM derived from densitometry was lower than FFM from skinfolds and impedance, but not different from FFM derived from BMI. Within the group of middle-aged women, no differences were observed in FFM as determined by the several methods.

Table 2. Energy expenditure at rest and during standardised activities of middle-aged and elderly women (mean ± SD).

	middle-aged (n=30)	elderly (n=33)	P
RMR (kJ/min)	3.51 ± 0.36	3.43 ± 0.38	0.39
Sitting (kJ/min)	4.60 ± 0.42	4.42 ± 0.49	0.13
+ arm activity (kJ/min)	5.11 ± 0.53	5.18 ± 0.56†	0.61
Walking (kJ/min)	12.62 ± 2.31	16.41 ± 3.71‡	< 0.05
PAR			
Sitting	1.31 ± 0.08	1.29 ± 0.09	0.29
+ arm activity	1.46 ± 0.09	1.51 ± 0.11†	0.06
Walking	3.59 ± 0.49	4.78 ± 0.80‡	< 0.05
RMR/FFM (J/min.kg)	81 ± 6§	94 ± 10‖	< 0.05

PAR: physical activity ratio (energy expended/energy at rest).

FFM: fat-free mass from densitometry.

* p-value of the difference between elderly and middle-aged subjects

† n=31; ‡ n=30; § n =29; ‖ n=28

Table 3. Pearson correlation coefficients between energy expenditure and weight, fat-free mass (FFM) and fat mass (FM) in middle-aged and elderly women.

	middle-aged (n=30)	elderly (n=33)
RMR		
Weight	0.71	0.59
FFM	0.76†	0.68‡
FM	0.53†	0.28‡ (NS)
Walking (kJ/min)		
Weight	0.78	0.61§
FFM	0.67†	0.46‖
FM	0.67†	0.54‖
PAR Walking		
Weight	0.50	0.38§
FFM	0.36† (NS)	0.19‖ (NS)
FM	0.50†	0.52‖

NS: $P > 0.05$. Other correlation coefficients are statistically significant.

PAR: physical activity ratio (energy expended/energy at rest).

FFM: fat-free mass from densitometry

FM: fat mass from densitometry

† n=29; ‡ n=28; § n=30; ‖ n=25

Table 4. Fat-free mass derived from densitometry using Siri's equation[30], and corrections made for age[35] and body fat[36].

	middle-aged (n=29)	elderly (n=28)
FFM Siri, (kg)	43.8 ± 4.9	37.0 ± 5.5*
FFM age corrected, (kg)	43.8 ± 4.9	38.1 ± 5.7*
FFM age and fat corrected, (kg)	44.4 ± 5.0	39.6 ± 5.6*
RMR/FFM Siri, (J/min.kg)	81 ± 6	94 ± 10*
RMR/FFM age corrected, (J/min.kg)	81 ± 6	91 ± 9*
RMR/FFM age and fat corrected, (J/min.kg)	80 ± 6	88 ± 8*

* p-value of difference between elderly and middle-aged subjects < 0.05

Energy expenditure

Data on energy expenditure and PARs are presented in Table 2. No difference was observed between the two groups in energy expended at rest. Energy expenditure expressed per kg FFM as obtained using either of the body composition methods revealed a significantly higher energy expenditure per unit of FFM in the elderly women, except when skinfolds were used to assess body composition. RMR was highly correlated with FFM and body weight (Table 3).

Energy costs of sitting without movements were not significantly different between the groups, whereas energy expenditure during sitting with arm activity tended to be higher in the elderly when expressed as PAR (Table 2).

Energy expenditure during walking at 3 km/hr speed showed higher levels in elderly women, both expressed in kJ/min and as expressed as PAR. Energy expenditure during walking correlated most strongly with body weight in both elderly and middle-aged women, whereas the PAR correlated highest with fat mass (FM) (Table 3). In Figure 1 and 2 the individual energy costs of walking of the middle-aged and elderly women are presented, also expressed per kg of body weight. The energy costs are sorted on increasing level, thereby illustrating the differences in energy costs between the two age-groups.

Discussion

This study was performed to investigate the energy expenditure of elderly women at rest and during physical activities. Data on middle-aged women were collected as reference data. In most studies comparing elderly with younger subjects, the younger groups are students with life styles that generally differ importantly from elderly people[8-11]. It is clear that differences between these groups will exist in many ways. In the present study, a control group of middle-aged women with a life style more comparable to the elderly women was used.

Body composition

Body weight and height in both age groups were not different from age-specific reference data of the Dutch population[37,38].

The assessment of body composition is always subject to assumptions that have to be made, dependent on the method to be used. Each of these assumptions is of debate for use in the elderly[39]. To overcome this problem in the present study body composition was assessed using several methods.

Comparisons between the two age groups revealed that fat-free mass was lower in the elderly women, with the exception of fat-free mass assessed from skinfolds. The criterion method of densitometry is subject to discussion where the conversion of density to FFM takes place using the traditional equations of Siri[30]. As bone mineral decreases and the water content of FFM changes, the density of FFM will change. However, the size of this change is difficult to predict and may vary substantially between subjects. A theoretical adaption of the Siri equation for age-effects is discussed by Deurenberg *et al*[35]. Additionally, debate is going on whether increased FM influences the water content of FFM. Again, theoretical adaptations of Siri's equation for level of fatness can be made[36]. Application of these adaptations results in changes as demonstrated in Table 4. The use of the corrections for age and body fat leads to a higher estimate of fat-free mass, especially in the older group.

With ageing internal body fat accumulates whereas subcutaneous fat deposits more on the trunk than on the limbs[40]. The higher waist/hip ratio in the elderly compared to the middle-aged women illustrates the increased accumulation of fat in the abdomen. Skinfolds only give an indication of subcutaneous fat, and decreased skin elasticity and compressibility further makes the use of skinfolds in elderly subjects less reliable[41]. The prediction equations of Durnin and Womersley for elderly women are based on data of 37 women aged 50 to 68 years and therefore may be less valid for the present elderly population, which was aged 67 to 78 years[29]. Analysis of body impedance was performed using the fat-specific prediction equations of Segal *et al*[32]. However, subjects in the latter study were aged 17 to 62 years, also not covering the age-range in the present study.

Furthermore in the study of Segal *et al*, densitometry was used as a criterion method using Siri's equation. As mentioned before, the use of Siri's equation in the elderly is subject to debate. Although bioelectrical impedance is a rapid and noninvasive method, its usefulness is again completely dependent on the assumptions made. Applying prediction equations generated in our laboratory[42] based on age- and fat specific adaptations of Siri's equation, reveals that FFM from bioelectrical impedance is 43.6 ± 5.4 and 39.0 ± 4.9 kg for middle-aged and elderly subjects respectively. These data are not different from densitometry using age- and fat specific corrections[35,36].

Energy expenditure

RMR was not different between the elderly and middle-aged women. This is in contrast with several publications in literature. In cross-sectional studies generally a lower RMR is found in older subjects, although the difference is not always linear with age[4,7]. Keys *et al* found that in men the decrease above age 50 was much less than the decline between age 20 and 40 years[3]. When RMR is expressed per kg of FFM, age differences tend to disappear, as FFM is a measure of active cell mass[2-7]. However, the use of the ratio of RMR to FFM is subject to extensive discussions as the relationship between RMR and FFM is a line with a non-zero intercept[12,43]. Nevertheless, most studies use the ratio to assess energy expended per kg of FFM. In a few studies it is reported that RMR per kg of FFM is lower in the elderly[8,9,43]. On the contrary in the present study, RMR expressed per kg of fat-free mass as assessed by densitometry revealed to be higher in elderly than in middle-aged subjects. An explanation could be that the composition of fat-free mass in elderly people is different from the fat-free mass in middle-aged people. Fat-free mass is not homogeneous but consists of components that vary considerably in metabolic rate[44]. With ageing, the various parts of FFM changes in different ways. Postmortem autopsies reveal that organ sizes of liver, spleen, kidneys and brain atrophy with ageing whereas lungs and heart hypertrophy[45]. However, postmortem analyses do not answer the question whether the subject died due to a reason associated with the organ size. Skeletal muscle mass at age 70 has lost 40% of its peak weight in early life[16]. When the proportion of low metabolically active muscle mass in the FFM is lower of

Figure 1. Individual energy costs of walking on a treadmill of 30 middle-aged (□) and 30 elderly (▨) women sorted by increasing level.

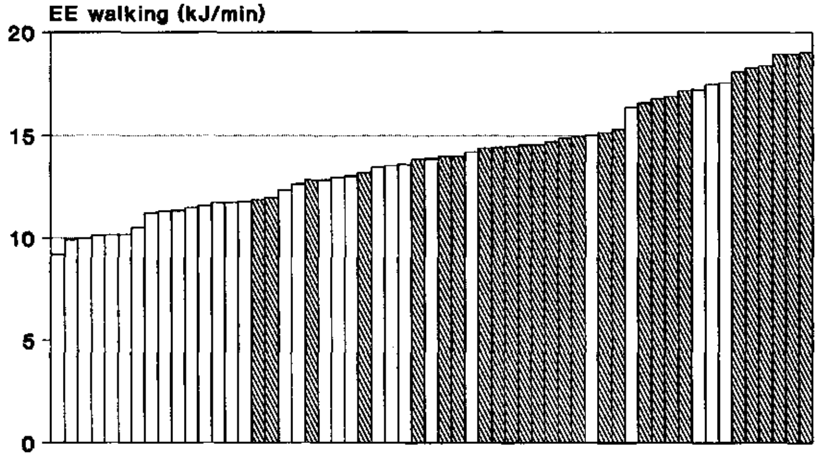
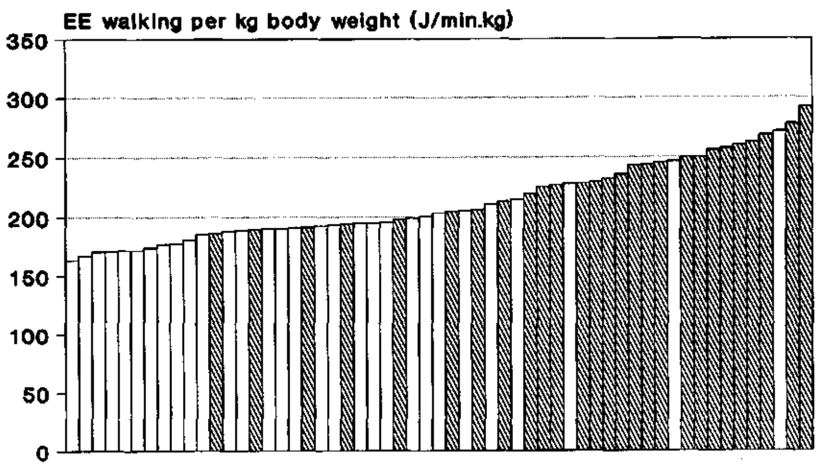


Figure 2. Individual energy costs of walking on a treadmill of 30 middle-aged (□) and 30 elderly (▨) women sorted by increasing level, expressed per kg of body weight.



elderly people compared to younger subjects, FFM will have a relatively higher metabolic rate. Similarly it has been shown that the FFM of men is metabolically less active than FFM of women, when expressed per kg. Tzankoff and Morris[4] assume that the combined mass of vital organs is not likely to change much with age. As discussed before, the assessment of FFM in elderly is not free of debate itself. Using the age- and fat specific adaption of Deurenberg *et al*[35,36], fat-free mass and RMR per kg fat-free mass are calculated as in Table 4. Although the differences between the groups became smaller after correction, differences remained statistically significant.

Comparing energy expenditure during sitting and sitting with arm activity revealed no differences between the two groups, although expressed as PAR the energy expenditure with arm activity tended to be higher in the elderly. However, because a small breakfast had to be given for ethical and practical reasons, a small increase due to dietary induced thermogenesis can be expected during sitting and sitting with arm activity. Therefore, no conclusion can be drawn from this part of the protocol. The meal was given both to the elderly women as well as to the middle-aged women. This suggests that important differences between the groups would have been detected, if they existed. The results in the present study are in agreement with other studies where energy expended during sitting is compared to energy expended at rest[6].

Energy expenditure at standardised walking on a treadmill showed significantly higher energy costs in elderly women than in the middle-aged group. As visualised in Figure 1 and 2, the difference between the age-groups is very consistent. Comparing young and elderly men, Durnin and Mikulicic[10] also found no differences in sitting with light arm activity but did find increased energy costs of elderly men during walking. It was postulated that elderly men seemed to have similar degrees of mechanical efficiency compared to younger men if exercise did not involve much gross body movements, but the larger muscle groups and the balance required by walking resulted in a marked decrease in efficiency and an increased energy expenditure, presumably due to general diminution of neuromuscular coordination[10]. Generally, elderly people walking at a free chosen speed have a reduced stride length and reduced step frequency compared to middle-aged people[46]. Restriction to a fixed speed results in more steps to cover the same distance for the elderly. As energy expenditure during walking is a resultant of step frequency and energy expended per step, this may result in increased energy costs of walking[47]. Also a general decrease in efficiency will lead to an further increase in energy expenditure. Pearce *et al*[48] found a higher energy expenditure of walking on a treadmill in elderly compared to younger subjects, but could not detect a difference when subjects were walking on a floor. They postulated that treadmill walking requires additional balance problems in the elderly. It is clear that more data on both treadmill walking and walking on a floor in both elderly and younger subjects are required to further evaluate the need for age-specific data.

In conclusion, the present study shows that energy expenditure at rest and during activities can differ between elderly and middle-aged women. As physical activity ratios generally are used to estimate daily energy expenditure and requirements, more age-dependent data are needed.

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Chapter 7

General discussion.

Introduction

With ageing, a generally observed feature is the decline in physical activity. This is a consequence of a wide variety of reasons, including physical impairments and cultural habits to obtain a quiet end of live. To maintain a stable body weight, energy consumption must be in balance with energy expenditure. A reduced physical activity level implies a decreased energy requirement. As requirements of most micronutrients are not changed with increasing age, an appropriate nutrient density is required both to keep a stable body weight and to provide a sufficient level of micronutrient intake. The reduction in energy expenditure in the elderly can result in either obesity due to a positive energy balance or the occurrence of nutrient deficiencies owing to an inadequate nutrient density. The maintenance of an appropriate level of expenditure might prevent these problems. In the present thesis a step-by-step approach was used to evaluate the relationship between physical activity, food consumption and nutritional status. Each part was a rational follow-up of a question raised by former parts of the study.

Cross-sectional comparison of physically active and sedentary elderly women

To investigate the existence of one of the unfavourable pathways mentioned before, two groups of elderly women differing in habitual physical activity were compared *(chapter 3)*. A cross-sectional design was chosen to study food consumption and nutritional status in women with commonly occurring habitual physical activity levels. Although a longitudinal design would have had the potential to give more information about cause and effect and would have lowered confounding, it was not appropriate for the present study. A cross-sectional evaluation is required before experimental physical activity intervention would be legitimate. To avoid confounding by disease as much as possible, a criterion was that the physical activity level of the subjects was not affected by any chronic disease. As it might appear that many elderly people are not active because it is unpleasant, uncomfortable, or even painful for them to move around[1], subjective health was used as a selection criterion to prevent the possibility of recruiting tired and lonesome elderly particularly in the sedentary group. After recruitment apparently healthy subjects were selected based on a medical questionnaire. Physical activity levels of the participants had to be as different as possible, without the specific recruitment of master athletes, to make results deducible to the general ageing population.

To assess physical activity, an appropriate method was not directly available. Methods that are not designed or validated for use in elderly individuals are less reliable because of specific problems arising with ageing. These problems include impaired physical functioning (eye-sight, short-term memory, writing difficulties) and changing activity pattern (loss of occupational activity, increase in leisure time). An existing questionnaire was adapted for use in the elderly and tested for reproducibility and validity *(chapter 2)*. As age-dependent data on energy expenditure during most prevalent activities in the elderly were only marginally available though needed, data obtained from younger people were used. The questionnaire proved to be suitable for classification of elderly men and women in three levels of physical activity. The urgent need for data on energy expenditure during common activities in the elderly could be overcome in a later phase of the study *(chapter 6)*.

Comparison of food consumption and nutritional status revealed that a sedentary life style goes hand in hand with a higher body weight. No remarkable differences were found on either food consumption or blood parameters, although the women with an active life style tended to have a more favourable food consumption pattern as compared with the Dutch Dietary Guidelines[2]. It is likely that the numbers of women in the study were too small to reach statistical significance on most variables studied. Also, the difference in physical activity level could be too small to find clear effects. However, the results indicate that in healthy elderly women nutritional deficiencies are not likely to be a major problem. It is possible though, that by selecting subjects that were not reduced in physical activity due to any chronic disease or with an unsatisfactory subjective health, the people with severe deficiencies were missed. As has been stated in the introduction *(chapter 1)*, in two other studies in The Netherlands aiming for a representative sample of healthy elderly people also no nutritional deficiencies were detected. Furthermore we have to realise that a biochemically detectable deficiency will not directly result in impaired physical functioning. Even if we missed the subjects with severe deficiencies consequently, and low nutrient intakes were prevalent, biochemical deficiencies would have been detected in the sedentary group. Nevertheless, a nutritional disorder was detected which could be related to physical activity level. With an equal body height, the body weight of sedentary women showed to be 12 kg higher than that from the physically active women. This could be a result of reduced physical activity with ageing without a sufficient reduction in energy intake. Due to the cross-sectional study design, no conclusions could be drawn about cause and effect. The higher body weight also could be a cause rather than a result of lower physical activity. Overweighed people generally have more difficulties with moving around. Also, it has been shown that in old age obesity can cause a sense of shame and thus influence confrontations with other people[3].

The comparison of physically active and sedentary elderly women induced two new questions for further investigation:

1. Is the low physical activity level a cause or an effect of observed higher body weight *(chapter 4)*? The answer to this question is extremely important to evaluate the importance of the conclusion that sedentary elderly women have a higher body weight.
2. Apart from a difference in body weight, do healthy elderly women with different habitual physical activity differ in other aspects of objective or subjective physical fitness *(chapter 5)*? The answer to this question could give more information about the quality of life in association with activity level.

Weight history and former physical activity

As cross-sectional studies in principle cannot evaluate cause-effect relationships, the problem whether low physical activity was a cause or a result from a high body weight could not be solved from the data collected. To resolve this problem methods were developed both to investigate physical activity and body weight in retrospective view *(chapter 4)*. The assessment of previous physical activity proved to be extremely difficult as validation is hardly possible. A very detailed questionnaire was developed which was thoroughly discussed through by panels of elderly women. Using in-depth interviews and focus group discussions it was ascertained that no important items were missed regarding physical activity at different ages. Through discussions with the elderly evaluating the questionnaire it was concluded that important differences in former physical activity could be detected using this questionnaire although objective validation was not possible. The retrospective assessment of body weight and height was complex, as no measurement data were available at former ages in life. The use of self-reported weight and height earlier in life as only measure was not regarded to be legitimate, as women from the generation of study have become used to the use of scales only recently. Several methods were used to estimate obesity level. New methods were developed and others adapted to assess body weight and height retrospectively. The adherence to a few retrospective "points of measurement" on strictly defined ages in life resulted in data that could well be compared between the groups. The currently sedentary women showed to have a higher "obesity level" starting in young adulthood as resulting from the "weight index", clothing measurements, self-reported weight and height, and scores on old photographs. Differences in former physical activity could not be detected. It was speculated that the current difference in physical activity was only present in old age. This could be a result of the higher body weight: the effort of breathing and moving could further discourage exercise[4]. In conclusion the present day higher body weight is not only caused by an inadequate adaptation of energy intake to lower physical activity. As no explicit data on body weight on different ages are available, it is not clear whether an increase in body weight in the sedentary individuals still takes place. It is well conceivable that the current low physical activity results in a further increase in body weight as compared to women that maintain a high level of physical activity. This way, these women could have entered a vicious circle of increasing body weight and subsequent further decrease in physical activity. It is important, therefore, that development of body weight should be checked regularly. More detailed data on energy expenditure and energy balance would be required.

Health risks associated with obesity in old age are less clear for old people than for younger people[5-7]. Regarding the problem of osteoporosis, a higher body weight even could be encouraged[8]. However, as obesity is often linked to loneliness and physical impairments such as breathlessness and osteoarthritis, the decreased physical activity in these women still should be signalled. It might be that for obese women, the threshold to participate in (age-directed) physical activity is higher than for women with a lower body weight.

Physical fitness

To evaluate the existence of differences in both objective and subjective fitness associated with physical activity, subjects were examined on a battery of fitness tests. The battery was especially developed to assess physical fitness in large groups of people, requiring as little technical assistance as possible. The battery therefore did not include a VO_{2max} measurement, being the method used most abundantly to assess physical fitness, but requiring medical assistance. However, VO_{2max} measurement only assesses one aspect of physical fitness, whereas the independency and quality of life is dependent on many other abilities to move. The use of tests that can be used by a large public has the advantage that no strict additional selection criteria are required for participation. This might lead to a further selection to extremely fit individuals. Motivation will be better in tests that do not require complete exhaustion. The most active group had better results both on endurance capacity and flexibility of hip and spine. The assessment of subjective health and fitness shows that on group level the subjective fitness is better in the most physically active group *(chapter 5)*.

Energy expenditure

In the present study differences in physical activity were more important than actual differences in energy expenditure. However, for more research about the etiology of weight gain with ageing, detailed data on energy expenditure are required. To deduce total daily energy expenditure, the use of tables of energy expenditure data is wide spread. Physical activity ratios often are used instead of gross energy expenditure, as they are presumed to be less dependent on body size or body composition. The comparison of energy expenditure in rest, sitting, sitting with arm activity and walking on a treadmill revealed that age differences are important, especially in walking *(chapter 6)*. This indicates that physical activity ratios should be used with caution within different age-groups.

The higher energy expenditure during walking in the elderly appeared to be associated with body weight. It is likely that the efficiency of walking is influenced by physical activity level or physical fitness. Unfortunately, only a few of the original group of sedentary women participated in the measurements of energy expenditure. Therefore, no separate analyses could be made based on physical activity level.
The gradual increase in body weight observed with ageing will result in a higher energy expenditure for any type and amount of physical activity[1]. As this might be experienced as being unpleasant, this might be one explanation to the potential decrease in physical activity of elderly women with a high body weight.

Consequences of the main findings of this study for nutrition counselling in the elderly

A low physical activity was not associated with nutrient deficiencies, both in intake data and biochemical assessments. The higher body weight observed in less active elderly women was not only a result from their current low physical activity, as it was shown that this group had higher body weights already earlier in life. The speculation that women with higher body weights tend to become less active as they age, more than the slimmer women do, gives rise to a potential vicious circle of further weight gain and further decreased physical activity. Therefore, more attention should be paid to those elderly women with high body weights. Body weights should be evaluated regularly to identify those elderly women at risk.
In general, physical activity should be encouraged because of the many preferable aspects associated with it on various levels. However, stimulation to a more active life style should be encompanied by thorough information regarding risks associated with unsupervised sudden increase in daily physical activity. An increase in energy expenditure with the purpose of improving appetite and nutrient intake can best be achieved by prolonging the time spent in light to moderate activities such as walking, cycling, playing golf, gymnastics, or dancing. These types of exercises allow the expenditure of about 16 to 20 kJ per minute[9,10] and are least likely to produce injury.

Consequences of the main findings of this study for future studies

Methodology

In this thesis methodological problems were solved that are encountered when a study is performed on the elderly. A physical activity questionnaire was developed and validated for epidemiological use *(chapter 2)*. The study on physical and subjective fitness in subjects recruited based on this questionnaire gave an extra validation *(chapter 5)*. As subjective fitness correlated well with objective measurements, they could be used more often to assess specific difficulties with physical fitness.

An attempt was made to collect retrospective data on physical activity earlier in life. The concept of using fixed ages connected to life events as far as we know has never been used before. The assessment of overweight status earlier in life was elucidated using several methods together, with a more or less objective validation by the use of photographs. Elderly women in the Netherlands generally are in the possession of such photographs and willing to show them.

Comparing energy expenditure at different physical activities revealed that physical activity ratios, often used to estimate daily energy expenditure, can be age-dependent and caution must be taken to use them. More data are required.

Physical activity and nutritional status

From this thesis it can be concluded that the generally observed decline in physical activity with ageing probably does not lead to nutritional deficiencies in healthy elderly women. A higher body weight in sedentary women has been prevalent already in young adult age, but might be still increasing with the present low activity level. The crude estimation of former activity level indicates that former physical activity was not different in the two groups. Probably, women with a higher body weight are more likely to diminish activity in old age than women with a lower body weight. In future studies declines in physical activity should be followed longitudinally to further evaluate the occurrence of vicious circles to lesser physical activity.

Conclusions and recommendations

The reduction in physical activity with ageing generally does not lead to major nutritional problems such as micronutrient deficiencies. The higher body weight found in sedentary elderly women is not only caused by present-day low physical activity. A higher body weight possibly increases the threshold for participation in physical activity in elderly women. Physically active women have a better endurance and hip flexibility than the sedentary women. Subjective health is better and a useful tool in the assessment of physical fitness. Age-dependent data on energy expenditure at standardised activities can be importantly different at different ages. The use of age-independent physical activity ratios is subject to debate. Additional data are required to accurately assess daily energy expenditure by factorial method in the elderly.

As physical activity appears to postpone several age-related functional changes, the participation in the elderly should be encouraged. Apart from increasing energy expenditure, many social, psychological, physiological and nutritional benefits can be attributed to physical activity, such as increased social contacts, mobility, bone density, improved feelings of well-being, and so forth[1]. Special attention should be paid to sedentary elderly with a high body weight, to assess their reasons for not participating in physical activity.

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Summary

A generally observed phenomenon with aging is a decrease in physical activity. The resulting reduction in energy expenditure requires an adaptation of the dietary energy intake. The present study was meant to investigate the nutritional risks of physical inactivity in older women, such as nutritional deficiencies or obesity. Therefore, the relationship between physical activity, dietary intake and nutritional status has been evaluated in groups of elderly women differing in level of habitual physical activity.

At the start of the study an existing physical activity questionnaire was adapted and tested for use in elderly people and showed to be sufficiently reproducible and valid to classify elderly people in levels of physical activity *(chapter 2)*.

The physical activity questionnaire and a general questionnaire were administered to 140 independently living elderly female volunteers. Recruitment initially was based on a good self-reported health and either a high or a low habitual physical activity level. Based on questionnaire results, the most and least active thirty out of 100 apparently healthy, elderly women aged 63 to 80 years were invited for further participation in the study. Twenty five active and 23 sedentary women actually took part (mean age 71 years). Food consumption was assessed based on an adapted dietary history method. Body composition and biochemical parameters in the blood were measured to assess nutritional status. The most striking result of the comparison of the two groups was a difference in body weight with equal body height of 12 kg, the sedentary group outweighing the physically active group *(chapter 3)*.

The observed weight difference was the basis for the next study, which included the retrospective analysis of body weight and physical activity in the same participants. Data on body weight and height were collected for four different ages (12, 25, 40 and 55 years), each related to important life events. Level of overweight was estimated using several methods. A "weight index" was developed consisting of subjective identification of the participants with a front silhouette and a side-view silhouette, in combination with a rating of overweight level compared to contemporaries. Also, at each of the selected ages, data were collected on self-reported weights and heights and clothing measures. As a more objective measure, old photographs were scored that showed body posture at different ages. Former physical activity level was estimated using a detailed

questionnaire. Results indicated that a difference in level of obesity between the groups existed since the age of 25, using each of the methods of assessment. A difference in former physical activity could not be detected. The current weight difference as observed in the study therefore could not simply be the result from a current difference in physical activity. It was speculated that heavier women tend to loose interest in physical activity when they age, more than slimmer women do. This could be induced by physical or social problems associated with overweight *(chapter 4)*.

The observed weight difference between the activity groups led to the question whether other differences in subjective or objective health and fitness existed that could be important for activities of daily living. In this part of study, the elderly women of the three original levels of physical activity (sedentary, intermediately active, high physically active) were submitted to a battery of tests to assess several aspects of physical fitness. Before start of the tests, subjective fitness was reported on each of the items to be tested. Differences in fitness levels between the groups were observed on endurance on a walk test and flexibility of the hip and spine as observed in a sit-and-reach test. Subjective fitness correlated with observed physical fitness *(chapter 5)*.

The development of the physical activity questionnaire *(chapter 2)* and the uncertainty about the cause of the high body weight in sedentary elderly women, needing data on energy balance *(chapters 3 and 4)*, stressed the need for age-specific data on energy expenditure. To overcome this problem, data were collected on energy expenditure during rest, sitting, sitting with standardised arm movement and walking on a treadmill with a 3 km per hour speed. A control group of middle-aged women (mean age 42 years) was included. Surprisingly, no differences were observed in energy expenditure at rest between older and younger women. Energy expenditure during walking however, proved to be importantly higher in the elderly women, even when expressed per kg of body weight *(chapter 6)*.

The results indicate that moving around takes more energy in younger than in older women. In overweighed elderly women this might be a cause for further decreasing their physical activity level with ageing. More attention should be paid to the risk of getting into a vicious circle of decreased physical activity and increase in body weight in elderly women.

Samenvatting

Bij veroudering is vermindering van lichamelijke activiteit een bekend verschijnsel. Het lagere energieverbruik vereist een aanpassing van de energieinneming met de voeding. Het doel van de studie was te onderzoeken of lichamelijke inactiviteit bij gezonde oudere vrouwen leidt tot voedingsproblemen zoals voedingstekorten of overgewicht. Daartoe werd de relatie bestudeerd tussen lichamelijke activiteit, voedselconsumptie en voedingstoestand in groepen vrouwen die van elkaar verschillen wat betreft het niveau van gebruikelijke lichamelijke activiteit.

Bij aanvang van het onderzoek werd een aanpassing gemaakt op een bestaande vragenlijst om lichamelijke activiteit vast te stellen en de nieuwe lijst werd getest voor gebruik bij ouderen mensen. Reproduceerbaarheid en validiteit bleken goed genoeg om ouderen consistent in te delen op activiteitenniveau *(hoofdstuk 2)*.

De vragenlijst naar lichamelijke activiteit en een algemene vragenlijst werden voorgelegd aan 140 zelfstandig wonende oudere vrouwelijke vrijwilligers. De werving was in eerste instantie gebaseerd op een, naar eigen zeggen, goede gezondheid en een niveau van lichamelijke activiteit dat ofwel hoog, ofwel laag was. Op grond van de vragenlijsten werden uit de 100 gezonde vrouwen tussen 63 en 80 jaar de 30 respectievelijk meest en minst actieve vrouwen uitgenodigd voor verdere deelname aan de studie. Vijfentwintig lichamelijk actieve en drieëntwintig weinig actieve vrouwen namen daadwerkelijk aan de studie deel. De gemiddelde leeftijd was 71 jaar. De voedselconsumptie werd vastgesteld met behulp van een aangepaste 'dietary history'. De voedingstoestand werd bepaald aan de hand van lichaamssamenstelling en biochemische parameters in het bloed. Bij vergelijking van deze twee groepen was het meest opvallende resultaat een verschil in lichaamsgewicht (bij een gelijke lengte) van 12 kilogram. Het lichaamsgewicht was hoger in de niet actieve groep oudere vrouwen *(hoofdstuk 3)*.

Het waargenomen verschil in lichaamsgewicht vormde de basis voor de volgende studie, waar, bij dezelfde deelneemsters, een retrospectieve analyse werd uitgevoerd van het lichaamsgewicht en de lichamelijke activiteit. Gegevens over lengte en gewicht werden verzameld voor vier verschillende leeftijden (12, 25, 40 en 55 jaar). Elk van deze leeftijden werd gerelateerd aan belangrijke gebeurtenissen of omstandigheden in het leven. Het niveau van overgewicht werd geschat aan de hand van verschillende

methodes. Een "gewichtsindex" werd geconstrueerd, bestaande uit (subjectieve) identificatie van een deelneemster met silhouetten van voor- en zijaanzicht, gekoppeld aan de persoonlijke beoordeling van het eigen lichaamsgewicht ten opzichte van dat van leeftijdsgenoten. Als een meer objectieve maat werden oude foto's die op de verschillende leeftijden het lichaamsfiguur goed weergaven, beoordeeld. Het niveau van lichamelijke activiteit in het verleden werd geschat aan de hand van een gedetailleerde vragenlijst. Resultaten gaven aan dat tussen de groepen sinds de 25-jarige leeftijd een verschil in mate van overgewicht bestond. Een verschil in vroegere lichamelijke activiteit kon niet worden aangetoond. Het huidige gewichtsverschil dat werd gevonden kon dus niet eenvoudigweg het resultaat zijn van een verschil in het huidig activiteitenniveau. Zwaardere oudere vrouwen zouden de neiging kunnen hebben de interesse in lichamelijke activiteit bij veroudering eerder te verliezen dan minder zware vrouwen. Dit zou het gevolg kunnen zijn van lichamelijke of sociale problemen die samenhangen met overgewicht *(hoofdstuk 4)*.

Het geconstateerde verschil in lichaamsgewicht tussen de groepen heeft geleid tot de vraag of ook andere verschillen in objectieve of subjectieve gezondheid en fitheid zouden bestaan die van belang zijn voor het verrichten van dagelijkse bezigheden. Aan dit deel van de studie namen vrouwen deel uit alle drie oorspronkelijke activiteitenniveaus (weinig actief, gemiddeld actief en zeer actief). De vrouwen werden onderworpen aan een batterij van testen om verschillende aspecten van lichamelijke fitheid te meten. Voorafgaand aan de testen werd de subjectieve fitheid op elk der testonderdelen nagevraagd. Verschillen in fitheid werden waargenomen op uithoudingsvermogen en flexibiliteit van heupgewricht en wervelkolom. De subjectieve fitheid was gecorreleerd aan de waargenomen lichamelijke fitheid *(hoofdstuk 5)*.

Zowel bij de ontwikkeling van de vragenlijst naar lichamelijke activiteit *(hoofdstuk 2)* als bij het zoeken naar een verklaring voor het hogere lichaamsgewicht bij niet-actieve oudere vrouwen *(hoofdstuk 3 en 4)* bleek er behoefte te bestaan aan leeftijd-specifieke gegevens betreffende het energieverbruik bij ouderen. Om hieraan tegemoet te komen werden bij 33 oudere vrouwen metingen verricht van het energieverbruik in rust, zittend, zittend met gestandaardiseerde armbewegingen, en lopend op een tredmolen met een snelheid van 3 kilometer per uur. Dertig vrouwen van middelbare leeftijd (gemiddelde leeftijd 42 jaar) werden gemeten als controlegroep. Verrassend was, dat er geen verschillen werden gevonden tussen de oudere en jongere vrouwen in energieverbruik in rust. Het energieverbruik tijdens lopen bleek echter belangrijk hoger bij de oudere vrouwen, ook wanneer dit werd uitgedrukt per kilogram lichaamsgewicht *(hoofdstuk 6)*. De resultaten geven aan dat het bewegen meer energie kost bij oudere dan bij jongere vrouwen. Bij zwaardere vrouwen zou dit een oorzaak kunnen zijn om hun activiteitenniveau bij veroudering verder te beperken. Er zou meer aandacht moeten worden besteed aan het risico om terecht te komen in een vicieuze cirkel van een verminderde lichamelijke activiteit en een verhoging van het lichaamsgewicht.

Curriculum vitae

Laura Elisabeth Voorrips werd op 10 maart 1963 geboren te Chêne-Bougeries in Zwitserland. In 1981 behaalde zij het Atheneum-B diploma aan het Van der Puttlyceum te Eindhoven. In hetzelfde jaar begon zij haar studie aan de Landbouwhogeschool (nu Landbouwuniversiteit) te Wageningen. In 1987 liep zij stage aan het 'Institut de Physiologie' van de medische faculteit van de universiteit van Lausanne (Zwitserland) onder begeleiding van Professor Jéquier. Het doctoraal-examen Voeding, met hoofdvakken Voedingsleer, Dierfysiologie en Celbiologie, werd afgelegd in september 1987.

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