DETERMINANTS OF BODY FATNESS

The Prediction From Childhood Values of Adult Skinfold Measurements, and the Relative Effects of Heredity and of the Environment on the Determination of Body Fatness Levels.

by

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M.D. UNIVERSITY OF EDINBURGH 1978.

I affirm that the work described in this thesis was performed exclusively by me.

ABSTRACT

Between 1960 and 1961 anthropometric measurements, including skinfold thicknesses, were recorded on offspring aged 2 to 15 years in 330 families. Between 1976 and 1977 repeat skinfold measurements have been made on 318 (88%) of the male offspring and 303 (86%) of the female offspring, who now range in age from 17 to 30 years. Skinfold measurements were taken at the triceps, subscapular, suprailiac and biceps sites.

The prediction from childhood values of adult individual skinfold measurements was found to vary from age to age in childhood and from site to site. No obvious pattern appeared and no one skinfold emerged as a more reliable predictor than any other. Where prediction was possible, the accuracies of the predictions were estimated to lie in 95% of cases between 13.1% and 24.2% in the males and between 10.6% and 26.2% in the females.

Calculations were repeated using the four skinfold measurements combined. The prediction from childhood values of the adult combined measurements, while more consistent than for the individual skinfolds, continued to vary from age to age in childhood. Where prediction was possible, the accuracies of the predictions were estimated to lie in 95% of cases between 10.6% and 18.0% in the males and between 8.0% and 18.0% in the females.

No greater relationship between childhood and adult skinfold measurements was found in the group selected with a childhood triceps or subscapular skinfold on or above the 75th centile.

The overall correlations between childhood and adult fatness levels, calculated from standardised scores, were 0.56 and 0.45 in the males and females respectively.

It is concluded that there is a moderate relationship between fatness levels in childhood and in adult life; a relationshp in which room is left to manoeuvre.

This is also a family study in which resemblances in body fatness have been assessed between 186 fathers, 211 mothers, 378 sons and 372 daughters. Amongst the offspring were 206 twin pairs.

No resemblances were found between parents and their offspring either as children or as adults. Midparent-offspring correlations were also not significant. In this study, parents and offspring at the time of measurement were not, largely, sharing common family environments. This suggests the common family environment to have been an important factor in determining resemblances previously noted between relatives.

The adult monozygotic twins resembled one another closely, as had been the case in childhood. The adult dizygotic male twins tended to resemble one another more closely than had been the case in childhood. The adult dizygotic female twins, by contrast, did not resemble one another at all. The similarities and differences found between the twins mirrored the similarities and differences noted between their lifestyles and habits. That the resemblances found were largely environmentally determined was supported by the finding that while the twins resembled one another, they did not resemble their singleton brothers or sisters.

The family data are considered to indicate the importance of environmental factors in the determination of body fatness levels.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

INTRODUCTION AND REVIEW OF THE LITERATURE

This is the first longitudinal study in which the relevance of body fatness in childhood to body fatness in adult life has been assessed from skinfold thickness measurements.

The assessment of body fatness relied for many years on the measurement of body weight. Physicochemical methods to measure total body fat and reliable skinfold calipers to measure subcutaneous tissue thickness were then developed. As a consequence, as will be shown, weight indices have been found to be unreliable measures of body fatness and skinfold thickness measurements to give a reasonable indication of total body fat.

Studies in which the assessment of body fatness has relied on measures of weight have shown that approximately 20% of overweight infants will become overweight children (Lloyd, Wolff & Whelan, 1961; Asher, 1966; Eid, 1970; Fisch, Bilek & Ulstrom, 1975). Recent studies,however, described in detail later, comparing skinfold thickness measurements made in infancy and repeated in childhood have found little or no relationship between the two.

Overweight children have been found to be at higher risk than their normal weight peers of becoming overweight adults (Mullins, 1958; Haase & Hosenfeld, 1958; Abraham & Nordsieck, 1960; Charney, Goodman, McBride, Lyon & Pratt, 1976). To determine whether there is any relationship between skinfold measurements made in childhood and repeated in adult life was the aim of this study.

This is also a family study in which skinfold measurements have been taken on both parents and offspring, amongst whom were twins. That 'overweight' runs in families has been noted by many observers (Davenport, 1923; Fellows, 1931; Dunlop & Murray-Lyon, 1931; Ellis & Tallerman, 1934; Gurney, 1936, Rony 1940; Bauer, 1945; Angel, 1949 Mayer, 1972). The implication, that body fatness levels are strongly genetically determined, is open to criticism for two reasons. There is the questionable relevance of any measure of overweight to body fatness levels and the fact that family members share not only genes but many common environmental circumstances. Resemblances found between them for body fatness levels may, more than anything else, reflect these. Studies comparing resemblances between family members for skinfold measurements are few. Further data on resemblances between relatives are provided in this study and their relevance discussed.

The Development of Skinfold Calipers and the Factors Affecting the Choice of Caliper for International Use

Fat accumulates under the skin. The thickness of this subcutaneous layer can be assessed from x-rays, from which a single layer of skin and subcutaneous tissue can be measured, or with calipers which measure the thickness of a fold of skin picked up between the fingers (henceforth called a "skinfold"). This latter method measures skin twice and a double layer of subcutaneous tissue.

Richer, in 1890, first described the use of calipers for skinfold measurements. Subsequently a variety of calipers were produced. They, however, exerted varying pressures at different jaw widths. Skinfolds compress by varying degrees depending on the pressure exerted (Garn, 1956; Brozek & Mori, 1958). These early calipers did not, therefore, give consistent results. Further progress awaited the development by Franzen (1929) of a "constant tension" caliper, i.e. one in which the pressure exerted by the jaws remains the same regardless of their distance apart. Whether in fact Franzen's caliper did exert "constant pressure" has been questioned (Brozek & Keys, 1953) but certainly today there are available calipers which meet this requirement (Harpenden, Lange, Holtain & Rizzoli calipers)

Comparison of subcutaneous tissue width measured from x-rays and by calipers, taking into consideration the compression of the latter and the double fold, shows good agreement. Correlations between the two have ranged from 0.80 to 0.89(Hammond, 1955; Garn, 1956; Brozek & Mori, 1958). Comparison of caliper readings with directly measured skinfolds also shows good agreement. Fry (1961) found a mean correlation of 0.82 between caliper readings and abdominal skinfold thicknesses, measured at operation on anaesthetised patients. In a post mortem study, Lee and Ng (1965) compared caliper readings with directly measured skinfolds over many areas in the body and found a mean correlation between the caliper readings and the direct measurements of 0.85 in males and 0.83 in females. They studied 43 males and 28 females ranging in age from one month to 74 years old. The cadavers were between half to four days old, all measurements were recorded at room temperature, and in the authors' opinion fat compressibility was very similar to that in living subjects.

It had previously been shown (Lee, 1957) and was reconfirmed in this post mortem study that the thickness of the skin varies with age, sex and the region of the body. Variations in the thickness of the skin had however little effect on the correlations between caliper readings and skinfold measurements. The mean correlations between caliper readings and subcutaneous fat alone, skin thickness having been excluded, were 0.84 in males and 0.82 in females (Lee & Ng, 1965).

Calipers of varying tensions and jaw face areas were compared by Edwards et al (1955) who confirmed that both of these factors had an important effect, not only on the observed thickness of the fold, but also on the consistency with which the measurements could be repeated (Edwards, Hammond, Healy, Tanner & Whitehouse, 1955). They recommended

1. that the face area of the skinfold caliper should be 6 mm x 15 mm;

2. that the spring pressure exerted over the range of opening 2 mm - 40 mm should not vary more than 2.0 g/mm^2;

3. that the pressure should be between the limits of 9 - 15 g/mm^2 with a recommended standard value of 10 g/mm^2;

4. that the scale of measurement should be read at least to 0.5 mm and preferably to 0.1 mm.

With these calipers repeat measurements could be made by a single observer, at the same site, with an accuracy of $\pm$ 5% or 0.3 - 0.6 mm at a jaw width of 7 mm. The differences between different observers, for the same site, were roughly twice this value i.e. 0.4 - 1.3 mm at a jaw opening of 7 mm.

Three calipers which meet the requirements of Edwards et al - Harpenden, Lange, Rizzoli - have been compared (Imbibo, Fidanza, Caputo &Moro, 1968). The results from each were similar and it was concluded that they were interchangeable.

Calipers exerting 10 g/mm^2 pressure have been recommended for general use by the International Biological Programme.

Physicochemical Methods of Estimating Total Body Fat

In 1887 Pfeiffer showed that the apparent differences in water content in fat and lean animals could be practically eliminated by making the calculations on the basis of fat free weight. Robertson in 1757 had shown that with increasing corpulence body density decreased. Behnke, Osserman & Welham (1953) amalgamating these findings proposed the theory which is fundamental to the physicochemical methods of estimating body fat. They considered that the body could be considered to consist of two compartments. The first, the "lean body mass" was of fixed composition and of fixed density. The other contained a variable amount of fatty tissue of a lower density than the lean body mass. Variation in body density was therefore determined by the amount of fat in the body and, by corollary, estimates of body density could give a quantative estimate of the amount of fat in the body.

The assessment of total body fat from body density requires an exact knowledge of the densities of the different compartments of the body, e.g. the "lean body" and the fat mass. These are not all known and the formulae commonly used to estimate total body fat from body density were derived on differing theoretical grounds (Rathbun & Pace, 1945; Keys & Brozek, 1953; Siri, 1956; Brozek, Grande, Anderson & Keys, 1963). The values obtained for total body fat from each formula compare favourably (Wilmore & Behnke, 1969; Behnke & Wilmore, 1970; Durnin & Womersley, 1974). The accuracy of prediction of total body fat from body density was estimated at ± 2% - 4% of gross body weight (Siri, 1960).

Further assumption of a lean body mass of constant water or potassium content has allowed the measurement of total body fat from measurements of total body water or total body potassium. The values obtained for total body fat assessed from body density and from the measurement of total body water have agreed reasonably well (Osserman, Pitts, Welham & Behnke, 1949-1950; Behnke & Siri,1957; Young, Martin, Chihan, McCarthy, Maniello, Harmith & Fryer, 1961; Heald, Hunt Schwartz, Cook, Elliot & Vajada, 1963). More variation is found when the total body fat is also estimated from the measurement of total body potassium (Womersley, Boddy, King & Durnin, 1972; Ward, Krzywicki, Rahman, Nelson & Consolazio, 1975). The differences found may reflect measurement errors in the complex laboratory procedures required (Durnin & Taylor, 1960; Forbes, Schultz, Cafarelli & Amirhakimi, 1968).

The possibility remains that, while there is good experimental evidence to support the general concept of a lean body mass (Von Dobeln, 1956), the density and composition of this lean body mass may alter with such factors as changing degrees of fatness or of muscle mass, or with age (Lesser, Kumar, Murray & Steele, 1963; Wedgewood, 1963; Forbes, 1964; Cheek, Schultz, Parra & Reba, 1970; Hume & Weyers, 1971; Lohman, Boileau & Massey, 1975; Forbes, 1976).

Comparison of Skinfold Measurements and Physicochemical Methods as Measures of Body Fat

Validation of skinfold thickness measurements as measures of body fat rests largely on their correlations with body density. In a study of 209 males and 272 females, aged 16 to 72 years, Durnin & Womersley (1974) found correlations between two or more skinfold measurements and body density ranging between -0.7 to -0.9. Total body fat could be predicted from the sum of four skinfold measurements with an accuracy of $\pm$ 3.5% body weight in women and $\pm$ 5% body weight in men. Others have found correlations in the same range, though female values have tended to be lower than male values (Tables 1 & 2).

As noted in the previous section the measurement of body density in itself has inaccuracies and the assumptions from which body fatness levels are derived from body density are many. The future development of more accurate methods to measure total body fat may show, as suggested by Womersley & Durnin (1977), that skinfold thickness measurements give a better indication of body fatness levels than do measures of body density.

TABLE

Correlations of Skinfold Measurements with Body Density

Males

AGE	NUMBER	INVESTIGATOR	YEAR	TRICEPS	BICEPS	SUBSCAPULAR	SUPRAILIAC
9-12	66	Parizkova	1961	-.84		-.87	
13-16	57	Parizkova	1961	-.93		-.74	
16-36	133	Wilmore	1969	-.64		-.69	-.73
17	48	Michael & Katch	1968	-.84		-.81	-.86
18-26	50	Sloan	1967	-.72		-.74	-.71
average 20.3	133	Brozek & Keys	1951	-.82		-.80	
average 22.08	88	Pascle	1956	-.77		-.73	
average 22.6	55	Haisman	1970	-.68	-.62	-.69	
average 42.0	122	Brozek & Keys	1951	-.82		-.80	

TABLE

Correlations of Skinfold Measurements with Body Density

Females

AGE	NUMBER	INVESTIGATOR	YEAR	TRICEPS	SUBSCAPULAR	SUPRAILIAC
9-12	56	Parizkova	1961	-.73	-.80	
13-16	62	Parizkova	1961	-.89	-.84	
17-25	50	Sloan	1962	-.68	-.71	
17-27	94	Young	1961	-.63	-.67	-.62
19-23	64	Katch & Michael	1968	-.59		
17-47	128	Wilmore & Behnke	1970	-.51	-.58	-.51

The Choice of Skinfold Site to Measure

Sites are better chosen which can be located precisely from obvious bony landmarks e.g. triceps, subscapular, suprailiac, biceps, as failure to locate the chosen point accurately has been shown to lead to important differences in the measurements obtained (Ruiz, Colley & Hamilton, 1971).

Triceps, biceps, subscapular and suprailiac skinfold thickness measurements, alone or combined, have been shown in a number of studies to reasonably predict total body fat in both males and females over an age range 9 - 72 years (Brozek & Keys, 1951; Pascale, Grossman, Sloan & Frankel, 1956; Parizkova, 1961; Young, Martin, Chihan, McCarthy, Maniello, Harmuth & Fryer, 1961; Sloan, Burt & Blyth, 1962; Sloan, 1967; Michael & Katch, 1968; Katch & Michael, 1968; Wilmore & Behnke, 1969; Wilmore & Behnke, 1970; Haisman, 1970, Durnin & Womersley, 1974).

A criticism of the majority of the studies is that only the four sites mentioned, and at times only one or two of these, were tested. The study on children aged 9 - 12 years by Parizkova (1961) was an exception, ten sites being tested. While little accuracy was lost using the sum of two skinfold measurements (triceps plus subscapular), total body fat was best predicted from the sum of the ten measurements. Again, in a study by Young et al (1967) on adult women, while total body fat could be reasonably predicted from the sum of the triceps and subscapular measurements, the best predictive skinfold was a suprapubic one (Young, Martin, Tensuan & Blondin, 1962).

The use of one skinfold measurement to assess body fatness in individuals of different ages presupposes that the ratio of fat at the site chosen to total body fat remains constant. This would not be the case when either the ratio of subcutaneous to deep fat or the distribution of subcutaneous fat varied.

The exact ratio of subcutaneous to deep fat in the human is not yet clear. Few post mortem studies have been carried out. Forbes (1962) found 42% of the total body fat in the subcutaneous region in a term newborn. Moore et al (1968) gave a value of 32% for a 67 year old woman who had died of carcinoma (Moore, Lister, Boyden, Ball, Sullivan & Dacher, 1968). Cross sectional studies have suggested that the proportion of subcutaneous fat falls with age (Young, Blondin, Tensuan & Fryer, 1963; Skerlj, Brozek & Hunt, 1953). The one available longitudinal study, in which body fat was measured twelve years apart in 27 men and 6 women, suggests however that no such change occurs (Chien, Peng, Chen, Huang, Chang & Fang, 1975). A greater proportion of internal to subcutaneous fat in women has been cited as a possible reason for the lower correlations found between the skinfold measurements and body density in this group (Durnin & Womersley, 1974).

The distribution of subcutaneous fat has been shown to vary between individuals and between males and females (Edwards, 1950, Garn, 1954, Garn, 1955, Garn, 1957) and, certainly in childhood, with age (Stuart & Sobel, 1946; Reynolds, 1950, Forbes & Amir Hakimi, 1970). Cross sectional studies suggest a trend in adult life in both sexes towards a greater increase in body fat than in limb fat (Edwards, 1951; Brozek, Chen, Carlsen, Bronczyk, 1953; Parizkova, 1963). That subcutaneous fat distribution does alter in adult life is also inferred from studies which have found skinfold measurements to correlate differently with each other at different ages (Brozek & Keys, 1951; Young, Martin, Tensuan, Blondin, 1961; Florey, 1970).

A combination of skinfold measurements will take some account of variations in the distribution of subcutaneous fat. The triceps plus biceps plus subscapular plus suprailiac combination has been shown to reasonably reflect total body fat over a wide age range (Durnin and Womersley, 1974). This combination has the added advantage of showing less between observer measurement error than is found for individual skinfold sites (Burkinshaw, Jones & Krupowicz, 1973; Womersley & Durnin, 1973).

Body Weight as a Measure of Body Fatness

Rogers in 1901 first called attention to the relationship between body weight and mortality (Transactions of the Association of Life Insurance Medical Directors of America, 1901). Since then Insurance Companies have provided tables of 'ideal' or 'average' weights based on their mortality figures (Actuarial Society of America, 1912; Metropolitan Life Insurance Company, 1942, 1943 & 1960; Society of Actuaries, Build & Blood Pressure Study, 1959).

The definition of overweight in adults has relied largely on comparisons with these tables, those with a body weight twenty per cent or more above standard weight being considered overweight and, by implication, fat. The choice of 20 per cent as the cut off point for overweight is arbitrary. Furthermore, the tables were compiled from data accumulated over periods of up to 20 years, thus ignoring the increases in weight and height which have been occurring by generation in the last century (Boyne, Aitken & Leitch, 1957; Maresh, 1972) Because of this secular trend childhood weight standard charts must also, to be valid, be constantly up-dated.

The limitations of relative body weight as an index of nutritional status were further indicated by Brozek & Keys (1951) who determined, from body density, the fat content of men of different ages but of similar relative weight. The average fat content for standard weight differed at different ages.

Weight reference tables have the further disadvantage of taking no account of variations in body build. Livi in 1897 had recognised the need for a body fatness indicator which did take account of body build. He suggested the use of "l'indice ponderale" $\sqrt[3]{\frac{\text{Weight}}{\text{Height}}}$. Subsequently a variety of ponderal indices have been developed, the most satisfactory at present being considered to be Quetelet's index $\frac{W}{H^2}$ (Keys, Fidanza, Karvonen, Kimura & Taylor, 1972). These indices have the advantage of not requiring reference standards. A difficulty remains in choosing the value of the index which separates normal from abnormal.

Indices of weight have therefore inherent difficulties as measures of body fatness. Their comparison against skinfold measurements and physicochemical methods of measuring body fat has further confirmed their unreliability as measures of body fatness both in children (Newans & Goldstein, 1972; Garn, Clark, Guire in Childhood Obesity ed. Winick, 1975) and in adults (Seltzer, 1966; Seltzer, Stoudt, Bell & Mayer, 1970; Goldbourt & Medalie, 1974; Womersley & Durnin, 1977).

Relationship between Fatness in Childhood and in Adult Life

Hernesniemi, Zachmann & Prader (1974) obtained skinfold measurements from the Zurich longitudinal growth study. This included approximately 400 children of Swiss parentage. All were normal babies and came from all socio-economic levels. Skinfold measurements over the biceps, triceps, subscapular and suprailiac areas were taken at the ages of 13 weeks, 39 weeks and 15 years. The skinfold values at 39 weeks of age were compared with those at 15 years and the increments during infancy, 13 to 39 weeks of age, were correlated with the absolute values at 15 years. The only significant correlation was the subscapular skinfold in girls as infants and as 15 year olds (0.30). Even in children selected with skinfolds on or above the 75th centile during infancy no or only weak correlations were found with later values. It was concluded that "the amount of fat in later years can be predicted only in a limited way from the values of skinfold thickness in a normal infant"

Poskitt & Cole (1977) traced 203 out of 300 children initially seen as infants by Shukla in 1972. Skinfold measurements were available from the first study and were repeated. Unfortunately direct correlations for individual children were not calculated. Instead the cumulative distributions of skinfold thickness in infancy and childhood were derived using Tanner's & Whitehouse's standards of 1962. Both triceps and subscapular skinfolds were thicker than reference standards in infancy but in childhood only the subscapular skinfold was thicker. From this it is not possible to ascertain to what extent the individual 'fat' infant remained 'fat' at five years old though the implication agrees with the findings of Hernesniemi et al, that the prediction of skinfold values in later years from infant values is perhaps only of mild importance when the subscapular skinfold is considered.

Hampton et al (1966) followed over 1,000 children through the ages 13 - 16 years old (Hampton, Huenemann, Shapiro, Mitchell & Behnke, 1966). Body fat was estimated from anthropometry and from body density. The average amount of body fat in girls increased from ages 13 - 15 years old and reduced at the age of 16 years old; in boys there was a slight increase between ages 13 - 14 years old and a more marked increase between 14 - 16 years old, probably reflecting the adolescent fat spurt. Taking 20% body fat as a cut off point for obesity almost the same percentage of boys in each year were obese. In girls there was a more marked difference, 11% when 13 years old, 12% when 14 years old, 17% when 15 years old and 14% when 16 years old. It is not specifically stated whether it was the same children in each year who remained obese or whether different children were involved.

There are, therefore, scant data on the changes in skinfold measurements and body fat with age in individual children and there are no data on the extent to which skinfold measurements in childhood predict those in adult life.

Family Resemblances in Body Fatness

Parent offspring skinfold correlations were found to be insignificantly different from zero in a study by Tanner & Israelsohn (1963). Parental age, which ranged from 23 to 64 years, was not taken into consideration in this study. Body fatness does not remain constant in adult life but tends to increase with age (Brozek & Keys, 1953; Lesser, Kumar, Murray & Steele, 1960; Brozek, Kihlberg, Taylor & Keys, 1963; Forbes, 1976).

Account was taken of variations in skinfold measurements with age in a large study in America including over 10,000 families (Garn & Clark, 1976). The children ranged in age from 2½ to 18½ years. Parents were divided into lean, medium and obese categories on the basis of age specific standards drawn up from the whole survey. The level of fatness of the children was seen to rise progressively with the level of fatness of the parental mating combination i.e. boys and girls with two lean parents tended to be the leanest and boys and girls with two obese parents to be the fattest. Overall, parent offspring correlations for the triceps skinfold measurement averaged 0.25. In a study on 403 Colombian families Mueller & Titcomb (1977) also found low parent offspring correlations for triceps, subscapular and suprailiac skinfolds, varying between 0.09 - 0.32. For the three skinfolds combined the father offspring correlation averaged 0.25 and the mother offspring correlation 0.32.

Results from studies comparing sibling resemblances have varied. Garn & Clark (1976) comparing childhood triceps measurements found a correlation between brothers of 0.38 (1230 pairs) and between sisters of 0.40 (1129 pairs). Mueller (1977), on smaller numbers, found a similar result for the triceps measurements between sisters, 0.41 (46 pairs) but a lower correlation between brothers, 0.25 (59 pairs). In Mueller's study a significant correlation between the triceps measurement was found for adult sisters but not for adult brothers.

Resemblances between family members may reflect their shared genes or the common environmental conditions which surround the family members. Resemblances between parents and their adopted children more clearly identify environmental influences. Evidence for a strong environmental element to body fatness levels comes from a study in which resemblances in triceps skinfold measurements between parents and their adopted children were compared with resemblances between parents and their natural children (Garn, Bailey & Cole, 1976). The parent adopted child correlation averaged 0.19 and the parent natural child correlations averaged 0.21.

That body fatness has a strong genetic element has however been suggested from two independent twin studies (Brook, Huntley & Slack, 1975; Borjeson, 1976). Identical twins as children were found to resemble one another closely for skinfold thickness measurements and to resemble one another more closely than non identical twins. Identical twin pairs have however been shown to share many environmental factors in common, and to share more environmental factors in common than nonidentical twins (Smith, 1965). The interpretation of the twin data has therefore particular problems, discussed in detail later. For genetically determined characteristics the midparent child correlations would be anticipated to be higher than the individual parent child correlations. This has not been found to be the case for skinfold measurements (Mueller & Titcomb, 1977).

STUDY GROUP

The families in this study were first seen and measured between 1960 and 1962 by Dr. R.M.C. Huntley (PhD Thesis, London 1966). Heights and weights of parents and children were recorded and skinfold measurements made on all children between the ages of 2 and 15 years old.

The initial study was primarily a twin study and each family contains twins. The families came from two sources. First, the families of all twins of suitable age who had attended the out-patient clinic at the Hospital for Sick Children, Great Ormond Street, London, were contacted. Second, an appeal to families with twins to volunteer for this study was made on television following a programme concerning twins. Twins were chosen from the hospital group who had attended with minor ailments. The television group served as a control against which they could be compared.

The skinfold measurements were not included in Dr. Huntley's thesis. The original twin skinfold data has been published (Brook, Huntley, & Slack, 1975). Dr. Huntley kindly consented to the families being re-traced in order to repeat these measurements and compare them with the original values.

METHODS

Tracing Families

Families were traced in three ways:

1. Through their addresses of 15 years previously.

2. Attempts were then made, with the help of the Department of Health and Social Security to contact more families through their Social Security Numbers. The name and date of birth of the eldest child in each missing family was given to the Department of Health and Social Security. This body has no authority to reveal addresses but forwarded letters provided by the author, included in which were stamped, addressed envelopes for replies.

3. The most successful method was the last one tried. This found families through the National Health Number of one of the children. A record of each person's National Health Number and the name of the Family Practitioner Committee responsible for that person's care is kept at a central office in Southport. From the Family Practitioner Committee it was then possible to trace the person's General Practitioner. This General Practitioner was contacted, by telephone or by letter, the nature of the study explained to him and his permission asked to contact the family member.

Measurement of Families

At the time of the first study all of the families lived in the Greater London area. Now they were widely scattered.

Measurement centres were set up in hospitals as close as possible to the maximum number of subjects. Arrangements were supervised by the appropriate paediatric consultants. Individual appointments were made, 15 minutes being allowed per person. Travelling expenses to and from the centre were reimbursed. Where it was impossible for all or one of the family to attend the centre, for example because of young children, home visits were made.

Skinfold Measurements

Skinfold thickness was measured using Holtain calipers (Fig 1) which conform to the standards proposed by Edwards, Hammond, Healy, Tanner & Whitehouse (1955). Four sites were measured, on the left side of the body.

1. TRICEPS; over the triceps muscle on a point mid-way between the tip of the acromial process and the olecranon and vertically above the olecranon. The subject's elbow was initially flexed to a right angle and the correct mid-point located using a measuring tape. This point was marked on the skin in ink. The skinfold measurement was taken at this point with the subject's arm hanging relaxed by his side.

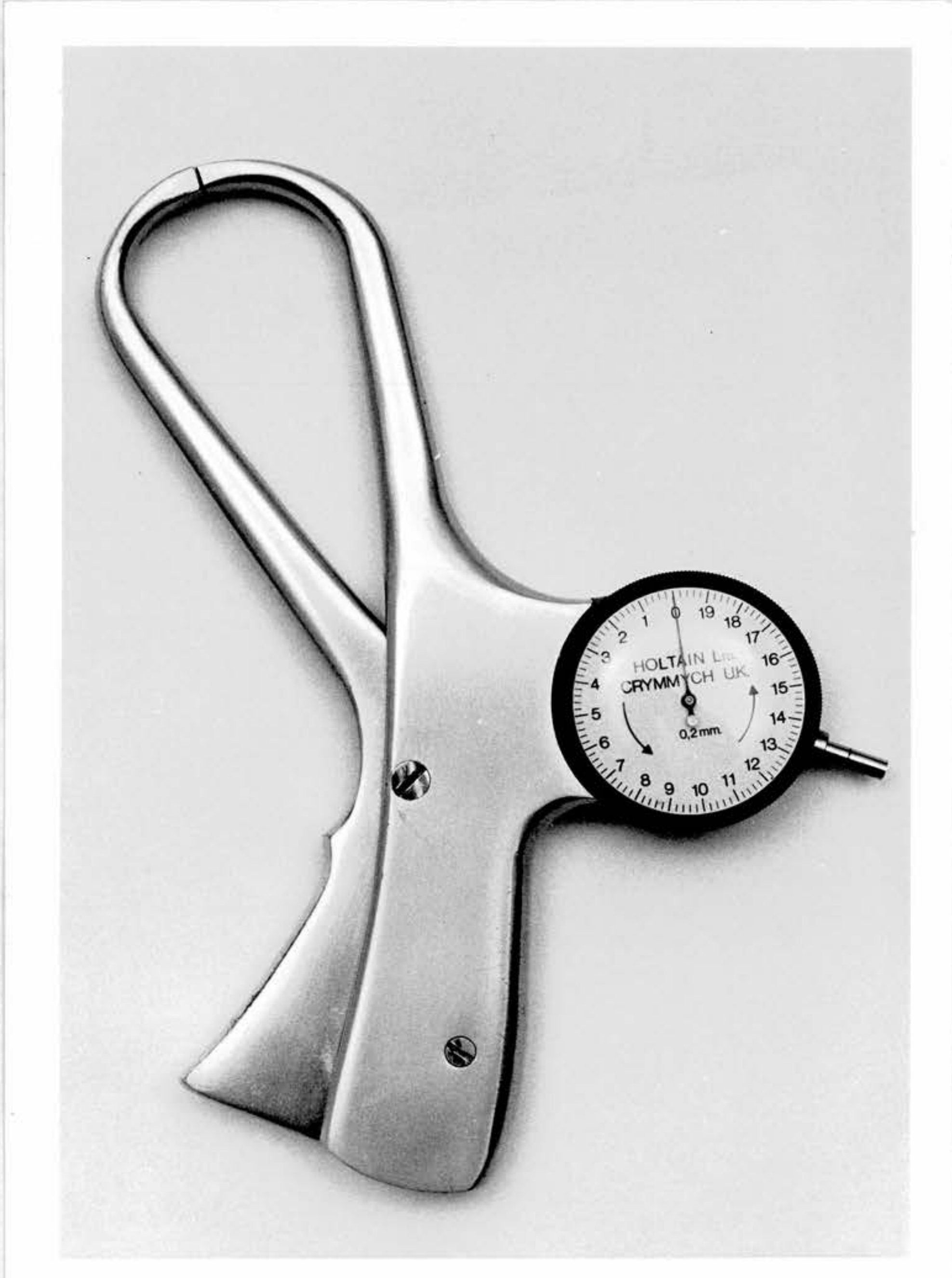
2. BICEPS; over the mid-point of the biceps muscle on the same plane as the triceps measurement with the arm supinated and hanging vertically.

3. SUBSCAPULAR; just below the angle of the scapula with the fold either in a verticle line or slightly inclined, in the natural cleavage line of the skin.

4. SUPRAILIAC; just above the iliac crest in the mid-axillary line.

Prior to measuring the study group practice with the calipers was undertaken with the co-operation of Middlesex Hospital Medical School students. In a pre-study trial of 43 girls and 37 boys the accuracy

Figure 1. Holtain Calipers.



of duplicate measurements, expressed as the percentage variation from the mean was as follows:

	BICEPS	TRICEPS	SUBSCAPULAR	SUPRAILIAC
Boys	4.2	2.0	2.4	3.4
Girls	4.0	2.6	3.6	3.7

This compares favourably with the ± 5% considered appropriate by Edwards (1955).

Skinfold measurements were repeated a minimum of 3 times at each site until a consistent reading was obtained. (A reading was considered consistent when similar on 3 consecutive occasions.) Where a consistent reading could not be obtained the average of the final 3 measurements was taken. When calipers are applied to the skin the dial needle falls rapidly to one point and, if the calipers are kept in position, the needle then falls slowly to another position. On each occasion the reading was taken where the needle first stopped and to the nearest 0.1 mm.

Height

The height of each subject was measured on a portable Holtain stadiometer (Figure 2). After each assembly, and before use, the calibration of the height meter was checked by the minimal reading of the counter which remained the same on each occasion.

The subject stood on the platform with his back to the vertical beam, his heels together, stretching upward to his fullest extent, aided by gentle traction by the measurer on the mastoid processes. This diminishes the effect of height variation dependant on the time of day (Whitehouse, Tanner & Healy, 1974). The head was positioned

Figure 2. Portable Holtain Stadiometer.

such that the Frankfurt plane - a line from the lower border of the left orbit to the upper margin of the external auditory meatus - was horizontal. A 300 G weight was placed on the counter-weight board to ensure close contact between this board and the subject's head. Care was taken to ensure that the subject's heels did not leave the base. Height was measured to the nearest 0.1 cm.

Weight

Weighing scales which were both portable and accurate were not easily found. Those used (Figure 3) were provided by C.M.S. Weighing Equipment Limited. This model was converted by C.M.S. Weighing Equipment Limited from weighting to a maximum capacity of 55 kg to weighing to a maximum capacity of 105 kg. Before use, the balancing arm was levelled using the counter-weight - this maintained the same position throughout the year. In addition, before use, the accuracy of the scales was confirmed by checking the weight of the packed portable stadiometer (20.4 kg). The scales remained accurate throughout the year. Weight was read to the nearest 0.1 kg.

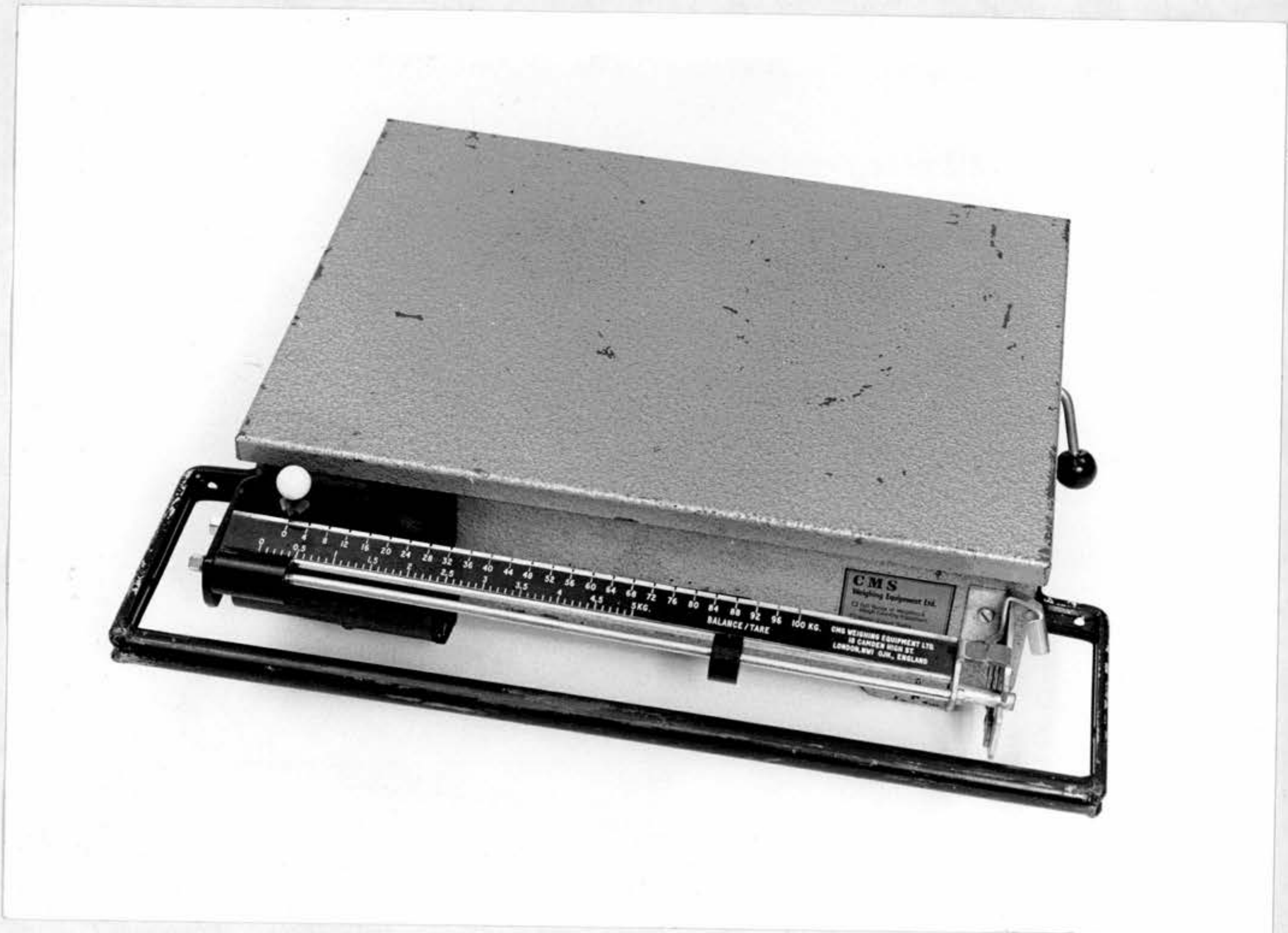
All children were weighed on both occasions wearing underclothes only.

Zygosity of Twins

In the initial study the twins were classified as monozygotic or dizygotic on the following criteria. First they were matched by the similarity method. Taken into account were:

- general appearance
- hair colour, form and texture
- eye colour
- shape of nose, ears, lips and chin

Figure 3. Weighing Scales.



- teeth formation and type of teeth
- type and proportions of hands, fingers and nails.

43 pairs of like sex twins were blood tested (as were their parents) for the following groups:

ABO

MNS

Rhesus

P.

Lutheran

Kelly

Lewis

Duffy

Xg^a

The criteria for selection for blood grouping were:

i. where the examiners were not entirely satisfied, having closely examined each twin,

ii. those classified as dizygotic with small finger ridge count differences and no family history of twins,

iii. those classified as monozygotic with large finger ridge count differences and a positive family history of twins.

On this first occasion 3 pairs considered dizygotic by the similarity method had identical blood groups. Two pairs were re-classified as monozygotic. The third pair were Chinese with Chinese parents who had very similar blood groups and this pair were maintained in the dizygotic group.

The Chinese twin pair have been excluded from this study. Of the 146 pairs of like sexed twins seen and re-measured 22 pairs were blood tested for the first time, 21 pairs had been blood tested in the first study and 3 pairs had blood tests on both occasions.

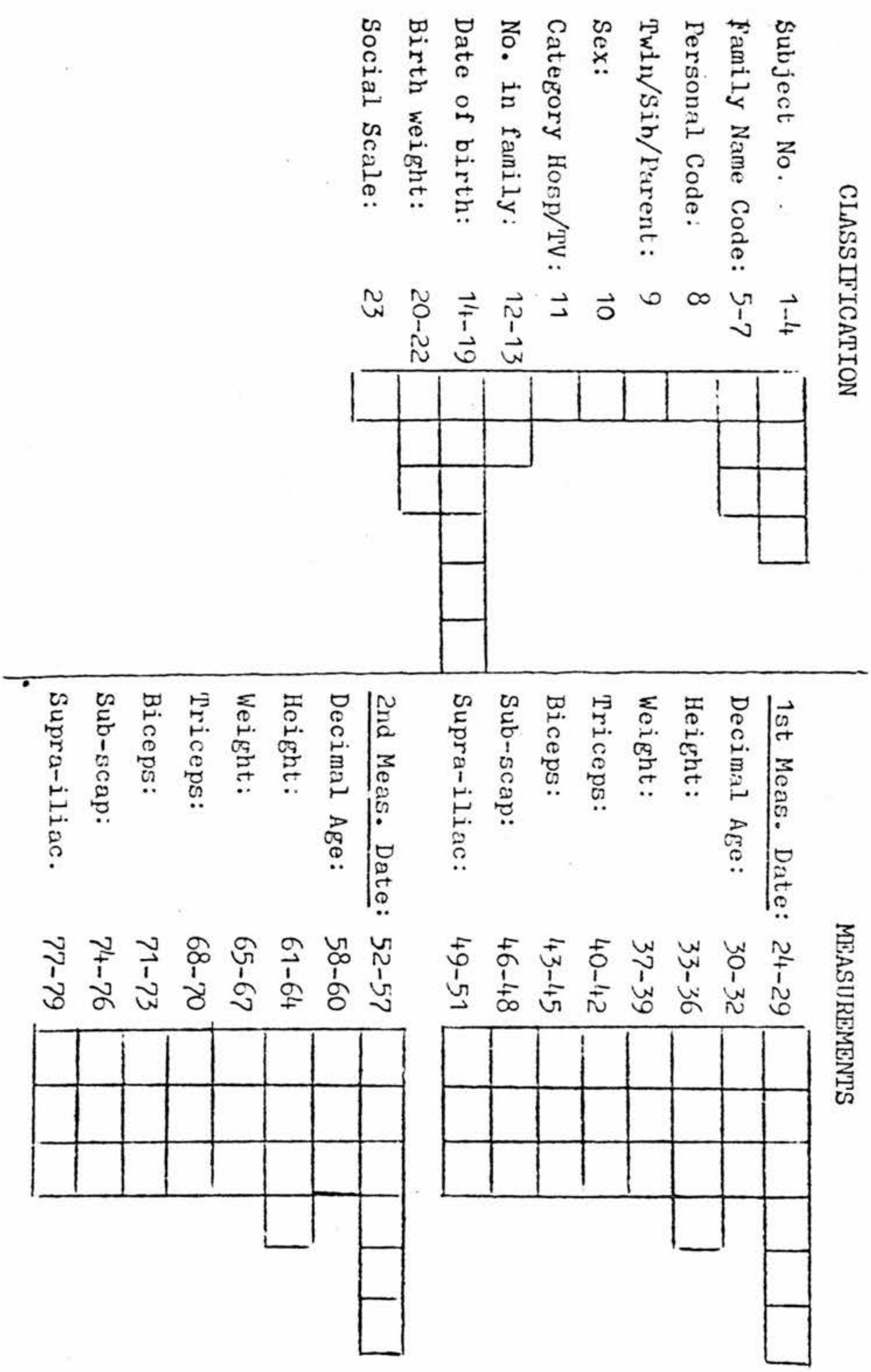
TIME OF BLOOD TESTING		MONOZYGOTIC		DIZYGOTIC	
		Male	Female	Male	Female
1st Study	21	8	7	3	8
2nd Study	22	4	1	12	5
1st & 2nd Study	3	0	2	0	1

Blood tests were carried out on this occasion where the monozygotic classified twins had grown less alike or the dizygotic twins had grown more alike. Each twin was tested for 42 blood groups (appendix P97). Each pair had been correctly classified, as shown by these blood tests, on the first occasion.

Computer Cards

The data for each individual, recorded as shown (Figure 4), were punched onto computer cards by an experienced punch operator. Each computer card contained 80 digits and there were 1,338 cards. Each card was subsequently checked for accuracy by another experienced punch operator, using a verifying maching designed for the purpose. 144 cards were found to have an error of 1 digit. These cards were re-punched and re-checked. 144 digit errors in 1,338 cards, each containing 80 digits, is an error rate of 0.2% for the unverified cards. The error rate for the verified cards cannot be accurately calculated, but will be less than 0.2%.

Figure 4. Computer Card Format.



Programme

The computer programme used was the statistical package for social sciences designed by W.R. Klecka, N.H. Nie and C. Hadlai Hull. From this were provided

- means & standard deviations
- frequency distributions
- scattergrams
- regression and correlation coefficients
- tests of significance
- Z scores

The significance of the difference between correlation coefficients was estimated using Fishers Z transformation. The accuracy of the prediction of adult skinfold values from childhood values was estimated from the regression analyses. The residual standard deviation of the regression was expressed as a percentage of the mean value of the dependent variable. Values of this variable could be predicted, in 95% of cases, from the independent variable with an accuracy 1.96 times this percentage.

Z Scores

Skinfold measurements change with age. The Z score transformation was used to standardise the measurements. A new variable was generated with a mean of 0 and a standard deviation of 1. The formula used is

$\frac{xj - \bar{x}}{S.D.}$ where xj = the original value of the J^{th} case for the variable being transformed.

$\bar{x}$ = the mean of the variable.

S.D. = standard deviation of the mean of the variable.

Z scores were calculated for each individual for the sum of the four skinfold measurements, triceps plus biceps plus subscapular plus suprailiac, log transformed. The means and standard deviations against which each individual was compared were the mean value and standard deviation for that individual's year group calculated from the study population.

RESULTS

SECTION I

Response Rate

294 (89%) of the 330 families were traced.

- through their home addresses of 15 years previously	98
- through the Department of Health and Social Security	72
- through the National Health Service Numbers	124

40 families traced but not measured are accounted for as follows:

Unwilling	16	(5%)
Emigrated	16	(5%)
Excluded (Family Chinese)	1	
Family too far distant in U.K.	3	
Family problems	2	
TOTAL	38	

Longitudinal Skinfold Analysis

Within the 256 families remaining skinfold measurements had been recorded on 364 male offspring and 354 female offspring. Repeat measurements were made on 318 (90%) of these male offspring and 303 (86%) of the female offspring.

Family Resemblances

In total, within the families the following numbers were measured.

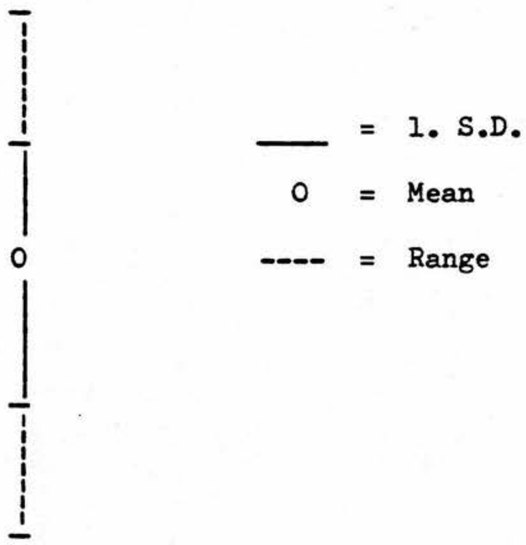
	Number Measured	Not Measured	Total
Fathers	186 (77%)	56	242
Mothers	211 (85%)	38	249
Sons	378 (84%)	71	449
Daughters	372 (85%)	62	434
Mother & Father in same family	172		

The missing members are accounted for as follows:

	Fathers	Mothers	Sons	Daughters
Unwilling	20 (8%)	17 (7%)	43 (8%)	24 (6%)
Abroad	2	1	21	21
Dead	12	19	1	4
Ill	6	7	1	-
Mental Handicap	-	-	2	1
Too Far	2	2	3	4
Pregnant	-	-	-	17
Divorced (No Trace)	6	-	-	-
	48	46	71	71

Childhood Values

The yearly mean triceps and subscapular skinfold measurements, heights and weights of the offspring as children are shown compared to the standards for British children of Tanner & Whitehouse (1969 & 1975)



All mean values fell close to the standard means. Full details are in the appendix (pages 93 - 103.)

Figure 5

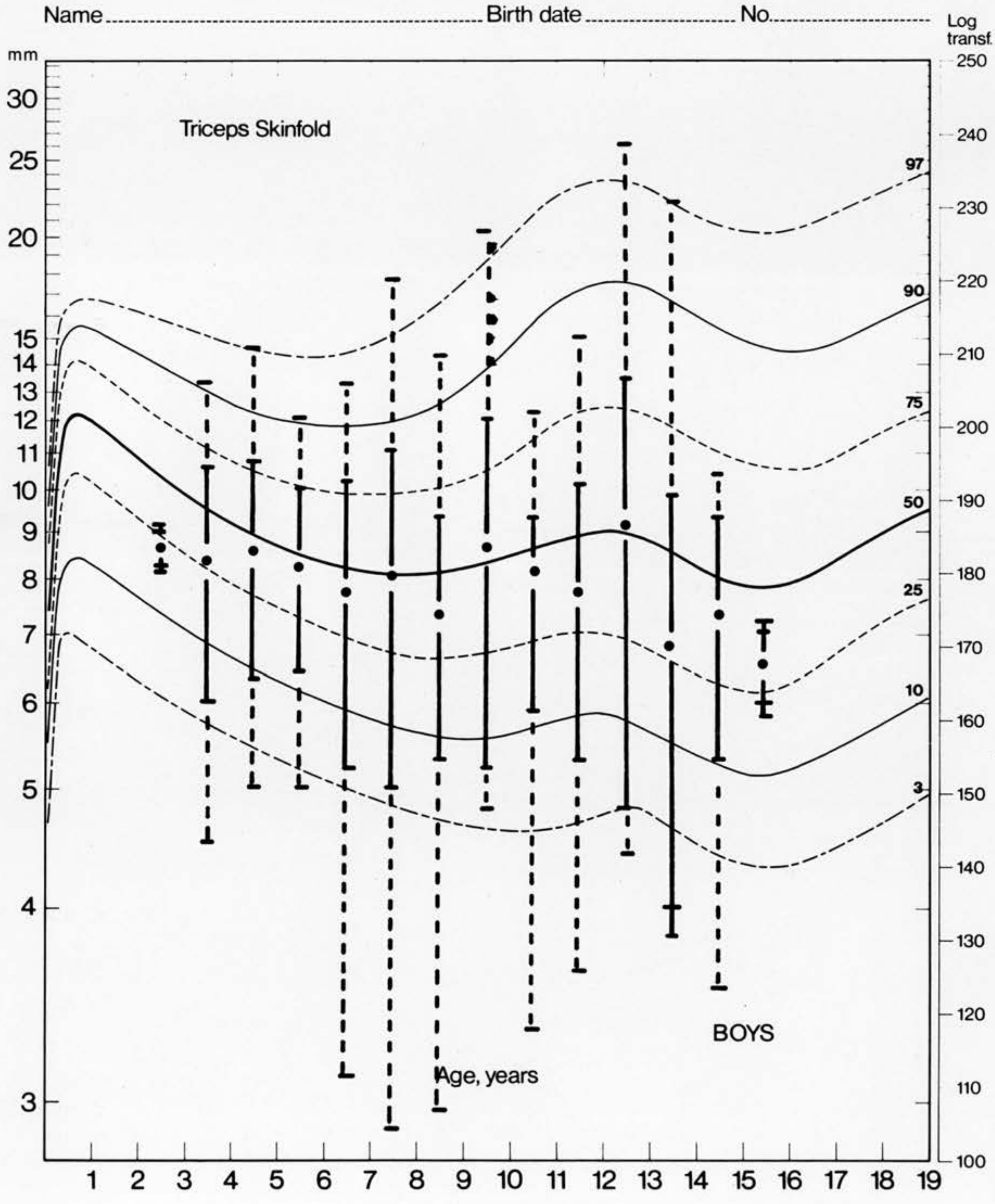

Name
Birth date
No.
Log transf.
mm
Triceps Skinfold
BOYS
Age, years
97
90
75
50
25
10
3
30
25
20
15
14
13
12
11
10
9
8
7
6
5
4
3
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

Figure 6

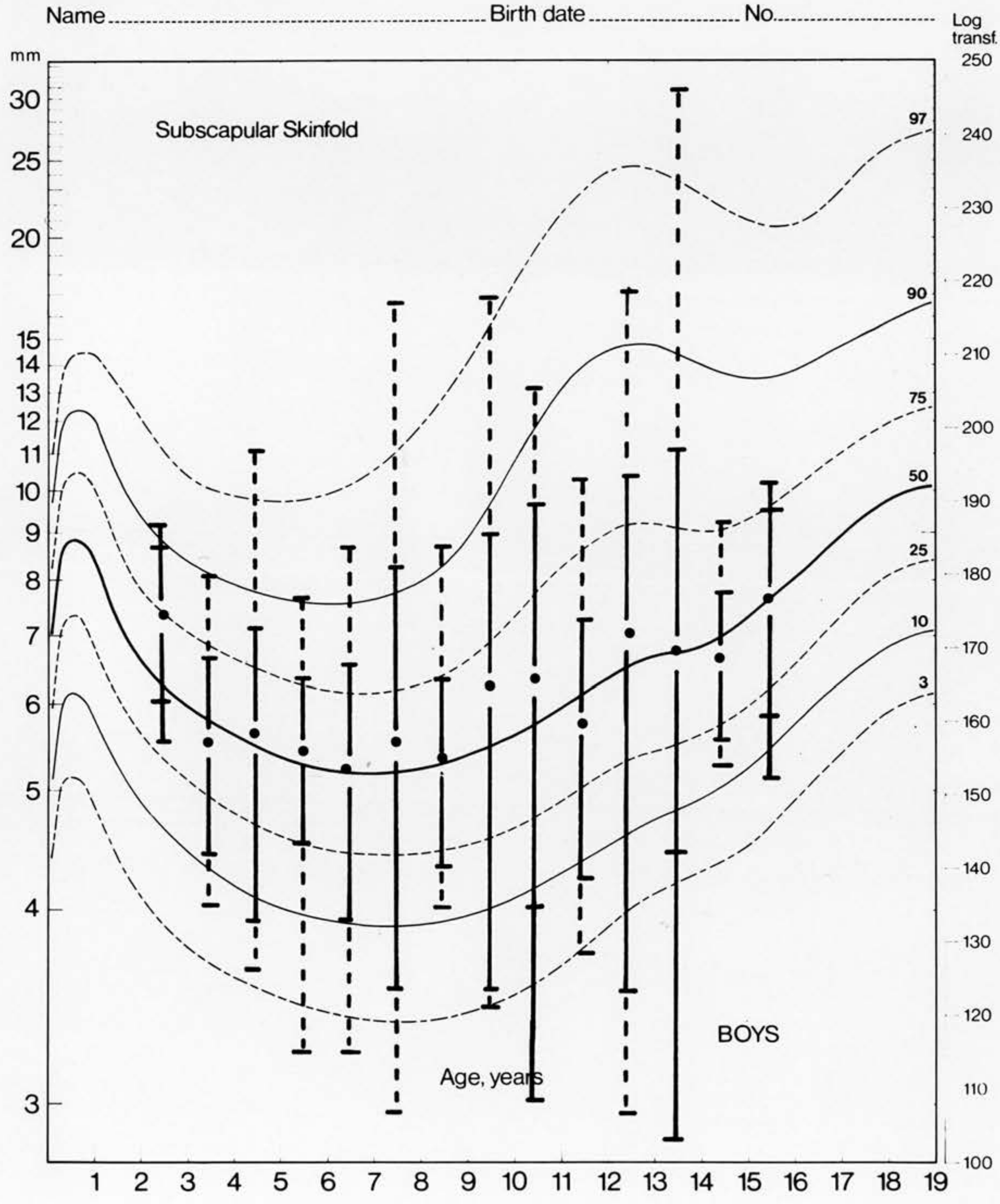

Name
Birth date
No.
Log transf.
mm
Subscapular Skinfold
BOYS
Age, years
97
90
75
50
25
10
3
30
25
20
15
14
13
12
11
10
9
8
7
6
5
4
3
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

Figure 7

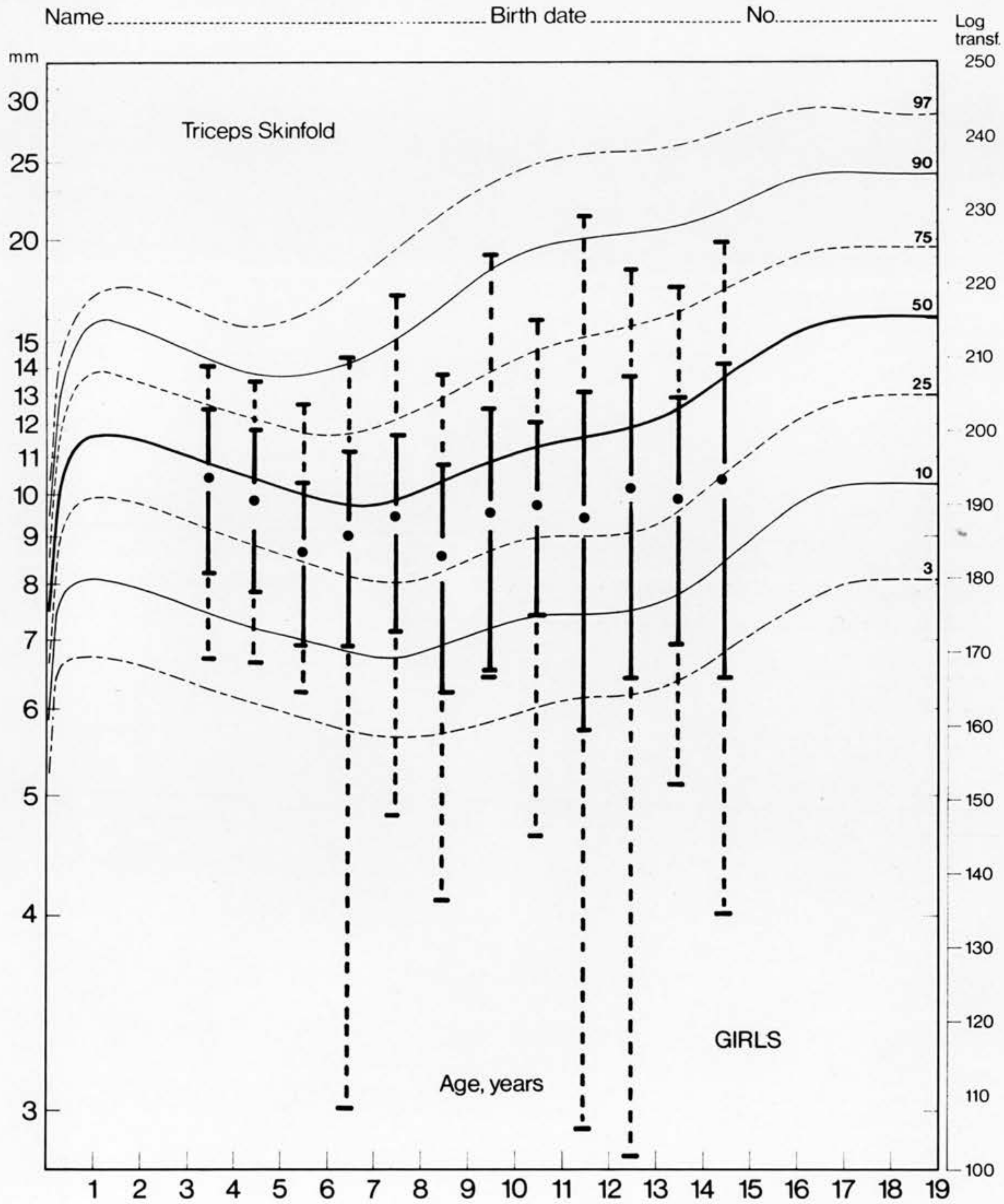

Name
Birth date
No.
Log transf.
mm
Triceps Skinfold
97
90
75
50
25
10
3
30
25
20
15
14
13
12
11
10
9
8
7
6
5
4
3
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
GIRLS
Age, years
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

Figure 8

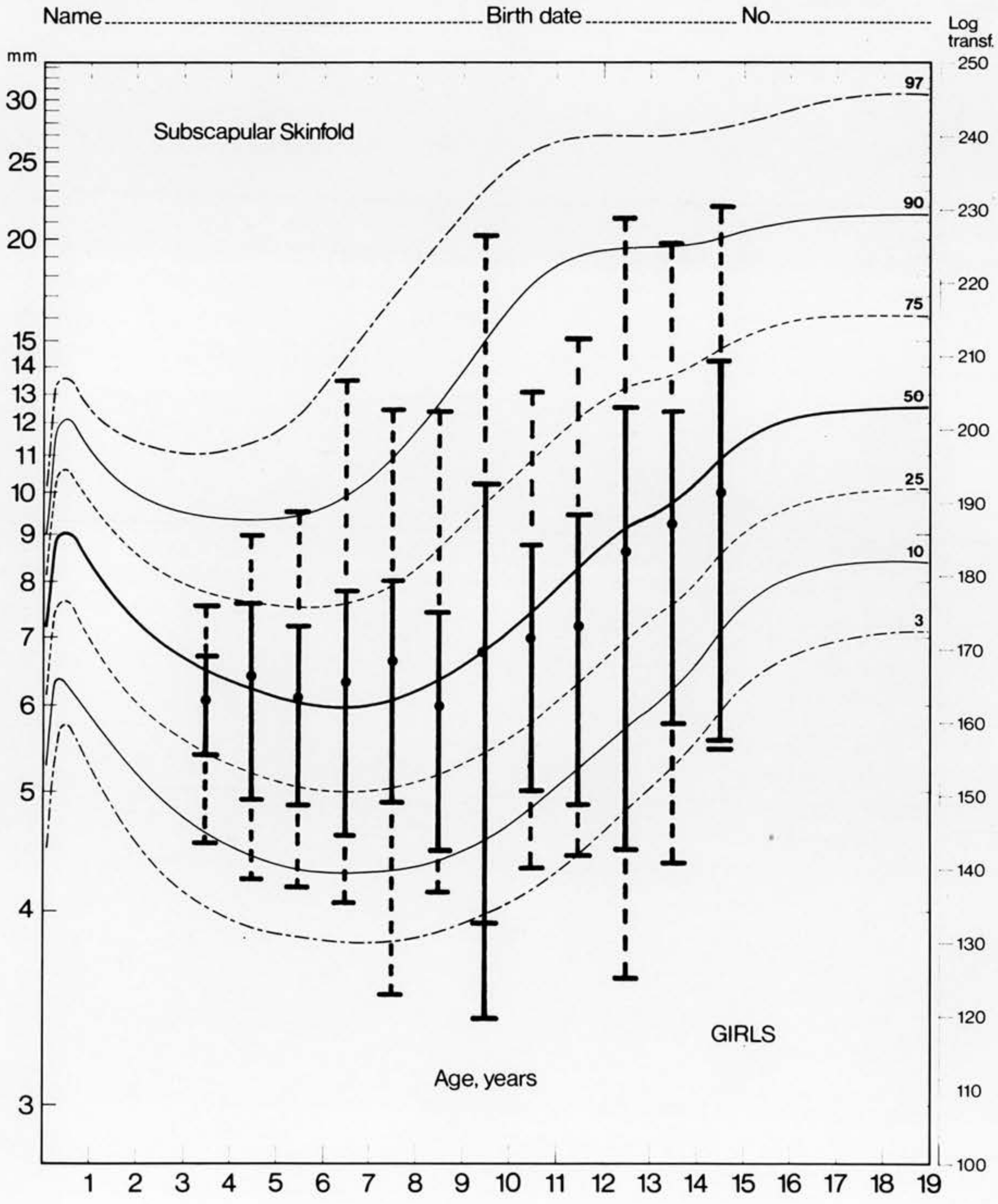

Name
Birth date
No.
mm
Log transf.
Subscapular Skinfold
30
25
20
15
14
13
12
11
10
9
8
7
6
5
4
3
97
90
75
50
25
10
3
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
GIRLS
Age, years
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

Figure 9

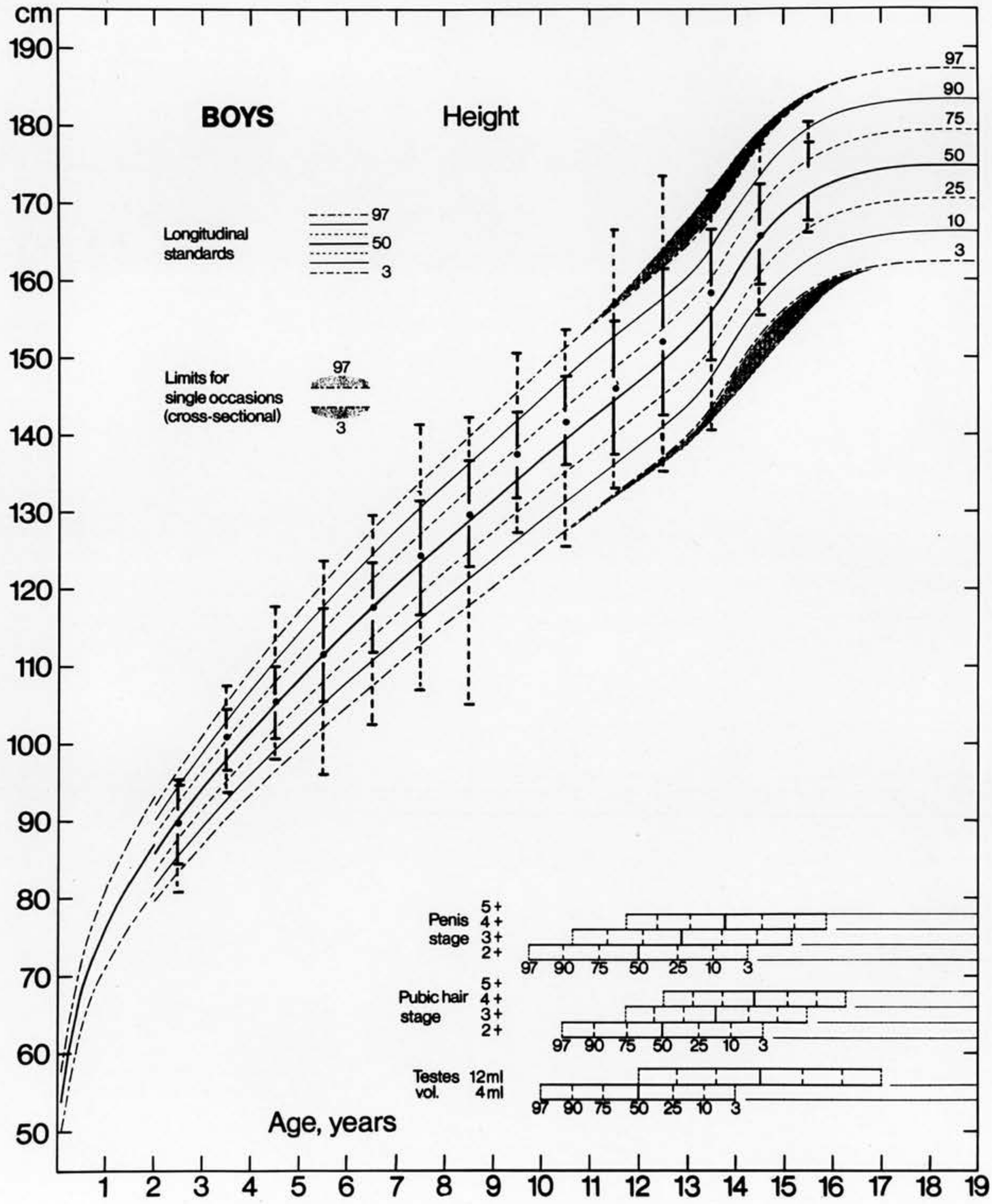

cm
BOYS
Height
Longitudinal standards
97
50
3
Limits for single occasions (cross-sectional)
97
3
Penis stage
5+
4+
3+
2+
Pubic hair stage
5+
4+
3+
2+
Testes vol.
12ml
4ml
97 90 75 50 25 10 3
Age, years
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

Figure 10

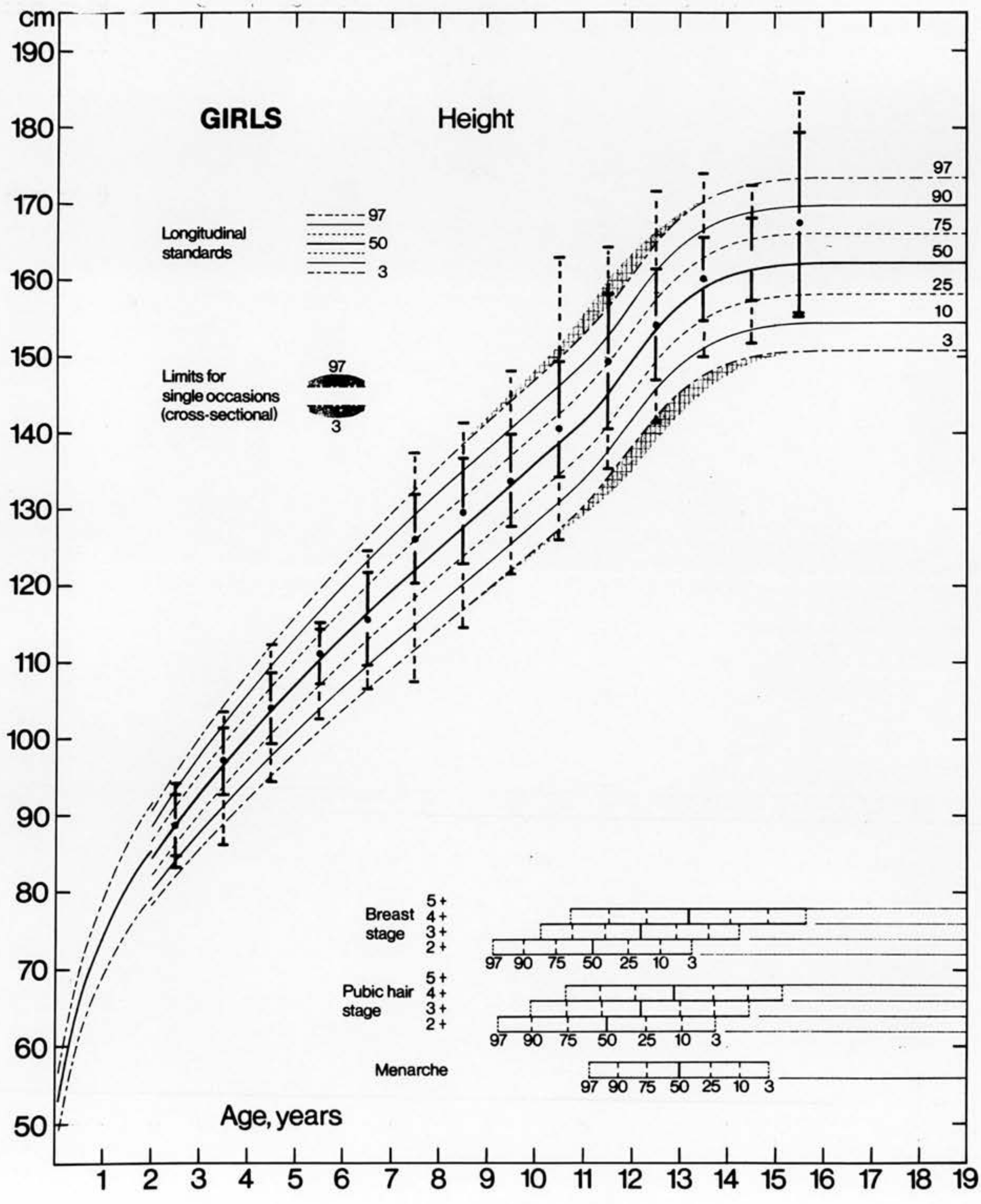
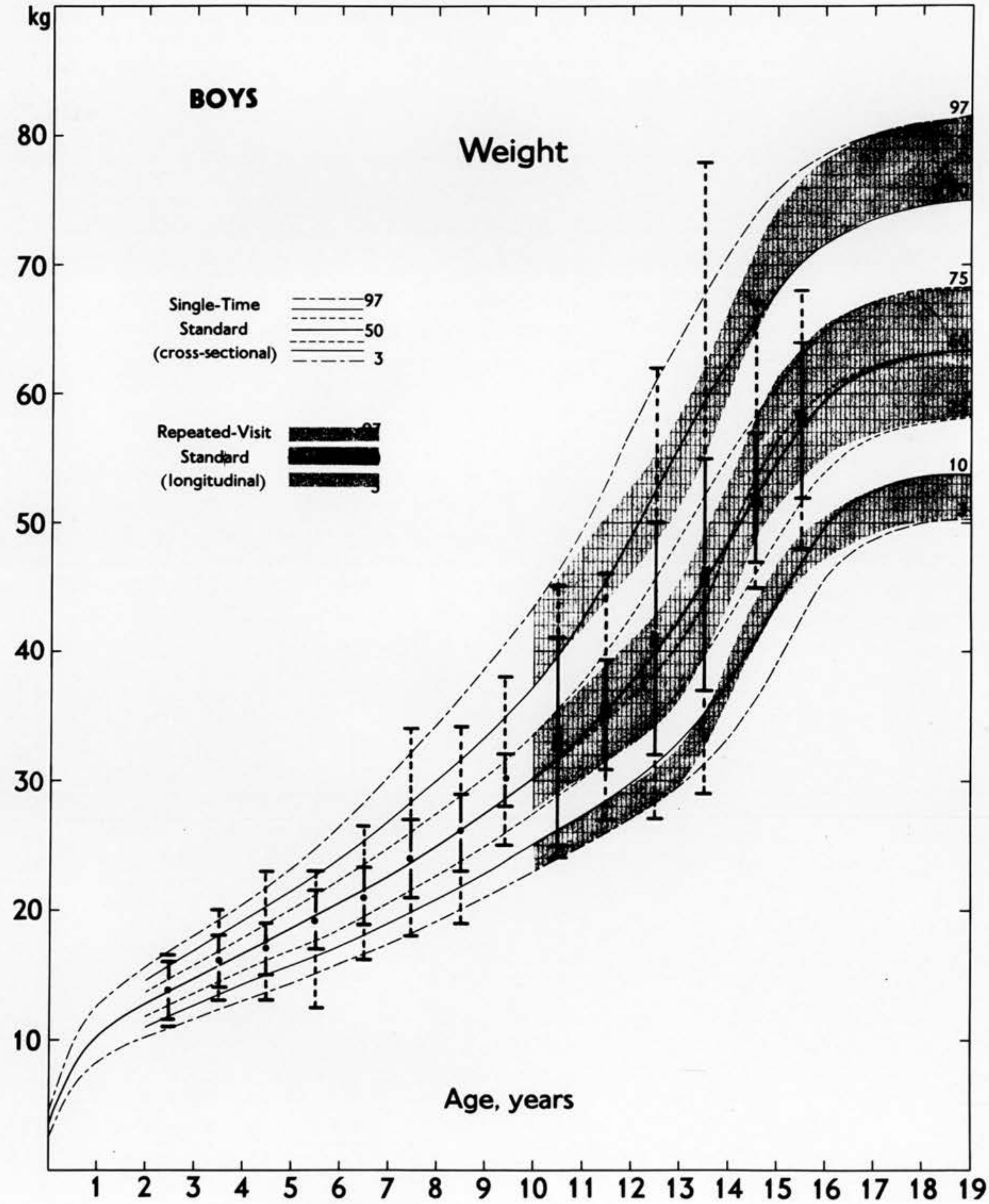
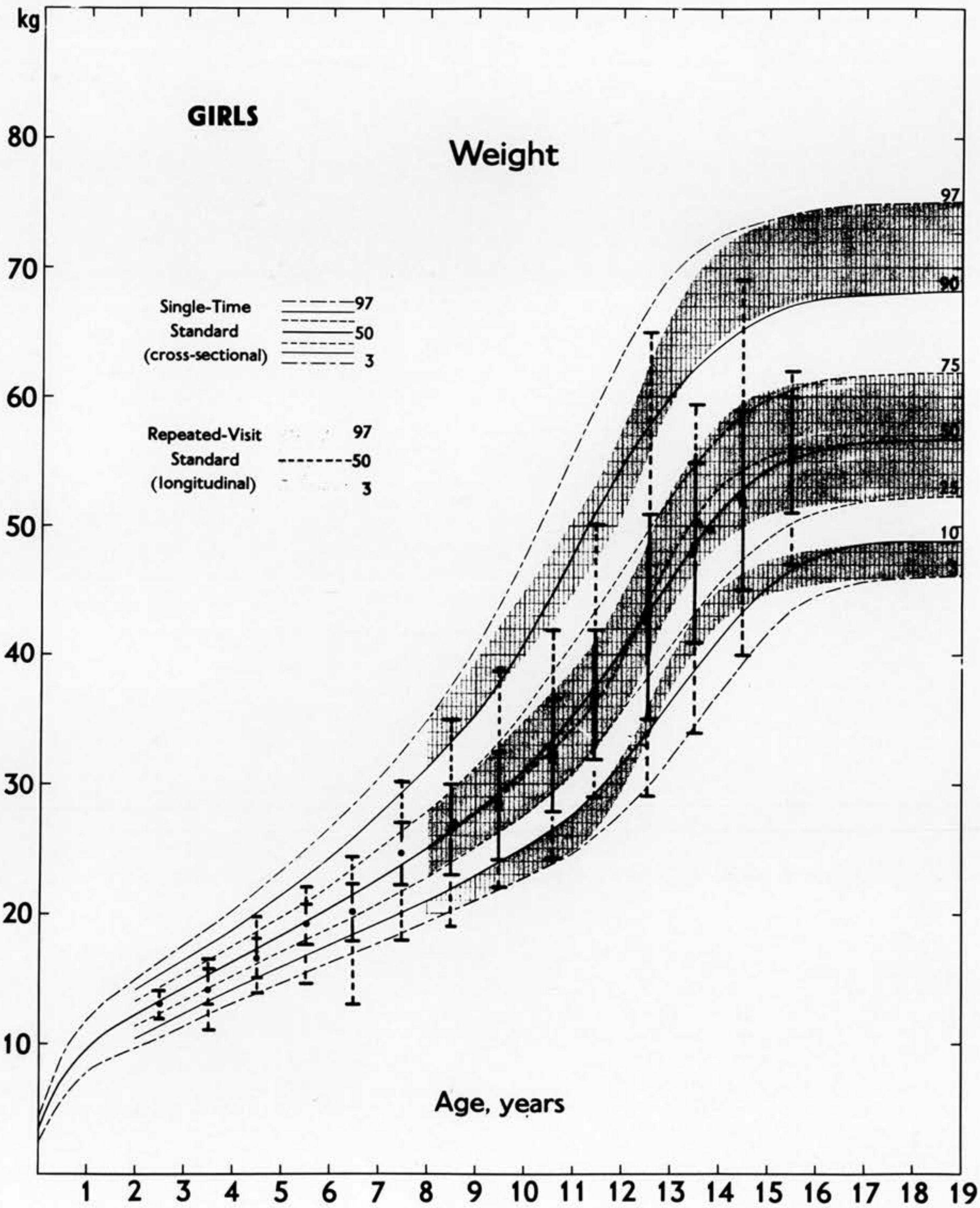

cm
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
GIRLS
Height
Longitudinal standards
97
50
3
Limits for single occasions (cross-sectional)
97
3
97
90
75
50
25
10
3
Breast stage
5+
4+
3+
2+
97 90 75 50 25 10 3
Pubic hair stage
5+
4+
3+
2+
97 90 75 50 25 10 3
Menarche
97 90 75 50 25 10 3
Age, years
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

Figure 11



kg
BOYS
Weight
Single-Time
Standard
(cross-sectional)
97
50
3
Repeated-Visit
Standard
(longitudinal)
97
75
10
80
70
60
50
40
30
20
10
Age, years
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

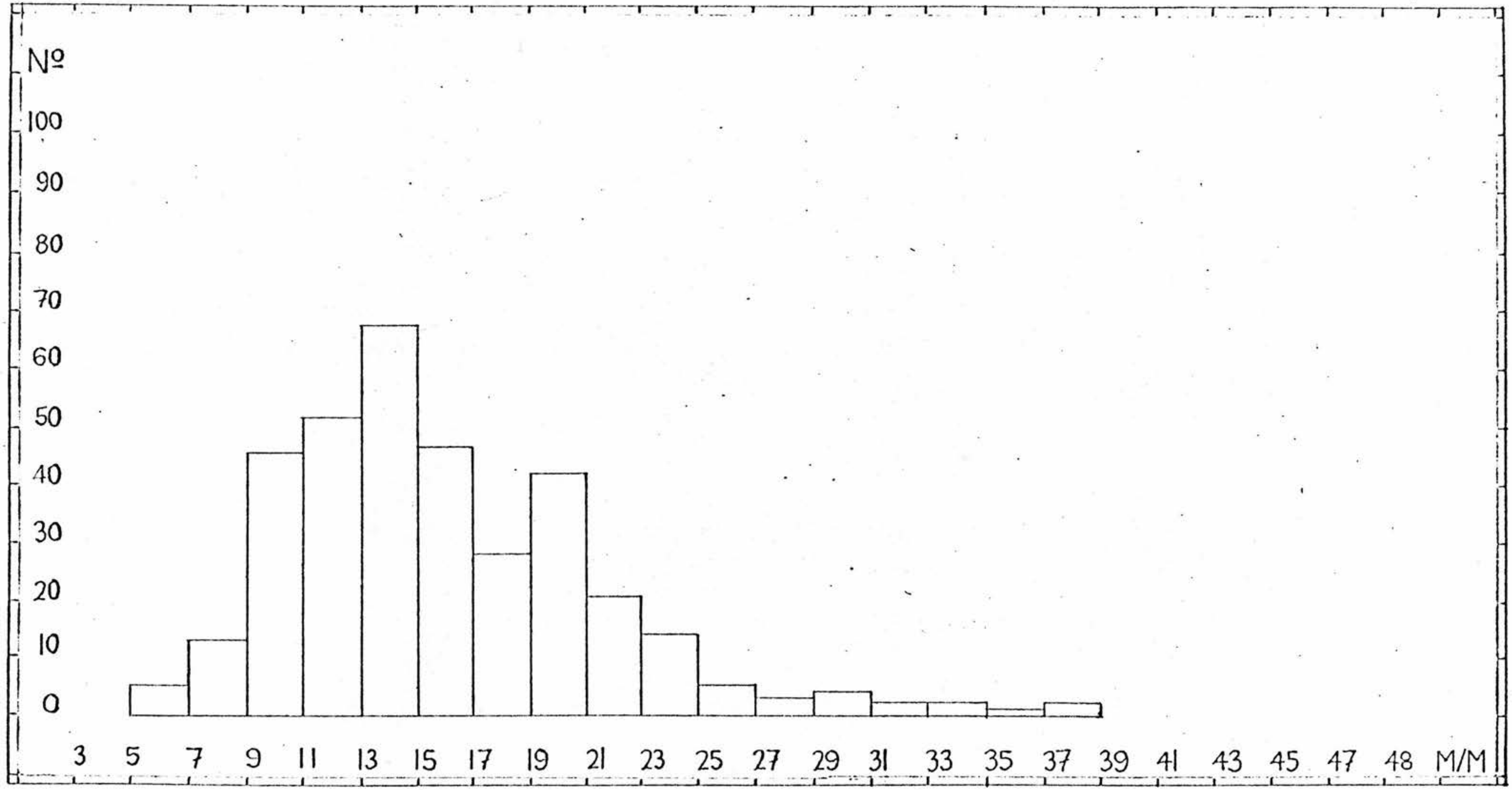
Figure 12


kg
GIRLS
Weight
80
70
60
50
40
30
20
10
Single-Time
Standard
(cross-sectional)
97
50
3
Repeated-Visit
Standard
(longitudinal)
97
50
3
97
90
75
50
25
10
3
Age, years
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

Distribution of Skinfold Measurements

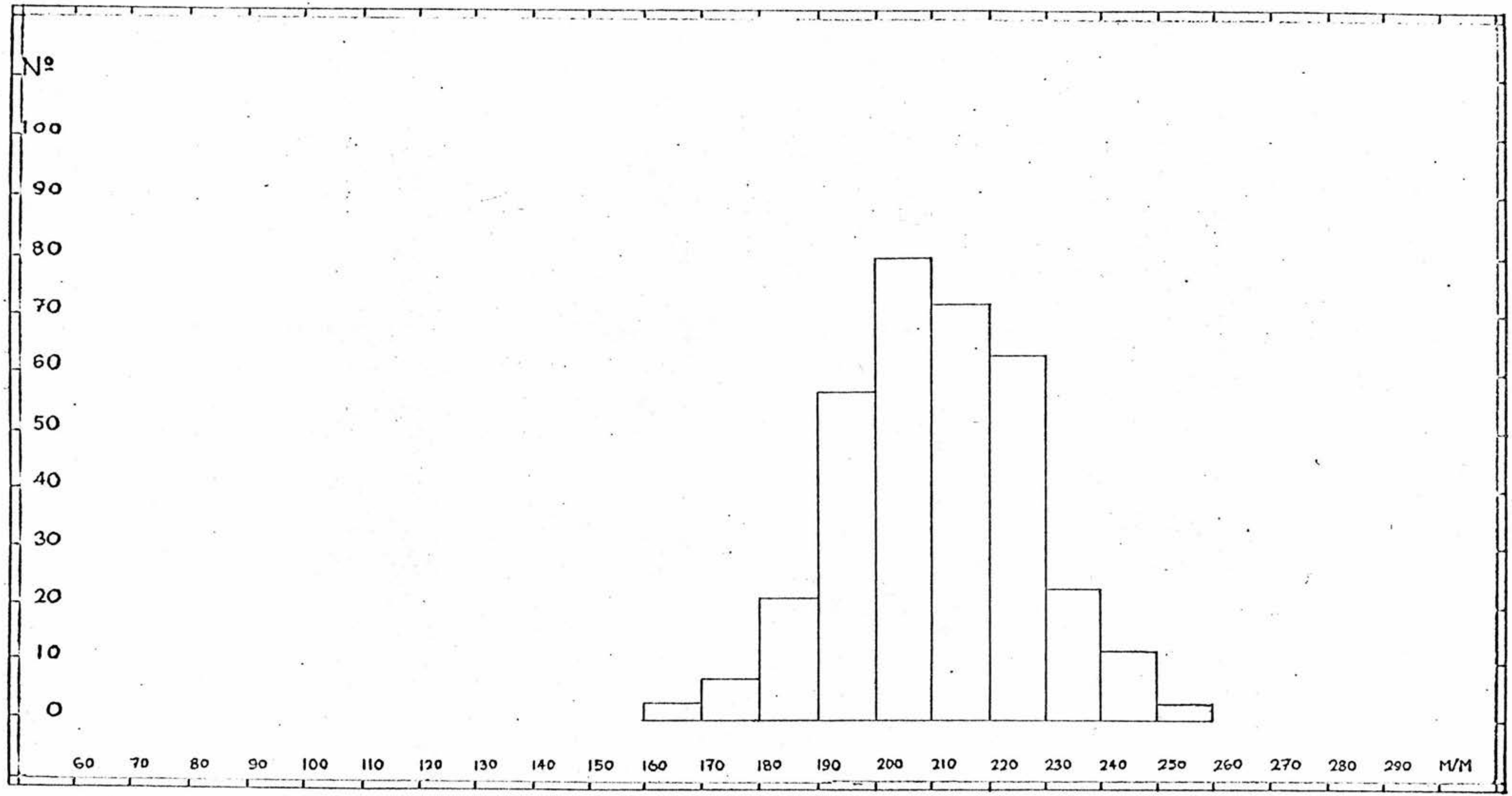
The distribution of each of the four skinfold measurements in all four groups, fathers, mothers, sons and daughters, was positively skewed with a long tail of high readings. As found by others, and as demonstrated in figures 13 & 14 log transformation of the data reduced the positive skewness (Edwards, Hammond, Healy, Tanner & Whitehouse, 1955; Durnin & Womersley, 1974). Frequency distributions of the other skinfolds before and after log transformation with the measures of skewness and kurtosis of each are in the appendix. As the log transformed data approached more closely the normal distribution log transformed skinfold data were used in all analyses.

Frequency Distribution Adult Triceps Skinfold - Female Children Raw Data Figure 13



Frequency Distribution Triceps - Log Transformed Adult Girls

Figure 14



Skinfold Measurement - Means

The yearly mean values for each skinfold from 2 to 70 years increase with increasing age (Figures 15, 16, 17 & 18) Full details of yearly means, standard deviations and the range of values found for each skinfold are in the appendix (100 to 104.)

FIGURE 15

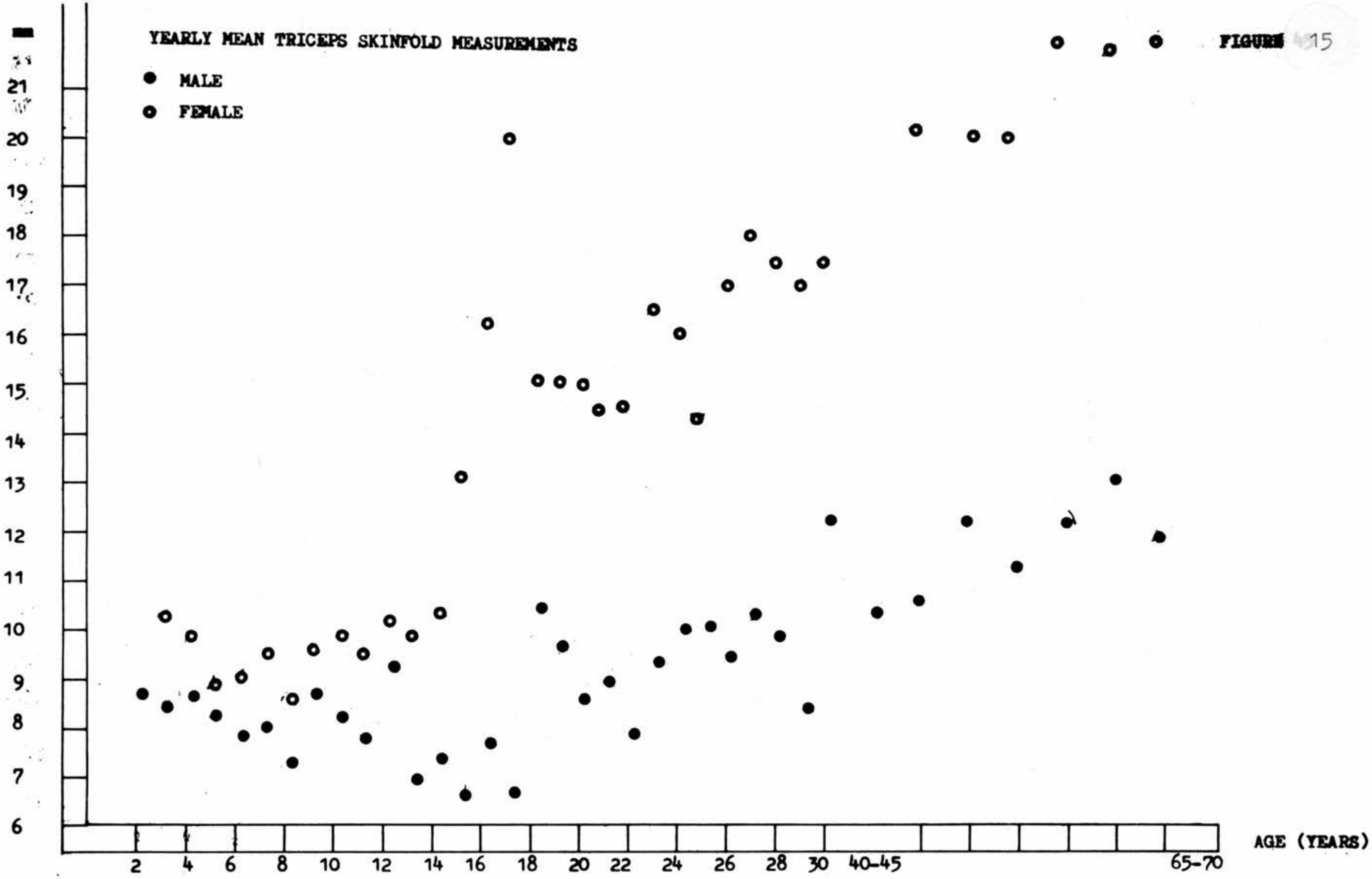
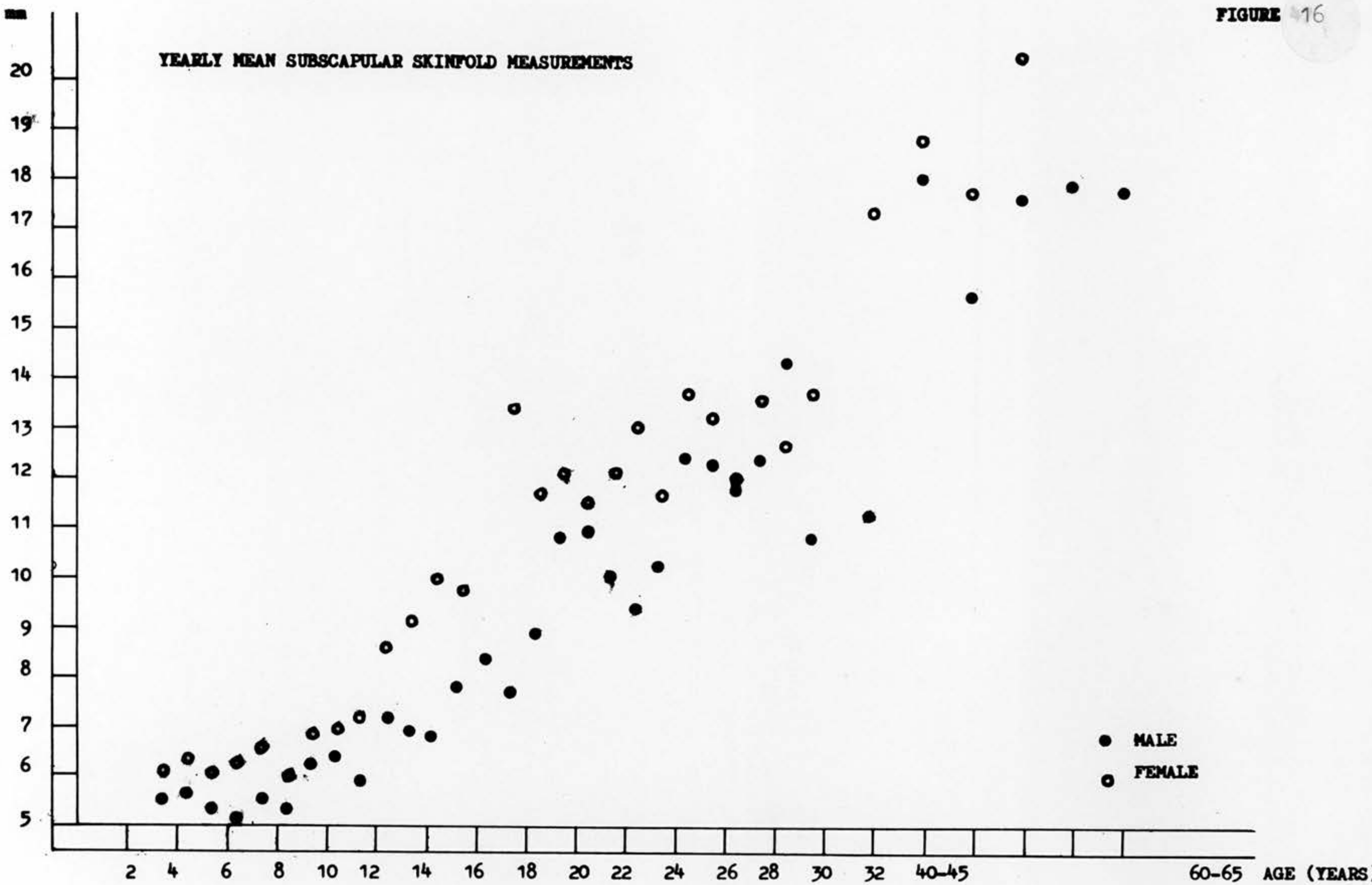

YEARLY MEAN TRICEPS SKINFOLD MEASUREMENTS
MALE
FEMALE
mm
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 40-45 65-70
AGE (YEARS)

FIGURE 16



YEARLY MEAN SUBSCAPULAR SKINFOLD MEASUREMENTS

FIGURE 17

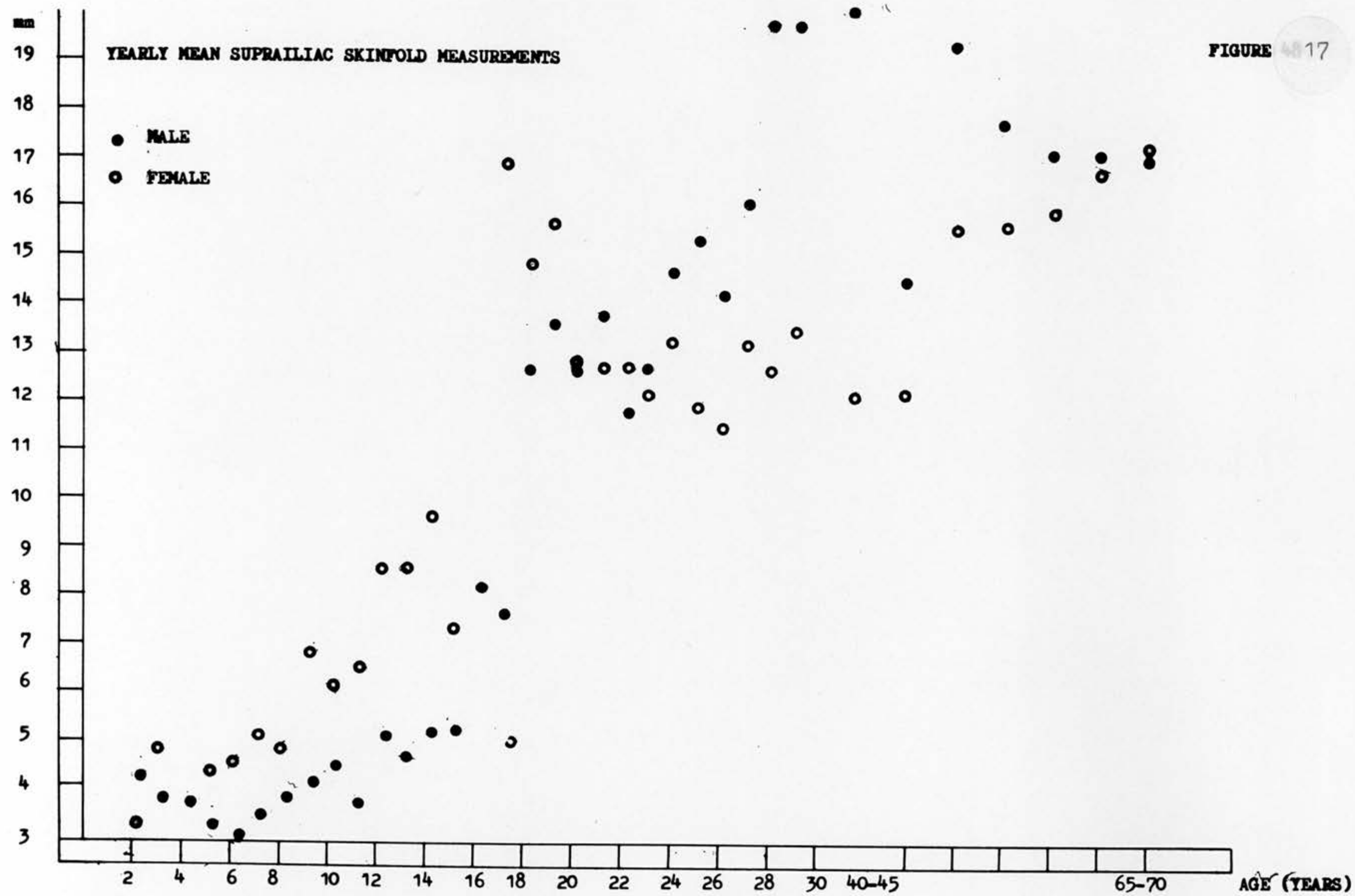
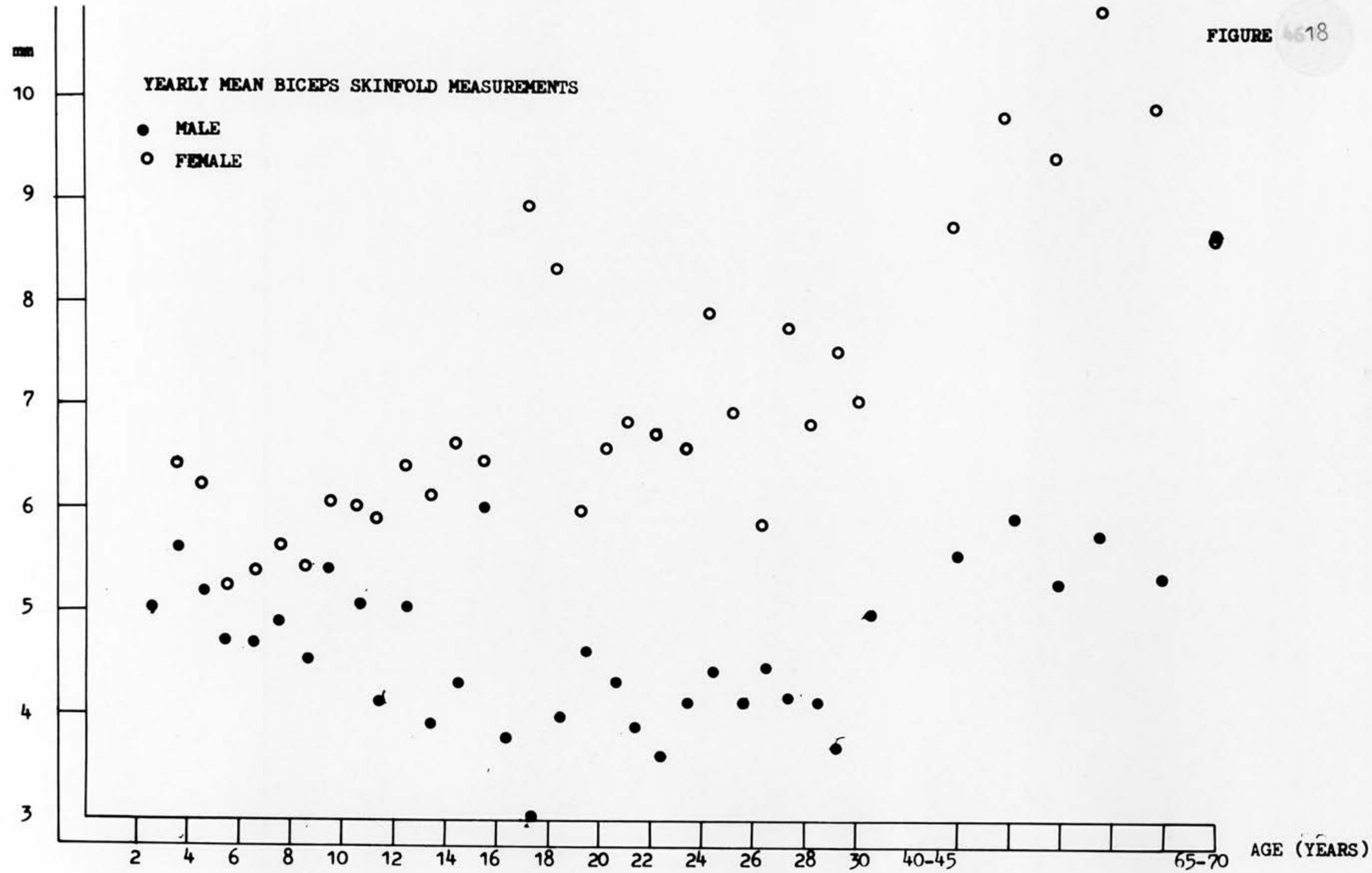

YEARLY MEAN SUPRAILIAC SKINFOLD MEASUREMENTS
MALE
FEMALE
mm
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
40-45
65-70
AGE (YEARS)

FIGURE 18


YEARLY MEAN BICEPS SKINFOLD MEASUREMENTS
MALE
FEMALE
mm
10
9
8
7
6
5
4
3
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
40-45
65-70
AGE (YEARS)

SECTION II

Relationships between Skinfold Measurements Made in Childhood and Repeated in Adult Life

The relationships between childhood and adult skinfold measurements were assessed separately for males and for females and in each group were calculated for three subgroups.

Group I individual year groups were used

Group II two year age groupings were used

Group III the total groups of males and of females were subdivided into three.

Calculations were repeated for each individual skinfold, triceps, biceps, subscapular, and suprailiac and for the four skinfolds combined (TBSS).

Individual Skinfolds

Group I: Significant correlations between childhood and adult individual skinfold measurements were found from some years in childhood and not from others (Tables 3 & 4).

TABLE 3

Individual Skinfold Measurements - Longitudinal Correlations - 1 Year Groups (GROUP I)

Males

Age at first Measurement	No.	TRICEPS 'r'	TRICEPS 'P'	BICEPS 'r'	BICEPS 'P'	SUBSCAPULAR 'r'	SUBSCAPULAR 'P'	SUPRAILIAC 'r'	SUPRAILIAC 'P'
4-5	(23)	.58	(0.01)	.15	(N.S.)	.46	(0.05)	.48	(0.05)
5-6	(35)	.38	(0.05)	.10	(N.S.)	.35	(0.05)	.14	(N.S.)
6-7	(28)	.53	(0.01)	.50	(0.01)	.28	(N.S.)	.41	(0.05)
7-8	(24)	.53	(0.01)	.42	(N.S.)	.85	(.001)	.72	(.001)
8-9	(31)	.31	(N.S.)	.20	(N.S.)	.41	(0.05)	.41	(0.05)
9-10	(31)	.73	(.001)	.57	(.001)	.51	(0.01)	.59	(.001)
10-11	(34)	.59	(.001)	.32	(N.S.)	.56	(.001)	.43	(0.01)
11-12	(21)	.41	(N.S.)	.11	(N.S.)	.51	(0.05)	.64	(0.01)
12-13	(33)	.62	(.001)	.60	(.001)	.32	(N.S.)	.27	(N.S.)
13-14	(30)	.80	(.001)	.74	(.001)	.77	(.001)	.43	(0.05)
14-15	(8)	.77	(0.05)	.24	(N.S.)	.65	(N.S.)	.80	(N.S.)

TABLE 4

Individual Skinfold Measurements Longitudinal Correlations - 1 Year Groups (GROUP I)

Females

		TRICEPS		BICEPS		SUBSCAPULAR		SUPRAILIAC	
Age at first Measurement	No.	'r'	'P'	'r'	'P'	'r'	'P'	'r'	'P'
4-5	(14)	.07	(N.S.)	.44	(N.S.)	.48	(N.S.)	.06	(N.S.)
5-6	(31)	.60	(.001)	.62	(.001)	.15	(N.S.)	.44	(0.05)
6-7	(33)	.32	(N.S.)	.24	(N.S.)	.18	(N.S.)	.20	(N.S.)
7-8	(25)	.71	(.001)	.52	(0.01)	.49	(0.05)	.50	(0.01)
8-9	(33)	.57	(.001)	.47	(0.01)	.46	(0.01)	.38	(0.05)
9-10	(24)	.15	(N.S.)	.26	(N.S.)	.11	(N.S.)	.10	(N.S.)
10-11	(38)	.33	(0.05)	.51	(.001)	.46	(0.01)	.44	(0.01)
11-12	(22)	.68	(.001)	.45	(0.05)	.81	(.001)	.90	(.001)
12-13	(29)	.38	(0.05)	.51	(0.01)	.44	(0.05)	.62	(.001)
13-14	(29)	.30	(N.S.)	.35	(N.S.)	.55	(0.01)	.54	(0.01)
14-15	(8)	.21	(N.S.)	.40	(N.S.)	.22	(N.S.)	.27	(N.S.)

The childhood ages from which the prediction of adult values was possible formed no obvious pattern and were different for males and for females. No one individual skinfold emerged as a more consistent predictor than any other.

Where prediction was possible, the accuracy of the prediction was assessed from the regression analysis as described (Methods page 25) The accuracies of the predictions were estimated to include 95% of cases and varied between ± 10.6% to ± 26.2% in the females and between 13.8% to 24.2% in the males.

Group II: When the age range in the analysis was widened to include two year groups significant correlations between childhood and adult individual skinfold measurements were again found for some groups and not for others. (Tables 5 & 6)

TABLE 5

Longitudinal Individual Skinfold Correlations - 2 Year Groups - (GROUP II)

Males

Age at first Measurement	No.	TRICEPS 'r'	TRICEPS 'P'	BICEPS 'r'	BICEPS 'P'	SUBSCAPULAR 'r'	SUBSCAPULAR 'P'	SUPRAILIAC 'r'	SUPRAILIAC 'P'
2-4	(20)	.24	(N.S.)	.42	(N.S.)	.73	(.001)	.29	(N.S.)
4-6	(58)	.47	(.001)	.16	(N.S.)	.43	(.001)	.39	(0.01)
6-8	(52)	.53	(.001)	.46	(.001)	.71	(N.S.)	.53	(.001)
8-10	(62)	.59	(.001)	.44	(.001)	.52	(.001)	.50	(.001)
10-12	(55)	.49	(.001)	.24	(N.S.)	.51	(.001)	.39	(0.01)
12-14	(63)	.67	(.001)	.67	(.001)	.60	(.001)	.38	(0.01)
16-16	(18)	.64	(0.01)	.09	(N.S.)	.23	(N.S.)	.57	(0.05)

TABLE 6

Longitudinal Individual Skinfold Correlations - 2 Year Groups - (GROUP II)

Females

		TRICEPS		BICEPS		SUBSCAPULAR		SUPRAILIAC	
Age at first Measurement	No	'r'	'P'	'r'	'P'	'r'	'P'	'r'	'P'
2-4	(17)	.62	(0.01)	.21	(N.S.)	.30	(N.S.)	.14	(N.S.)
4-6	(45)	.44	(0.01)	.37	(0.05)	.27	(N.S.)	.27	(N.S.)
6-8	(58)	.53	(.001)	.46	(.001)	.36	(0.01)	.38	(0.01)
8-10	(57)	.37	(0.01)	.39	(0.01)	.12	(N.S.)	.19	(N.S.)
10-12	(60)	.53	(.001)	.49	(.001)	.80	(.001)	.64	(.001)
12-14	(58)	.35	(0.01)	.43	(.001)	.48	(.001)	.58	(.001)
14-16	(18)	.21	(N.S.)	.44	(N.S.)	.28	(N.S.)	.30	(N.S.)

Where prediction was possible, the accuracies of the predictions varied between ± 12.9% to ± 23.5% in the females, and between ± 13.1% to ± 20.5% in the males.

Group III: All correlations were significant with the exception of the subscapular skinfold for the female group aged 2-6 years at the time of first measurement (Table 7)

Adult measurements could be predicted in 95% of cases with accuracies varying between ± 18.0% to ± 22.2% in the females, and between ± 14.5% to ± 23.5% in the males.

TABLE 7

Individual Skinfold Measurements - Longitudinal Correlations - (GROUP III)

Males

Age at first Measurement	No.	TRICEPS 'r'	TRICEPS 'P'	BICEPS 'r'	BICEPS 'P'	SUBSCAPULAR 'r'	SUBSCAPULAR 'P'	SUPRAILIAC 'r'	SUPRAILIAC 'P'
2-6	(78)	.36	(.001)	.20	(N.S.)	.52	(.001)	.34	(0.01)
6-10	(114)	.47	(.001)	.44	(.001)	.59	(.001)	.54	(.001)
10-15	(126)	.58	(.001)	.41	(.001)	.62	(.001)	.47	(.001)

Females

Age at first Measurement	No.	TRICEPS 'r'	TRICEPS 'P'	BICEPS 'r'	BICEPS 'P'	SUBSCAPULAR 'r'	SUBSCAPULAR 'P'	SUPRAILIAC 'r'	SUPRAILIAC 'P'
2-6	(62)	.46	(.001)	.36	(0.01)	.21	(N.S.)	.32	(0.01)
6-10	(115)	.41	(.001)	.40	(.001)	.35	(.001)	.25	(0.01)
10-15	(126)	.40	(.001)	.46	(.001)	.53	(.001)	.49	(.001)

Relationship Between Childhood and Adult Combined Skinfold Measurements, Triceps + Biceps + Subscapular + Suprailiac (TBSS)

Group I: All correlations between childhood and adult combined measurements in the male group were significant. The female group showed more variation (Table 8)

TABLE 8

Combined Skinfold Measurements (TBSS) - Longitudinal Correlations - (GROUP I)

Age at first Measurement	NUMBERS Male	NUMBERS Female	CORRELATIONS BETWEEN CHILDHOOD & ADULT TBSS Male 'r'	Male 'P'	Female 'r'	Female 'P'
4-5	23	14	.48	(0.05)	.06	(N.S.)
5-6	35	31	.36	(0.05)	.65	(.001)
6-7	28	33	.58	(.001)	.24	(N.S.)
7-8	24	25	.65	(.001)	.62	(.001)
8-9	31	33	.51	(0.01)	.45	(0.01)
9-10	31	24	.67	(.001)	.12	(N.S.)
10-11	34	38	.55	(.001)	.46	(0.01)
11-12	21	22	.61	(0.01)	.76	(.001)
12-13	33	29	.57	(.001)	.63	(.001)
13-14	30	29	.59	(.001)	.32	(N.S.)
14-15	8	8	.78	(0.05)	.51	(0.05)

Adult combined measurements could be predicted in 95% of cases in the group of males with accuracies varying between ± 10.6% to ± 14.5% and in the group of females between ± 8.0% to ± 13.3%.

With two year age grouping (Group II) variations remained in the female group.

TABLE 9

Combined Measurements (TBSS) - Longitudinal Correlations - (GROUP II)

Age at first Measurement	NUMBERS Male	NUMBERS Female	CORRELATIONS BETWEEN CHILDHOOD & ADULT TBSS Male 'r'	Male 'P'	Female 'r'	Female 'P'
2-4	20	17	.48	(0.05)	.14	(N.S.)
4-6	58	45	.48	(.001)	.45	(0.01)
6-8	52	58	.70	(.001)	.49	(.001)
8-10	62	57	.63	(.001)	.21	(N.S.)
10-12	55	60	.48	(.001)	.65	(.001)
12-14	63	58	.56	(.001)	.38	(0.01)
14-16	18	18	.53	(0.05)	.31	(N.S.)

Predictive accuracies varied in the males between ± 14.1% to ± 18.0%, and in the females between ± 12.9% to ± 13.9%.

A further increase in the numbers (Group III) led to significant correlations for the combined measurements in all groups of males and females.

TABLE 10

Combined Measurements (TBSS) Longitudinal Correlations(GROUP III)

Age at first Measurement	NUMBERS Male	NUMBERS Female	CORRELATIONS BETWEEN CHILDHOOD & ADULT TBSS Male 'r'	Male 'P'	Female 'r'	Female 'P'
2-6	78	62	.54	(.001)	.35	(0.01)
6-10	114	115	.58	(.001)	.33	(.001)
10-15	126	126	.54	(.001)	.50	(.001)

These correlations between males and females were significantly different. The accuracy of the predictions varied in males between ± 14.7% to ± 15.4% and in the females between ± 11.9% to ± 18.0%.

In Summary, for both the individual and the combined measurements, Group I results indicated there to be some years in childhood from which adult skinfold measurements could be better predicted. With increasing group size and widening of the age range included in the analysis, (Group II and Group III results,) the correlations coefficients fell in value, the ability to predict adult from childhood values increased, but the accuracy of the prediction tended to fall.

TABLE 11

Range of Predictive Accuracies, Described as Percentage Variation of the Means

	GROUP	INDIVIDUAL SKINFOLDS	COMBINED SKINFOLDS
	I	10.6 - 26.2	8.0 - 13.3
Female	II	12.9 - 23.5	12.9 - 13.9
	III	19.0 - 22.2	11.9 - 18.0
	I	13.8 - 24.2	10.6 - 14.5
Male	II	13.1 - 20.5	14.1 - 18.0
	III	14.5 - 23.5	14.7 - 15.4

Z Score Transformations

Using the Z score transformation (Methods - Page 25), the total groups of males and of females could be considered together. The overall longitudinal correlations found were:

Male	0.56	(318)
Female	0.45	(303)

The difference is statistically significant.

Relationship Between Fatness in Childhood and in Adult Life in Fatter Children

Individuals were selected who had a childhood triceps or subscapular skinfold measurement on or above the 75th centile (Tanner & Whitehouse, 1975). Age groupings were as in Group III.

TABLE 12

Childhood Triceps Skinfold - Greater than 75th Centile

	NUMBERS		CORRELATION BETWEEN CHILDHOOD & ADULT TBSS			
Age at first Measurement	Male	Female	Male		Female	
			'r'	'P'	'r'	'P'
2-6	11	-	.69	(0.05)	-	-
6-10	17	9	.55	(0.05)	.04	(N.S.)
10-15	10	9	.07	(N.S.)	.21	(N.S.)

TABLE 13

Childhood Subscapular Skinfold - Greater than 75th Centile

Age at first Measurement	NUMBERS Male	NUMBERS Female	CORRELATION BETWEEN CHILDHOOD & ADULT TBSS Male 'r'	Male 'P'	Female 'r'	Female 'P'
2-6	13	19	.60	(0.05)	.09	(N.S.)
6-10	23	14	.61	(0.01)	.04	(N.S.)
10-15	11	11	.06	(N.S.)	.01	(N.S.)

None of the correlations in the female group were significant. In the males aged 2-6 and 6-10 the correlations were not significantly different from the correlations found for the total population.

SECTION III

Resemblances in Skinfold Measurements Between Parents and Offspring

Parents and their offspring had skinfold measurements taken when they were of widely different ages. The average present ages of the fathers and mothers respectively were 57.2, S.D, 6.1 and 54.1, S.D, 5.4. Offspring were first measured when they ranged in age between 2-15 years and measurements were repeated when they ranged in ages between 17-30 years.

Parents and offspring were therefore compared using the Z score transformations. (Page 25 - 26)

TABLE 14

Correlations Between Parents and their Growing Offspring (15 years or less)

	'r'	'P'	Number
Father - Son	0.21	(N.S)	(280)
Father - Daughter	0.16	(N.S)	(271)
Mother - Son	0.19	(N.S)	(316)
Mother - Daughter	0.11	(N.S)	(286)
Midparent - Son	0.21	(N.S)	(252)
Midparent - Daughter	0.19	(N.S)	(253)

TABLE 15

Correlations Between Parents and their Adult Offspring (20 years or more)

	'r'	'P'	Number
Father - Son	0.19	(N.S)	(264)
Father - Daughter	0.10	(N.S)	(257)
Mother - Son	0.21	(N.S)	(311)
Mother - Daughter	0.20	(N.S)	(250)
Midparent - Son	0.23	(N.S)	(238)
Midparent Daughter	0.24	(N.S)	(228)

No resemblances were found between parents and their growing offspring or between parents and their adult offspring. Midparent offspring correlations were also never significant.

Twin Resemblances in Body Fatness

The intrapair twin correlations were calculated directly from the skinfold measurements, as twins are of the same age. (Table 16 & 17)

TABLE 16

Twin Intrapair Correlations for Skinfold Measurements : Childhood

	MONOZYGOTIC		DIZYGOTIC	
	Male	Female	Male/Male	Female/Female
No. Pairs	29	20	46	45
	'r'	'r'	'r'	'r'
Triceps	.84	.58	.62	.51
Biceps	.54	.60	.37	.54
Subscapular	.96	.47	.48	.28
Suprailiac	.84	.66	.16	.42
T + S	.83	.59	.44	.46
T + B + S + S	.81	.81	.48	.51

TABLE 17

Twin Intrapair Correlations for Skinfold Measurements : Adults

	MONOZYGOTIC		DIZYGOTIC	
	Male	Female	Male/Male	Female/Female
No. Pairs	29	20	46	45
	'r'	'r'	'r'	'r'
Triceps	.79	.93	.60	.23
Biceps	.85	.79	.44	.18
Subscapular	.80	.77	.75	.19
Suprailiac	.67	.65	.63	.16
T + S	.84	.88	.69	.16
T + B + S + S	.74	.82	.68	.16

In childhood the monozygotic twins resembled one another closely both for individual and for combined skinfold measurements and resembled one another more closely than the dizygotic twins. As adults the monozygotic twins continued to resemble one another closely for individual and combined measurements. The like sexed adult dizygotic male twins tended to resemble one another more than had been the case in the childhood. By contrast, the like sexed adult female dizygotic twins showed very little resemblance.

Approximately half of the twins in each of these categories (monozygotic male and female and dizygotic like sexed male and female) had been living apart for four years or longer. In order to see if this altered the extent to which they did or did not resemble one another, intrapair correlations were recalculated separately for the two groups. The resultant correlations were the same as for the total groups. Intrapair correlations were further recalculated in the groups of female twins, those twin pairs being excluded where one or both girls had had a child (six monozygotic twin pairs and nine dizygotic twin pairs). The intrapair correlations remained in the same range as for the total group.

Intrapair correlations for the unlike sexed twin pairs were calculated from the combined skinfold (TBSS) Z transformations.

<u>Intrapair Correlations Between Male/Female Dizygotic Twin Pairs - Z Transformations</u>

		Number of Pairs
Childhood	0.55	66
Adult	0.45	66

Throughout childhood they resembled one another as much as the like sexed dizygotic twins. As adults they resembled one another less than the male dizygotic twins but more than the female dizygotic twins.

Sibling Resemblances

The Z score transformations were used to compare in childhood and in adult life brothers with brothers of different ages, sisters with sisters of different ages and brothers with sisters. In contrast to the twin results no resemblances were found between siblings, of whom neither was a twin, in childhood and only a slight resemblance was found in adult life between brothers.

TABLE 18

Childhood Correlations Between Siblings (Neither one a Twin)

	'r'	'P'	Number of Pairs
Brother - Brother	.20	(N.S)	15
Sister - Sister	.34	(N.S)	13
Brother - Sister	.30	(N.S)	28

TABLE 19

Adult Correlations Between Siblings (Neither One A Twin)

	'r'	'P'	Number of Pairs
Brother - Brother	.30	(.05)	25
Sister - Sister	.05	(N.S)	20
Brother - Sister	.25	(N.S)	37

When sibling resemblances were calculated between a singleton sibling and one twin, brothers resembled one another slightly both as children and as adults. Sisters showed no resemblances.

TABLE 20

Childhood Correlations Between Siblings (One Twin and One Singleton in each Pair)

	'r'	'P'	Number of Pairs
Brother - Brother	.34	(.05)	68
Sister - Sister	.19	(N.S)	38

TABLE 21

Adult Correlations Between Siblings (One Twin and One Singleton in Each Pair)

	'r'	'P'	Number of Pairs
Brother - Brother	.36	(.05)	60
Sister - Sister	-.03	(N.S)	48

DISCUSSION

Relationship Between Childhood and Adult Skinfold Measurements

The data in this study on mean yearly skinfold values are cross-sectional and no less open to criticism than previous such studies. The relevance of the findings to any one individual can only be inferred. Two features appeared relevant to the proposal that subcutaneous fat distribution is not constant.

Firstly, in childhood, for each skinfold, female values were consistently higher than male values, while beyond the age of 24 years female and male subscapular values were closely similar and male suprailiac values exceeded female suprailiac values. Second, if from the data the percentage increase in each skinfold measurement with age is calculated, the following is found.

Percentage Increase in Skinfold Measurement with Age

(6-70 years)

	Males	Females
Triceps	50%	150%
Biceps	25%	66%
Subscapular	250%	233%
Suprailiac	400%	220%

In both sexes there is a proportionately greater increase in body fat than in limb fat and the sexes differ for the triceps and suprailiac measurements.

With a change in the distribution of subcutaneous fat the ratio of subcutaneous fat at any one site to total body fat would alter. In this circumstance, it would theoretically be possible to find a positive correlation between the two ages for total body fat while, at the same time, finding no correlation between the two skinfold measurements.

Changes in subcutaneous fat distribution might explain, at least in part, the finding that adult triceps, biceps, subscapular or supra-iliac measurements individually, could be predicted from some years in childhood and not from others.

The variations found might, however, reflect measurement errors. The individuals in the study were measured on each occasion by different observers. This leaves room for measurement errors by each individual and for measurement errors between the observers because of different techniques used. It was not possible to compare the measurement techniques of the first observer, who has now retired, with those of the present observer. It is doubtful, in any case, if any reliability could have been placed on such an analysis, it being fifteen years since the original observer took the measurements.

While measurement errors cannot be entirely dismissed, several factors indicate them to be an unlikely explanation of the variations found. The present observer found that repeat measurements could be made at the same site with an accuracy greater than the $\pm$ 5% quoted by Edwards, Hammond, Healy, Tanner & Whitehouse (1955). Indirect evidence that the original measurements were consistent comes from the finding that the study population yearly mean triceps and subscapular measurements fell close to the mean values from the standard charts for British children of Tanner & Whitehouse (1975). The range of values in each year group showed no 'wild' results, though some of the measurements were smaller than would be expected in the childhood population of today. The analysis was repeated excluding all those children with very low skinfold measurements and the results were equally variable.

The combination of the four skinfold measurements, triceps plus biceps plus subscapular plus suprailiac, is used to indicate body fatness levels. Combined measurements make no allowance for changes in the ratio of subcutaneous to deep fat which might lead to a situation analogous to that described for changes in the distribution of subcutaneous fat. In the absence of suitable data this possibility must remain entirely speculative. This combination has, however, two advantages. Some account is taken of changes in the distribution of subcutaneous fat and between observer measurement error is less than for individual skinfold measurements. That these factors may be relevant is suggested from the finding that while the correlations between childhood and adult combined measurements did show variations, they were more consistent than for the individual skinfolds.

Dugdale (1975) has postulated that body fatness levels fluctuate periodically throughout childhood in relation to periods of growth, the level of body fatness rising prior to each growth spurt, thus providing the extra energy required. The pre-adolescent gain in subcutaneous fat which is known to occur prior to the adolescent growth spurt fits this hypothesis well. As can be seen from the graph comparing twins and siblings (Appendix P 118-127) combined skinfold thickness levels in this study population fluctuated throughout childhood.

Adults have more body fat than children. If adult body fatness levels are held constant, higher longitudinal correlations would be anticipated from those ages in childhood when body fatness levels were at 'peak' rather than at 'trough' values. If, next, adult body fatness levels are allowed to vary, these variations would effect the longitudinal correlations from each age in childhood. If it is postulated that adult body fatness levels fluctuate less than childhood body fatness levels it would be anticipated that, overall, longitudinal correlations would tend to be better from childhood peak fatness years but this would not be entirely consistent. The findings in this study for the combined measurements in Group I fit such a hypothesis.

With increasing groupsize for both the individual and the combined skinfolds the correlation values tended to fall but the ability to predict adult from childhood values increased. As skinfold measurements change with age, widening of the age range included in the analysis would be expected to reduce the correlations. The numbers in Group I were small. Whether, as suggested from Group I results there are particular ages during childhood when the level of body fatness is of importance to the level of body fatness in adult life or whether, as suggested from Group II and Group III results, there is an overall and less specific relationship cannot be definitely stated.

The Z score correlations, which allowed for age changes in skinfold measurements and for the total groups of males and of females to be considered together were 0.56 and 0.45 respectively. Where prediction was possible, the accuracies of the predictions, calculated as previously described, ranged for the individual skinfolds between ± 10.6% to ± 26.2%, and for the combined skinfolds between ± 8.0% to ± 18.0%. These findings suggest there to be a moderate relationship between childhood and adult body fatness levels; a relationship in which room is left to manoeuvre.

Family Resemblances

Had there been no twins in this study group it might reasonably have been stated that body fatness levels do not run in families and reasonably implied that the level of body fatness is in no way determined by hereditary influences. Had there been only twins in this study group it might reasonably have been stated that body fatness levels do run in families and reasonably implied that the level of body fatness is strongly genetically determined. Therein lie the problems in the interpretation of family data.

The childhood growth patterns of the twins and of the siblings did not differ significantly (Appendix -P 118-127). Neither were there any significant differences in the relationships found between childhood and adult skinfold measurements in the two groups.

Family members share both genes and many common environmental factors. Resemblances found between them might be the result of either or both. Fisher (1918) demonstrated how, for fully genetically determined characteristics, different family members would be expected to resemble one another. He followed up his analysis with details on the resemblances found between family members for adult height. The correlations found came close to those anticipated for a fully genetically determined characteristic. An assumption he made in his analysis was that the environment was not contributing anything towards the resemblances seen. The average adult height in Western countries has increased by approximately 10 cm in the last century. While this might reasonably be attributed to improved environmental conditions overall, and for each generation, dramatic alterations in adult height attained might reasonably be considered to require somewhat violent environmental effects eg. major trauma.

That environmental factors e.g. exercise or diet can and do influence body fatness levels is in no doubt (Parizkova, 1963; Jokl, 1963; Sims, Goldman, Gluck, Horton, Kelleher & Rowe, 1968). How much the resemblances found between relatives for body fatness levels reflects their shared genes or their shared common environments is therefore much more open to question. The results from twin data on body fatness levels, in particular, becomes difficult to interpret.

An attempt was made throughout the study to assess each individual's activity level. Taken into account were:

(i) Sports played at school and teams represented.

(ii) Sports played at University/College and teams represented.

(iii) Type and frequency of sports still enjoyed.

(iv) Age at which regular sporting activities ceased.

(v) Present level of daily exercise.

There proved to be too many variables to allow satisfactory statistical analysis. Several trends emerged in the groups of twins, however, which I believe to be important. I was greatly impressed by the extraordinary similarity of life styles and habits of many of the monozygotic twins. This was much less obvious between the dizygotic twins. Many of the monozygotic girls commented on the advantage of being the same size, thus allowing each a choice of clothing from two wardrobes. In general, it seemed to me, male twin pairs, monozygotic and dizygotic took advantage of having a brother of the same age with whom to play, for example,squash. This was much less in evidence among the female twins.

The resemblances in body fatness found between the twins mirror these differences. Monozygotic twins resembled one another closely as children and as adults and more closely than dizygotic twins. The male and female dizygotic twins resembled one another equally as children but as adults the male dizygotic twins continued to resemble one another while the female dizygotic twins did not resemble one another at all.

The almost total lack of resemblances in body fatness found in this study between siblings stands in marked contrast to the twin results. The methods of analysis were different, twins being compared directly using the combined skinfold measurement totals and siblings with the Z score transformations. Intrapair twin correlations were recalculated using the Z score transformations, with the following results.

Twin Intrapair Z Score Transformation Correlations

		Childhood	Adult Life
Monozygotic	Male	0.84	0.68
	Female	0.72	0.81
Dizygotic	Male	0.41	0.65
	Female	0.54	0.21

The differences between the correlations in each twin group, calculated from Z scores and from direct measurements, do not suggest that differences in the methods of analysis in themselves are sufficient to explain the different sibling results.

The obvious difference between the twin and sibling groups is the variation in age between the sibling pairs. While siblings share many common environmental factors their difference in age produces difference between them which do not occur between twins. For example, children, certainly in my experience, are frequently encouraged to "empty your plate". What is on the plate is determined largely by the attitude of the mother and the prevailing financial circumstances. It might reasonable be argued that a mother with, for example, four children did not provide the same quantity/quality of food for each child at equivalent age, either because of a change in attitude on the mother's part or a change in financial circumstances. Each twin in a pair, by contrast, meets the same prevailing attitudes, and circumstances and is it not reasonable to suppose they are given identical amounts to avoid any suggestions of "favouritsm".

It is not intended to suggest that the only factor of any relevance to body fatness levels is the amount eaten. The salient point is the contrast between the siblings and the twins, a contrast which could be argued for many other circumstances.

That the differences in resemblances for body fatness between the twins and siblings is largely environmentally induced is further supported by the finding that while twins resembled one another they did not resemble their singleton brothers or sisters.

The parents' skinfold measurements were not taken between 1961 and 1962 when the offspring ranged in age from 2-15 years. When the parents skin-fold measurements were recorded between 1976 and 1977 approximately 75% of the offspring were no longer living at home. All of the parent-growing offspring correlations and the majority of the parent-adult offspring correlations therefore reflect the situation where parents and children are not sharing common family environments. The lack of resemblances found in this study between parents and their offspring who were not, at the time of measurement, sharing common family environmental conditions, compared to the positive correlations found by others between parents and their offspring when the offspring were still living at home, suggest the common family environment to be an important factor in the determination of body fatness levels.

For characteristics which are largely genetically determined the midparent offspring correlations would be anticipated to be higher than the individual parent offspring correlations. This was not found to be the case in this study.

The results found in this study on family resemblances in body fatness levels are considered to be best explained on the basis that body fatness levels are largely determined by environmental factors.

Implications

The adult yearly mean skinfold values were closely similar to those found in two large American surveys (Montoye, Epstein & Kjelsberg, 1967; Frisancho, 1974). There are no suitable adult British standards for comparison. The heights, weights and skinfold measurements of the study population in childhood compare favourably with British standards. It seem therefore reasonable to infer that the results from this study are applicable to the population in general.

Single skinfold measurements have been found to reasonably predict total body fat in different groups of different ages. Different sites have however been found by different observers to predict total body fat best and, on the whole, only a few sites have been tested.

The results from this study support the limited data available which suggests that subcutaneous fat distribution is not constant. The possibility is therefore raised that as an index of body fatness, particularly in groups of different ages, the use of one skinfold measurement is not adequate. Conflicting results, reviewed by Mann (1974), have come from studies comparing the level of body fatness, assessed from one skinfold measurement, with the risk of having or of developing hypertension or cardiovascular disease. In many of these studies the ages of the individuals ranged widely. It is suggested that while only one skinfold measurement is used in such studies results will continue to give conflicting and not necessarily reliable results.

Overall, a moderate relationship has been found between childhood and adult skinfold measurements. Further studies are required to determine more clearly whether there are indeed certain ages in childhood from which adult measurements can be better predicted or whether the relationship is less specific.

Recalculation of the data on individuals selected with a childhood skinfold measurement on or above the 75th centile produced no evidence to indicate a greater relationship between childhood and adult skinfold measurements in this plumper group. There were no very obese children in this study group. If obese children form the upper end of the normal spectrum these results might reasonable be applied to them. It remains, however, to be determined if very obese children are, rather, a distinct subgroup.

The family data support environmental influences as being largely responsible for body fatness levels. The variable relationships found between childhood and adult fatness levels might be argued to indicate that some individuals carry with them into adult life the life styles and habits of childhood while others, left to their own devices,do not.

SUMMARY

1. The development of physicochemical methods to measure total body fat has indicated weight indices to be inconsistent as measures of body fatness and the measurement of skinfold thickness with calipers to reasonably reflect total body fat.

2. Studies using criteria of weight have indicated that overweight infants and overweight children are at higher risk than their normal weight peers of remaining overweight in later life. Recent studies comparing skinfold measurements made in infancy and repeated in childhood have found little or no relationship between the two. No previous study on the relationship between skinfold measurements made in childhood and repeated in adult life has been carried out.

3. Overweight has been noted by many to run in families with the implication being drawn that body fatness is largely genetically determined. The data available on resemblances between relatives for skinfold measurements vary and have produced conflicting opinions on the relative effects of heredity and of the environment in the determination of body fatness levels.

4. Fifteen years ago skinfold thickness measurements were recorded at the triceps, biceps, subscapular and suprailiac sites on offspring aged 2-15 years in 330 families. Amongst the offspring were twins.

5. In this follow up and family study 296 (89%) of the families have been retraced and 256 (77%) remeasured. Within the 256 families 318 (90%) of the males and 303 (86%) of the females who had skinfolds measured on the first occasion were remeasured. Resemblances between relatives

were calculated between 186 (77%) fathers, 211 (85%) mothers, 378 (84%) sons and 372 (85%) daughters, who had skinfolds measured on this occasion.

6. The distribution of each of the skinfold measurements was found to be logarithmic. Log transformation of the data normalised the distribution. Log transformed data were used in all analyses.

7. The relationship between childhood and adult skinfold measurements was calculated fromregression analyses for each individual skinfold and for the four skinfolds combined (triceps plus biceps plus subscapular plus suprailiac). Calculations were repeated in three groups in either sex. In Group I each year group was considered individually. In Group II 2 year age groupings were used. In Group III the total number of males and of females were divided into three subgroups.

8. For each individual skinfold the Group I results showed there to be significant correlations between childhood and adult measurements from some years in childhood but not from others. The childhood ages from which the prediction of adult values was possible formed no obvious pattern and the skinfolds which predicted best varied. No one skinfold emerged as a more consistent predictor than any other. The significant correlations ranged from 0.35 to 0.85 in the males and from 0.33 to 0.90 in the females. Where prediction was possible the accuracies of the predictions were estimated to lie, in 95% cases, between $\pm$ 10.6% to $\pm$ 26.2% in the females and between $\pm$ 13.8% to $\pm$ 24.2% in the males.

9. Consideration is given to the possibility that the variations

found in the results from Group I for the individual skinfolds might reflect (i) measurement errors, which cannot be entirely dismissed, or (ii) changes in the ratio of subcutaneous to deep fat, changes as yet not clearly documented but suggested to occur. The variations are considered to reflect changes in the distribution of subcutaneous fat with age, changes which are inferred to occur from the study population data. (The distribution of subcutaneous fat was different in males and females and the differences altered with age. Body subcutaneous fat increased proportionately more with age than did limb subcutaneous fat.)

10. For the individual skinfolds widening of the age range included in the analysis and an increase in the numbers in each subgroup i.e. Group II and Group III results led to a drop in the correlation values and an increase in the ability to predict adult from childhood values. Subgroups remained, however, in which adult values could not be predicted from childhood values.

The significant correlations and the estimated accuracies of the predictions varied as shown.

		GROUP II	GROUP III
Male	Correlations	0.38 - 0.73	0.34 - 0.62
	Predictive Accuracies	13.1% - 20.5%	14.5% - 23.5%
Female	Correlations	0.37 - 0.80	0.32 - 0.53
	Predictive Accuracies	12.9% - 23.5%	19.0% - 22.2%

11. The combination of the four skinfold measurements, triceps plus biceps plus subscapular plus suprailiac, used as the estimator of body fatness, takes some account of variations in the distribution of subcutaneous fat and has the added advantage of showing least between observer measurement error (the individuals in this study were measured on each occasion by different observers). For the combined measurements in Group I variations were present but less marked than for the individual measurements. All correlations in the male group were significant, ranging from 0.36 to 0.78. The correlations in the female group were not consistently significant, those that were ranging from 0.45 to 0.76. Predictive accuracies varied in the males between ± 10.6% to ± 14.5% and in the females between ± 8.0% to ± 13.3%.

12. The mean yearly combined skinfold measurements were found to fluctuate in value periodically throughout childhood. The better longitudinal correlations for the combined measurements in Group I tended to occur from those ages in childhood when body fatness levels were at 'peak' values.

13. For the combined measurements as for the individual measurements, an increase in the numbers in the analysis, i.e. Group II and Group III results, led to a drop in the correlation values. The correlations in the male group remained consistently significant and in the female group inconsistently significant. The significant correlations and the estimated accuracies of the predictions varied as shown

		GROUP II	GROUP III
Male	Correlations	0.45 - 0.70	0.54 - 0.58
	Predictive Accuracies	14.1% - 15.0%	14.7% - 15.4%
Female	Correlations	0.35 - 0.65	0.33 - 0.50
	Predictive Accuracies	12.9% - 13.9%	11.9% - 18.0%

14. The results for the individual and the combined measurements from Group I suggest there to be certain ages in childhood when body fatness levels are of relevance to adult body fatness levels. The results from Groups II and III suggest the relationship to be less specific.

15. Z score transformations were calculated for the combined skinfold measurements of each individual, thus allowing for age changes in skinfold measurements and for the total groups of males and of females to be considered together. The correlations between childhood and adult Z scores were 0.56 and 0.45 in males and females respectively.

16. The data were recalculated on individuals selected with a childhood triceps or subscapular measurement on or above the 75th centile. The results did not suggest any greater relationship between childhood and adult body fatness levels in this plumper group.

17. Overall a moderate relationship has been found between childhood and adult skinfold measurements, a relationship in which room is left to manoeuvre.

18. Family members, twins excepted, having been measured at different

ages, were compared using the combined skinfold measurement Z score transformations. The parents' skinfold measurements were not taken fifteen years ago when the offspring ranged in age from 2-15 years. When the parents skinfold measurements were recorded approximately 75% of the offspring were no longer living at home. All of the parent growing offspring correlations and the majority of the parent adult offspring correlations therefore will reflect the situation when parents and offspring are not sharing common family environments.

19. No resemblances were found between parents and their growing offspring or between parents and their adult offspring. The lack of resemblances found in this study between parents and their offspring who were not, at the time of measurement, sharing common family environmental conditions, compared to the positive correlations found by others between parents and their offspring when the offspring were still living at home, suggest the common family environment to be an important factor in the determination of body fatness levels.

20. For characteristics which are largely genetically determined the midparent offspring correlations would be anticipated to be higher than the individual parent child correlations. This was not found to be the case in this study.

21. Male and female monozygotic twins were found to resemble one another closely for body fatness levels both as children and as adults. The intrapair correlations, calculated using the skinfold measurements directly ranged as shown.

INTRAPAIR CORRELATIONS

	No. Pairs	Childhood	Adult
Monozygotic Male	(29)	0.54 - 0.96	0.67 - 0.85
Monozygotic Female	(20)	0.47 - 0.51	0.65 - 0.93

22. Dizygotic twins resembled one another generally less than the monozygotic twins. In adult life the like sexed male dizygotic twins resembled one another more closely than had been the case in childhood while the like sexed female dizygotic twins did not show any significant resemblances.

DIZYGOTIC TWIN INTRAPAIR CORRELATIONS

	No. Pairs	Childhood	Adult
Male/Male	(46)	0.16 - 0.62	0.44 - 0.75
Female/Female	(45)	0.28 - 0.54	0.16 - 0.23
Male/Female	(66)	0.55	0.45

23. An attempt was made throughout the study to assess each individual's activity level. There proved to be too many variables to allow satisfactory statistical analysis. Similarities and differences noted between the life styles and habits of the different twin types mirrored the similarities and differences found between them for body fatness levels.

24. In contrast to the twin results, few and then only slight resemblances were found between siblings both as children and as adults.

The methods of analysis differed, twins being compared using the skinfold measurements directly and siblings using the Z score transformations. The twin data were recalculated using the Z score transformations. The differences between the correlations in each twin group calculated from Z scores and from direct measurements were insufficient to suggest that the differences in the methods of analysis adequately explained the different results found for the twins as compared to siblings and to parents and their offspring.

25. Twins, being of the same age, may reasonably be argued to share more environmental factors in common than siblings of different ages. The twin and sibling results are argued to indicate the importance of environmental influences in the determination of body fatness levels. In support of this is the finding that while the twins resembled one another they were not found to resemble their singleton siblings.

26. The data on resemblances for body fatness levels found between the different family members are considered to indicate that body fatness levels are largely determined by environmental factors.

27. It is implied from this study that subcutaneous fat distribution is not constant. A particular level of thickness of one individual skinfold cannot necessarily be taken to represent the same amount of body fat in individuals of different ages. It is suggested that in studies assessing the relevance of body fatness levels to health or disease, particularly when ages range widely, the use of one skinfold is inadequate.

28. It is concluded from this study that there is a moderate relationship between childhood and adult skinfold measurements and body fatness levels and that body fatness is determined largely by environmental influences. The two are not mutually exclusive. However fat an adult is or becomes may reasonably be considered to reflect, in part, the attitudes and habits instilled in childhood and, in part, the attitudes and habits adopted in adult life.

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APPENDIX

BLOOD ANALYSIS

Each Twin Had Blood Analysed For The Following Characteristics:

(i) Erythrocytic Antigens

ABO	
Rhesus	
MNS	M. N. S. Ē.
P	P_1 P
Lutheran	a. b.
Kell	K. k. Kpa Kpb
Lewis	a. b.
Duffy	a. b.
Kidd	a. b.
Xga	

(ii) Low Frequency Erythrocytic Antigens

Wr a Sw a Pt a Ri a He Bp a Hut Go a

(iii) Red Cell Enzymes

Red cell acid phosphatase

Phospho glucomutase

Adenine deaminase

Adenylate kinase

(iv) Serum Factors

Haptoglobin

Gc

(v) Haemoglobin type

Mean Heights and Weights - Childhood Male Offspring

AGE	HEIGHT				NUMBER	WEIGHT			
2-3	89.9	S.D.	5.4	(80.8-94.8)	4	13.7	S.D.	1.0	(12.6-15.0)
3-4	101.0	S.D.	4.4	(93.9-107.6)	23	16.3	S.D.	1.6	(13.5-20.0)
4-5	105.4	S.D.	4.6	(98.1-117.9)	29	17.7	S.D.	2.2	(13.5-23.2)
5-6	111.5	S.D.	6.0	(96.0-123.7)	41	19.1	S.D.	2.5	(12.3-23.5)
6-7	117.6	S.D.	5.8	(102.4-129.6)	31	21.3	S.D.	2.6	(16.5-26.3)
7-8	124.2	S.D.	7.3	(107.1-141.4)	27	23.9	S.D.	3.4	(18.2-34.1)
8-9	129.9	S.D.	6.9	(105.0-142.4)	35	26.5	S.D.	3.3	(18.9-34.8)
9-10	137.4	S.D.	5.6	(127.4-150.8)	33	31.5	S.D.	3.8	(25.4-38.3)
10-11	141.8	S.D.	5.7	(125.5-153.8)	40	33.8	S.D.	8.4	(24.5-45.0)
11-12	146.0	S.D.	8.7	(133.0-166.7)	21	36.0	S.D.	4.9	(27.0-46.6)
12-13	152.0	S.D.	9.5	(135.3-173.4)	35	41.1	S.D.	9.3	(26.7-62.1)
13-14	158.2	S.D.	8.5	(140.5-171.4)	36	46.0	S.D.	9.5	(29.5-78.8)
14-15	165.8	S.D.	6.5	(155.6-177.5)	12	52.5	S.D.	6.8	(45.6-66.8)
15-16	172.9	S.D.	5.0	(166.1-180.5)	13	58.5	S.D.	6.6	(48.3-68.1)

Mean Heights and Weights - Childhood Female Offspring

AGE	HEIGHT				NUMBER	WEIGHT			
2-3	88.7	S.D.	5.5	(84.8-92.7)	2	13.1	S.D.	.9	(12.4-13.8)
3-4	97.1	S.D.	4.4	(86.3-103.6)	19	14.0	S.D.	1.2	(11.3-16.4)
4-5	104.0	S.D.	4.7	(94.6-113.3)	14	16.9	S.D.	1.8	(13.9-19.4)
5-6	111.1	S.D.	4.0	(102.7-114.5)	34	19.0	S.D.	1.8	(14.5-22.1)
6-7	115.7	S.D.	6.1	(106.6-124.7)	39	20.3	S.D.	2.9	(13.0-24.6)
7-8	126.1	S.D.	5.9	(107.4-137.5)	31	25.0	S.D.	2.9	(17.9-30.5)
8-9	129.9	S.D.	6.9	(114.6-141.4)	37	27.0	S.D.	4.0	(17.1-34.8)
9-10	133.9	S.D.	6.0	(121.8-148.2)	24	28.4	S.D.	4.2	(21.8-38.5)
10-112	141.9	S.D.	7.6	(126.1-163.0)	45	32.0	S.D.	4.3	(24.4-42.2)
11-12	149.5	S.D.	9.8	(135.4-164.4)	28	37.5	S.D.	5.7	(29.0-50.0)
12-13	154.2	S.D.	7.2	(141.6-171.7)	31	40.2	S.D.	7.9	(29.5-64.0)
13-14	180.3	S.D.	5.4	(150.0-174.0)	33	48.1	S.D.	7.1	(34.5-59.5)
14-15	162.6	S.D.	5.5	(151.8-172.5)	22	52.3	S.D.	7.1	(39.9-69.1)
15-16	167.7	S.D.	11.8	(155.8-184.4)	8	55.9	S.D.	5.5	(47.5-62.3)

Skinfold Measurements - Male Offspring

AGE	TRICEPS	BICEPS	SUBSCAPULAR	SUPERILIAC	NUMBER
2-3	8.6 S.D. .5 (8.2-9.0)	5.1 S.D. .1 (5.0-5.2)	7.3 S.D. 1.8 (6.0-8.6)	4.6	2
3-4	8.3 S.D. 2.3 (4.5-13.2)	5.6 S.D. 1.1 (3.3-8.0)	5.5 S.D. 1.1 (4.0-8.0)	4.2 S.D. 1.4 (2.6-9.2)	21
4-5	8.5 S.D. 2.2 (5.0-14.6)	5.2 S.D. 1.4 (3.2-8.8)	5.6 S.D. 1.5 (3.6-11.0)	4.1 S.D. 1.7 (2.4-10.4)	28
5-6	8.2 S.D. 1.8 (5.0-12.0)	4.7 S.D. .9 (3.2-7.0)	5.4 S.D. .9 (3.2-7.6)	3.6 S.D. .8 (2.4-5.4)	41
6-7	7.7 S.D. 2.5 (3.1-13.2)	4.7 S.D. 1.4 (2.6-8.0)	5.2 S.D. 1.3 (3.2-8.6)	3.5 S.D. 1.0 (2.0-6.8)	30
7-8	8.0 S.D. 3.0 (2.7-17.6)	4.9 S.D. 1.9 (3.0-11.4)	5.5 S.D. 2.7 (3.5-16.4)	3.9 S.D. 2.9 (2.0-16.2)	27
8-9	7.3 S.D. 2.0 (2.8-14.2)	4.5 S.D. 1.3 (4.2-7.2)	5.3 S.D. 1.0 (4.0-8.6)	4.2 S.D. 2.4 (2.6-16.8)	35
9-10	8.6 S.D. 3.4 (4.8-20.2)	5.4 S.D. 2.2 (3.0-10.2)	6.2 S.D. 2.7 (3.4-16.6)	4.5 S.D. 2.1 (2.4-12.2)	33
10-11	8.1 S.D. 2.2 (3.3-12.1)	5.1 S.D. 2.7 (3.0-18.5)	6.3 S.D. 3.3 (4.0-13.0)	4.9 S.D. 2.9 (2.8-17.2)	40
11-12	7.7 S.D. 2.4 (3.6-15.0)	4.1 S.D. 1.1 (2.8-7.4)	5.7 S.D. 1.5 (3.7-10.2)	4.1 S.D. 1.4 (2.4-9.2)	21
12-13	9.1 S.D. 4.3 (4.4-26.0)	5.1 S.D. 2 4 (2.6-13.0)	7.0 S.D. 3.3 (2.8-17.0)	5.5 S.D. 3.2 (2.8-17.0)	35
13-14	6.8 S.D. 3.0 (4.0-22.0)	3.9 S.D. 1.2 (2.4-10.2)	6.7 S.D. 4.3 (4.4-31.0)	5.0 S.D. 3.5 (3.0-24.4)	36
14-15	7.3 S.D. 2.0 (3.5-10.4)	4.3 S.D. .8 (3.0-5.8)	6.6 S.D. 1.1 (5.2-9.1)	5.6 S.D. 1.7 (4.0-9.6)	12
15-16	6.5 S.D. .7 (6.0-7.0)	6.2 S.D. 2.2 (4.6-7.8)	7.6 S.D. 2.5 (5.8-9.4)	5.6 S.D. .2 (5.4-5.8)	2

Skinfold Measurements - Male Offspring

AGE					NO
16-17	7.6 S.D. 2.4 (5.0-11.2)	3.8 S.D. 0.9 (3.0-5.4)	8.3 S.D. 2.6 (5.2-13.0)	9.7 S.D. 4.8 (5.6-18.0)	6
17-18	6.6 S.D. 1.3 (5.4-8.4)	3.0 S.D. 0.4 (2.6-3.6)	7.6 S.D. 1.5 (5.6-10.0)	9.0 S.D. 2.4 (5.0-11.0)	6
18-19	10.2 S.D. 3.0 (7.8-14.4)	3.9 S.D. 0.8 (2.8-5.0)	8.8 S.D. 2.0 (6.4-11.4)	13.4 S.D. 3.2 (11.0-20.0)	6
19-20	9.3 S.D. 4.0 (6.2-17.0)	4.6 S.D. 2.1 (2.8-9.6)	10.8 S.D. 4.2 (6.4-18.0)	14.1 S.D. 3.1 (5.2-27.0)	8
20-21	8.3 S.D. 4.0 (4.4-16.0)	4.3 S.D. 1.9 (2.6-8.4)	10.9 S.D. 6.3 (6.2-30.0)	13.0 S.D. 9.7 (4.2-42.0)	18
21-22	8.5 S.D. 3.7 (3.2-20.0)	3.8 S.D. 1.4 (2.0-8.0)	10.0 S.D. 3.8 (5.0-24.0)	14.2 S.D. 9.0 (3.8-39.8)	62
22-23	7.7 S.D. 2.5 (4.6-15.6)	3.6 S.D. 1.4 (2.0-8.0)	9.4 S.D. 2.4 (6.4-16.4)	12.1 S.D. 5.4 (4.0-26.0)	20
23-24	9.2 S.D. 4.0 (4.0-22.0)	4.2 S.D. 2.3 (2.2-12.4)	10.2 S.D. 4.3 (6.4-30.0)	13.3 S.D. 8.4 (4.6-39.5)	20
24-25	9.6 S.D. 4.4 (4.2-20.0)	4.4 S.D. 1.8 (2.0-9.0)	12.4 S.D. 6.3 (5.4-33.0)	15.0 S.D. 9.5 (5.0-44.0)	41
25-26	9.8 S.D. 4.4 (4.0-20.0)	4.3 S.D. 1.8 (2.0-9.0)	12.3 S.D. 6.2 (6.4-36.6)	15.5 S.D. 8.6 (4.6-40.0)	24
26-27	9.2 S.D. 3.8 (4.8-20.0)	4.6 S.D. 2.3 (2.2-13.0)	11.9 S.D. 4.7 (7.2-24.0)	14.5 S.D. 8.1 (4.6-34.0)	25
27-28	10.3 S.D. 5.0 (4.0-24.2)	4.3 S.D. 1.8 (2.2-10.4)	12.3 S.D. 5.5 (6.2-28.0)	16.7 S.D. 9.1 (5.2-38.0)	37
28-29	9.4 S.D. 4.0 (3.6-17.0)	4.3 S.D. 1.9 (2.2-9.8)	14.4 S.D. 7.6 (6.6-37.0)	20.5 S.D. 12.1 (5.2-45.0)	28
29-30	7.9 S.D. 3.0 (3.4-14.6)	3.9 S.D. 1.1 (2.2-6.4)	10.8 S.D. 2.9 (6.4-16.0)	13.9 S.D. 6.4 (4.6-25.4)	20
30-31	11.8 S.D. 3.7 (5.0-19.0)	5.3 S.D. 2.2 (3.0-10.6)	14.0 S.D. 5.5 (7.0-26.6)	20.9 S.D. 9.6 (7.2-38.0)	16

Skinfold Measurements - Female Offspring

AGE	TRICEPS	BICEPS	SUBSCAPULAR	SUPRAILIAC	NUMBER
3-4	10.4 S.D. 2.2 (6.7-14.0)	6.4 S.D. 2.0 (3.4-11.6)	6.1 S.D. .9 (4.5-7.8)	5.3 S.D. 1.0 (3.8-7.0)	17
4-5	9.8 S.D. 2.0 (6.6-13.4)	6.1 S.D. 1.2 (4.0-8.2)	6.4 S.D. 1.4 (4.4-9.2)	5.1 S.D. 1.5 (3.4-8.8)	12
5-6	8.6 S.D. 1.7 (6.2-12.6)	5.2 S.D. 1.1 (3.2-8.0)	6.1 S.D. 1.3 (4.2-9.8)	4.5 S.D. 1.3 (2.4-7.2)	34
6-7	9.0 S.D. 2.1 (3.0-14.2)	5.3 S.D. 1.0 (3.6-7.6)	6.3 S.D. 1.7 (4.0-13.8)	4.8 S.D. 1.8 (2.0-11.8)	39
7-8	9.4 S.D. 2.3 (4.8-17.0)	5.6 S.D. 1.3 (3.5-8.4)	6.6 S.D. 1.6 (3.5-12.6)	5.4 S.D. 1.6 (2.6-9.2)	31
8-9	8.5 S.D. 2.3 (4.1-13.6)	5.3 S.D. 1.2 (3.4-9.2)	6.0 S.D. 1.5 (4.1-12.5)	5.1 S.D. 1.8 (2.2-11.4)	37
9-10	9.5 S.D. 3.0 (6.4-19.0)	6.0 S.D. 1.6 (3.5-9.4)	6.9 S.D. 3.5 (4.0-20.0)	7.1 S.D. 4.9 (2.8-25.2)	24
10-11	9.7 S.D. 2.3 (4.6-15.8)	5.9 S.D. 1.6 (2.8-10.4)	7.0 S.D. 1.9 (4.3-13.4)	6.5 S.D. 3.0 (2.4-17.6)	45
11-12	9.4 S.D. 3.7 (2.8-21.1)	5.8 S.D. 1.7 (3.8-11.6)	7.2 S.D. 2.3 (4.4-15.2)	6.9 S.D. 3.8 (4.0-24.0)	28
12-13	10.1 S.D. 3.6 (2.4-18.2)	6.3 S.D. 1.7 (3.4-10.2)	8.6 S.D. 4.1 (3.6-22.0)	8.7 S.D. 5.1 (3.0-23.8)	31
13-14	9.9 S.D. 3.0 (5.1-17.4)	6.0 S.D. 1.9 (2.8-11.0)	9.2 S.D. 3.4 (4.4-20.0)	8.7 S.D. 3.1 (3.6-16.6)	33
14-15	10.4 S.D. 3.7 (4.0-19.8)	6.7 S.D. 1.9 (3.4-11.2)	10.0 S.D. 4.4 (5.7-22.0)	10.0 S.D. 5.4 (5.3-29.0)	22

Skinfold Measurements - Female Offspring

AGE					NO
15-16	12.2 S.D. 5.2 (6.4-22.0)	6.5 S.D. 2.0 (3.0-10.0)	9.8 S.D. 3.0 (5.4-14.4)	9.4 S.D. 4.2 (4.2-16.0)	5
16-17					
17-18	16.7 S.D. 7.4 (9.0-26.4)	9.1 S.D. 7.1 (3.4-22.6)	13.5 S.D. 6.7 (6.2-21.4)	17.5 S.D. 11.9 (7.0-38.0)	6
18-19	19.9 S.D. 5.3 (14.6-25.0)	8.4 S.D. 1.7 (7.0-11.0)	11.7 S.D. 5.5 (8.4-20.0)	15.1 S.D. 6.8 (11.0-25.4)	3
19-20	15.0 S.D. 4.4 (9.6-24.0)	6.0 S.D. 1.7 (4.2-9.0)	12.2 S.D. 4.7 (7.0-21.0)	16.1 S.D. 9.7 (5.0-30.0)	9
20-21	15.0 S.D. 4.2 (8.2-26.0)	6.5 S.D. 2.3 (2.8-14.0)	11.6 S.D. 3.5 (7.2-20.2)	13.2 S.D. 6.1 (5.0-28.6)	36
21-22	15.0 S.D. 5.7 (7.0-30.0)	6.9 S.D. 3.3 (2.6-15.0)	12.2 S.D. 5.1 (6.0-26.0)	12.8 S.D. 6.1 (6.0-29.6)	33
22-23	14.6 S.D. 5.5 (9.2-30.0)	6.8 S.D. 3.4 (4.0-20.0)	13.1 S.D. 6.2 (6.8-28.0)	13.0 S.D. 6.4 (6.6-31.0)	23
23-24	14.6 S.D. 3.3 (7.8-21.6)	6.6 S.D. 2.3 (3.0-11.6)	11.7 S.D. 3.2 (7.0-18.0)	12.5 S.D. 5.1 (5.6-24.0)	28
24-25	16.5 S.D. 6.8 (7.6-38.0)	8.1 S.D. 5.0 (3.6-31.0)	13.8 S.D. 7.3 (7.0-42.0)	13.6 S.D. 6.7 (5.0-33.0)	27
25-26	15.8 S.D. 4.2 (8.4-24.0)	6.9 S.D. 2.9 (3.0-13.4)	13.3 S.D. 6.5 (5.8-32.0)	12.6 S.D. 5.2 (5.0-24.0)	32
26-27	14.3 S.D. 3.8 (6.6-20.6)	5.8 S.D. 1.8 (2.6-10.0)	12.1 S.D. 4.2 (7.0-21.0)	11.8 S.D. 6.0 (4.0-24.0)	29
27-28	16.8 S.D. 7.5 (7.0-38.0)	7.7 S.D. 3.6 (2.6-16.0)	13.7 S.D. 5.7 (6.0-25.4)	13.6 S.D. 8.9 (4.6-38.6)	28
28-29	17.6 S.D. 5.8 (8.8-31.0)	6.7 S.D. 2.5 (3.4-13.6)	12.7 S.D. 5.3 (7.6-28.4)	13.1 S.D. 7.8 (5.4-8.0)	30
29-30	17.1 S.D. 6.8 (6.6-34.0)	7.6 S.D. 3.9 (3.0-16.8)	13.8 S.D. 6.3 (7.2-30.0)	13.9 S.D. 7.6 (5.8-34.4)	30
30-31	17.6 S.D. 4.8 (11.0-24.6)	7.3 S.D. 2.6 (4.0-12.4)	12.8 S.D. 3.0 (8.8-17.6)	14.6 S.D. 5.0 (7.0-25.0)	10

Skinfold Measurements - Fathers

AGE	TRICEPS	BICEPS	SUBSCAPULAR	SUPRAILIAC	NUMBER
40-45	10.6 S.D. 6.7 (4.8-18.0)	5.6 S.D. 3.3 (2.6-9.2)	11.4 S.D. 4.8 (6.4-16.0)	14.8 S.D. 8.7 (6.6-24.0)	3
45-50	12.4 S.D. 5.7 (4.8-26.6)	5.8 S.D. 3.0 (2.6-13.6)	18.2 S.D. 9.6 (8.2-46.0)	19.2 S.D. 9.5 (7.8-45.0)	22
50-55	11.1 S.D. 4.2 (5.4-24.4)	5.3 S.D. 2.6 (2.0-13.6)	15.8 S.D. 5.9 (6.0-33.6)	17.7 S.D. 8.3 (5.0-43.0)	41
55-60	12.1 S.D. 5.4 (3.0-36.0)	5.7 S.D. 3.1 (2.0-22.0)	17.7 S.D. 8.5 (5.2-45.0)	18.5 S.D. 9.6 (4.0-41.0)	63
60-65	12.5 S.D. 4.9 (4.4-29.0)	5.4 S.D. 2.0 (2.0-11.6)	18.0 S.D. 9.0 (6.0-44.0)	17.4 S.D. 9.5 (4.4-44.0)	36
65-70	11.8 S.D. 4.0 (7.4-20.0)	8.8 S.D. 11.2 (3.4-50.0)	17.9 S.D. 7.6 (9.0-39.0)	17.3 S.D. 9.0 (6.4-37.0)	16
70-75	9.5 S.D. 2.7 (6.6-12.0)	4.3 S.D. 3.0 (2.6-7.8)	13.3 S.D. 7.5 (9.0-22.0)	11.0 S.D. 9.4 (5.6-22.0)	3

Skinfold Measurements - Mothers

AGE	TRICEPS	BICEPS	SUBSCAPULAR	SUPRAILIAC	NUMBER
40-45	20.8 S.D. 6.7 (11.8-35.0)	8.9 S.D. 4.0 (3.2-18.0)	17.3 S.D. 7.6 (8.0-34.0)	12.6 S.D. 5.2 (6.0-22.0)	9
45-50	20.5 S.D. 7.2 (11.0-43.0)	9.7 S.D. 7.1 (3.0-39.0)	18.8 S.D. 9.6 (6.6-44.0)	16.4 S.D. 9.9 (5.0-42.0)	31
50-55	20.2 S.D. 8.0 (7.4-91.0)	9.5 S.D. 5.0 (2.6-26.0)	17.8 S.D. 8.4 (5.4-43.0)	16.0 S.D. 9.8 (3.6-44.0)	65
55-60	22.3 S.D. 6.9 (8.6-44.0)	11.3S.D. 5.1 (3.6-31.0)	20.5 S.D. 7.6 (5.8-40.0)	16.5 S.D. 8.5 (4.0-44.0)	65
60-65	22.2 S.D. 8.3 (8.8-39.5)	10.2 S.D. 5.5 (2.6-27.4)	21.2 S.D.10.7 (6.4-42.0)	18.0 S.D.11.5 (5.0-42.0)	35
65-70	22.4 S.D. 6.2 (14.8-29.0)	8.8 S.D. 2.1 (5.8-11.6)	23.4 S.D. 7.9 (13.4-32.0)	20.4 S.D. 9.3 (10.4-36.0)	5

Skewness and Kurtosis of Distribution of Height, Weight and Skinfolds - Male Offspring

				SKEWNESS		KURTOSIS	
		MEAN	STANDARD DEVIATION	RAW DATA	LOG TRANSFORM	RAW DATA	LOG TRANSFORM
Childhood	Triceps	7.6	2.8	1.8	-.4	7.0	1.9
	Biceps	4.4	1.8	2.4	.03	12.1	.3
	Subscapular	5.6	2.5	4.8	1.1	35.0	3.4
	Suprailiac	4.0	2.4	3.8	.2	20.2	1.9
Adult	Triceps	9.0	4.1	.98	-.1	.55	-.5
	Biceps	4.0	1.9	1.4	-.07	2.1	-.3
	Subscapular	11.5	5.9	1.9	.7	4.1	.2
	Suprailiac	15.2	9.4	1.1	-.01	.5	-.6
Childhood	Height	134.2	22.9	.1		-.8	
	Weight	31.7	14.7	1.0		.5	
Adult	Height	176.9	7.1	.14		-.21	
	Weight	69.8	10.1	.9		2.3	

Skewness and Kurtosis of Distribution of Height, Weight and Skinfolds - Female Offspring

				SKEWNESS		KURTOSIS	
		MEAN	STANDARD DEVIATION	RAW DATA	LOG TRANSFORM	RAW DATA	LOG TRANSFORM
Childhood	Triceps	9.1	2.8	.7	-.8	1.5	6.6
	Biceps	5.4	1.6	.7	-.2	.9	.04
	Subscapular	6.9	3.3	4.3	.9	30.4	2.2
	Suprailiac	6.1	3.5	2.7	-.1	10.6	1.5
Adult	Triceps	15.7	5.6	1.1	.05	1.6	-.1
	Biceps	6.7	3.2	2.0	-.2	9.7	.1
	Subscapular	12.5	5.4	1.5	.4	3.2	-.3
	Suprailiac	12.8	6.7	1.6	.08	1.2	-.5
Childhood	Height	136.4	22.0	-.1		-.9	
	Weight	32.9	.7	.7		-.2	
Adult	Height	163.9	6.4	.2		.4	
	Weight	57.1	7.7	.9		3.0	

Skewness and Kurtosis of Distribution of Height, Weight and Skinfolds - Fathers

			SKEWNESS		KURTOSIS		
	MEAN	STANDARD DEVIATION	RAW DATA	LOG TRANSFORM	RAW DATA	LOG TRANSFORM	NUMBER
Weight 1960-2	73.7	10.5	.6		.3		
Weight 1976-7	76.0	11.7	.8		.7		186
Height	174.2	7.1	-.07		-.5		186
Triceps	11.6	5.0	1.3	-.4	3.2	1.1	185
Biceps	5.2	2.7	2.0	-.1	6.9	1.0	185
Subscapular	17.0	8.1	1.2	.03	1.4	-.2	185
Suprailiac	17.6	9.2	.8	-.4	.2	-.2	185

Skewness and Kurtosis of Distribution of Height, Weight and Skinfolds - Mothers

			SKEWNESS		KURTOSIS	
	MEAN	STANDARD DEVIATION	RAW DATA	LOG TRANSFORM	RAW DATA	LOG TRANSFORM
Weight 1960-62	61.9	10.6	1.0		2.1	
Weight 1976-7	64.2	11.0	1.2		3.2	
Height	162.7	5.8	.07		1.0	
Triceps	20.7	7.2	.4	-.4	-.3	.07
Biceps	10.5	5.3	1.7	-.6	4.7	.8
Subscapular	18.7	8.2	.3	-.4	-.6	-.4
Suprailiac	15.7	8.5	.9	-.3	.2	-.2

FIGURE 19

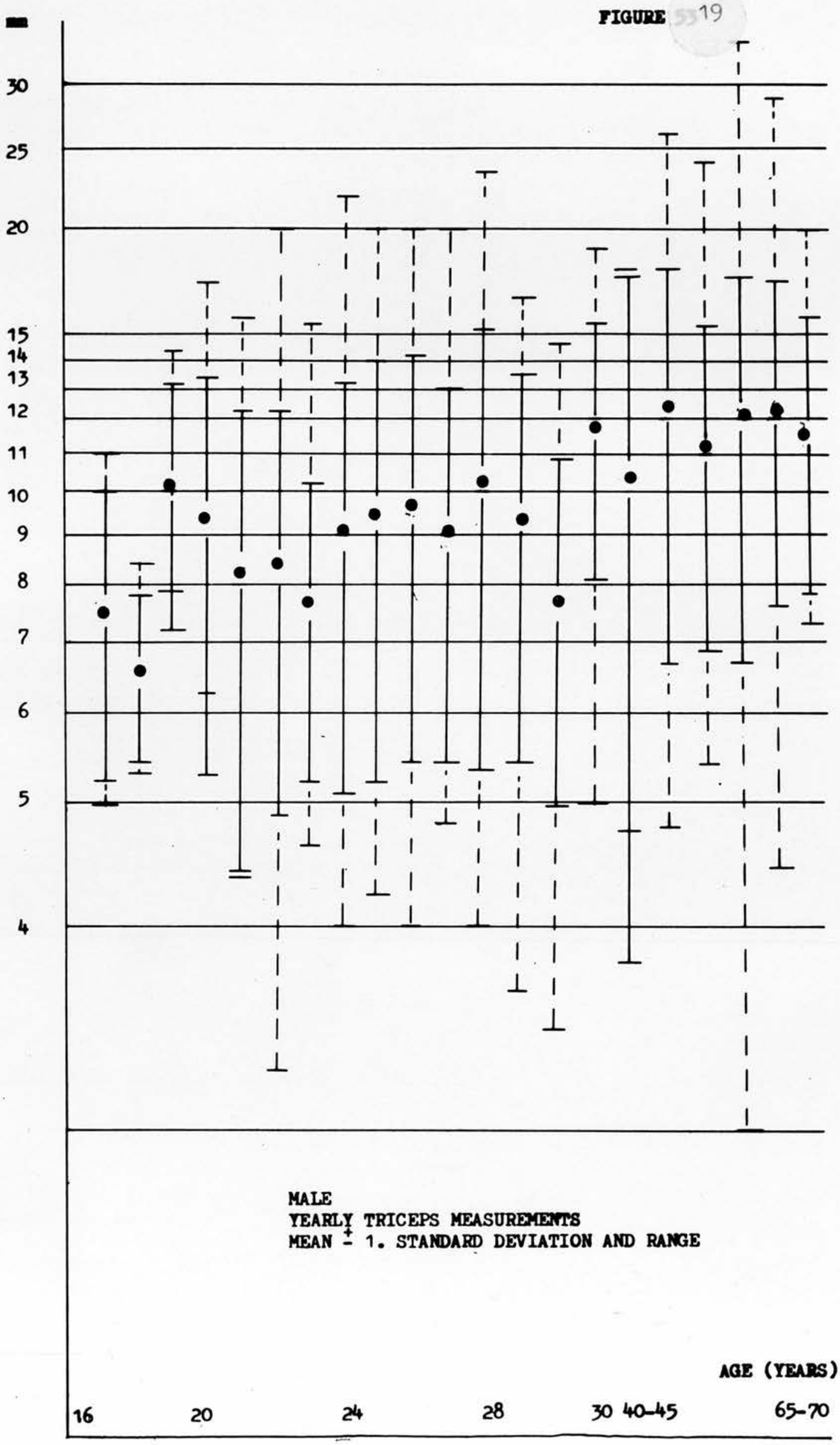
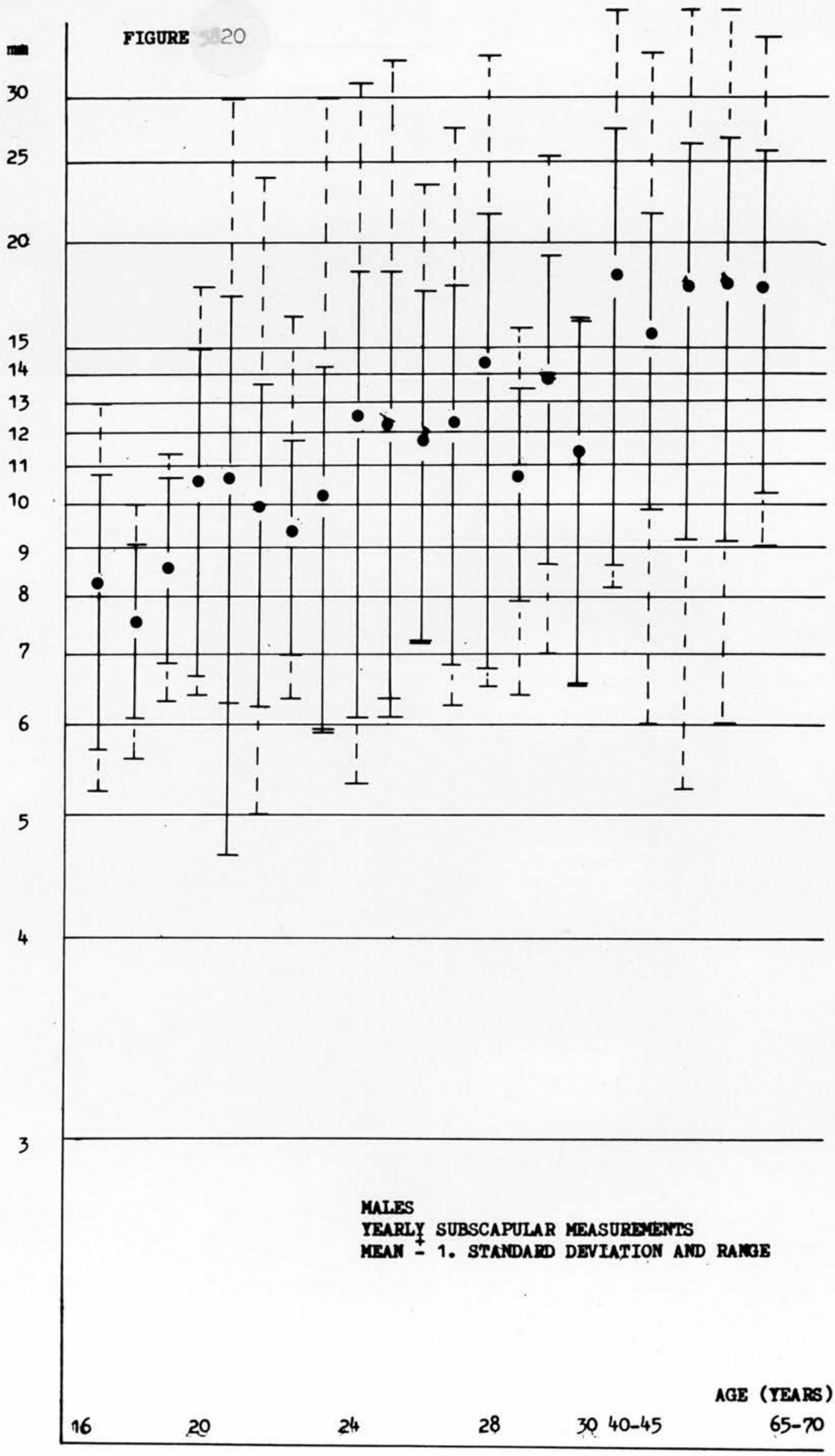
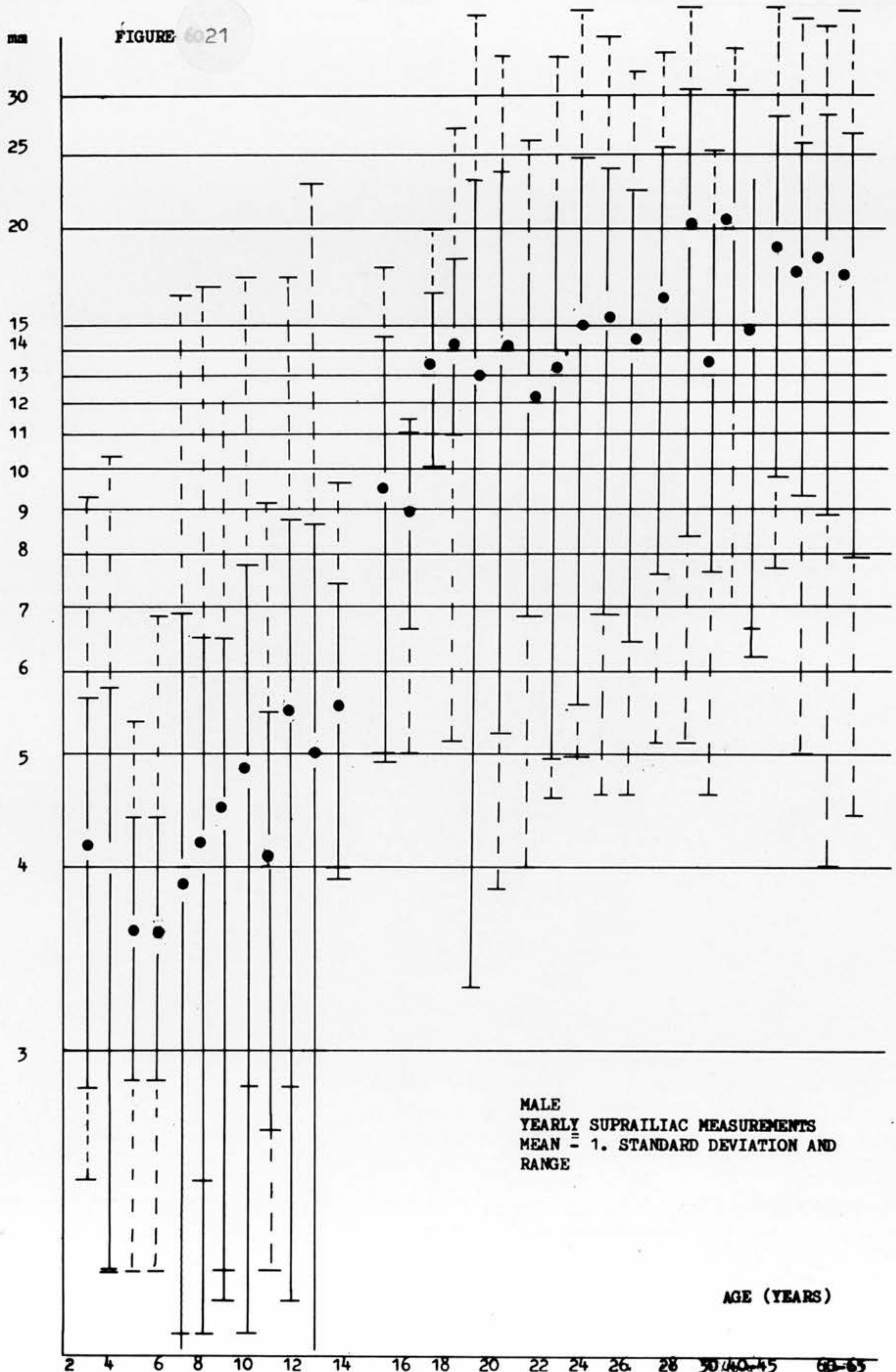

mm
30
25
20
15
14
13
12
11
10
9
8
7
6
5
4
MALE
YEARLY TRICEPS MEASUREMENTS
MEAN ± 1. STANDARD DEVIATION AND RANGE
AGE (YEARS)
16
20
24
28
30 40-45
65-70

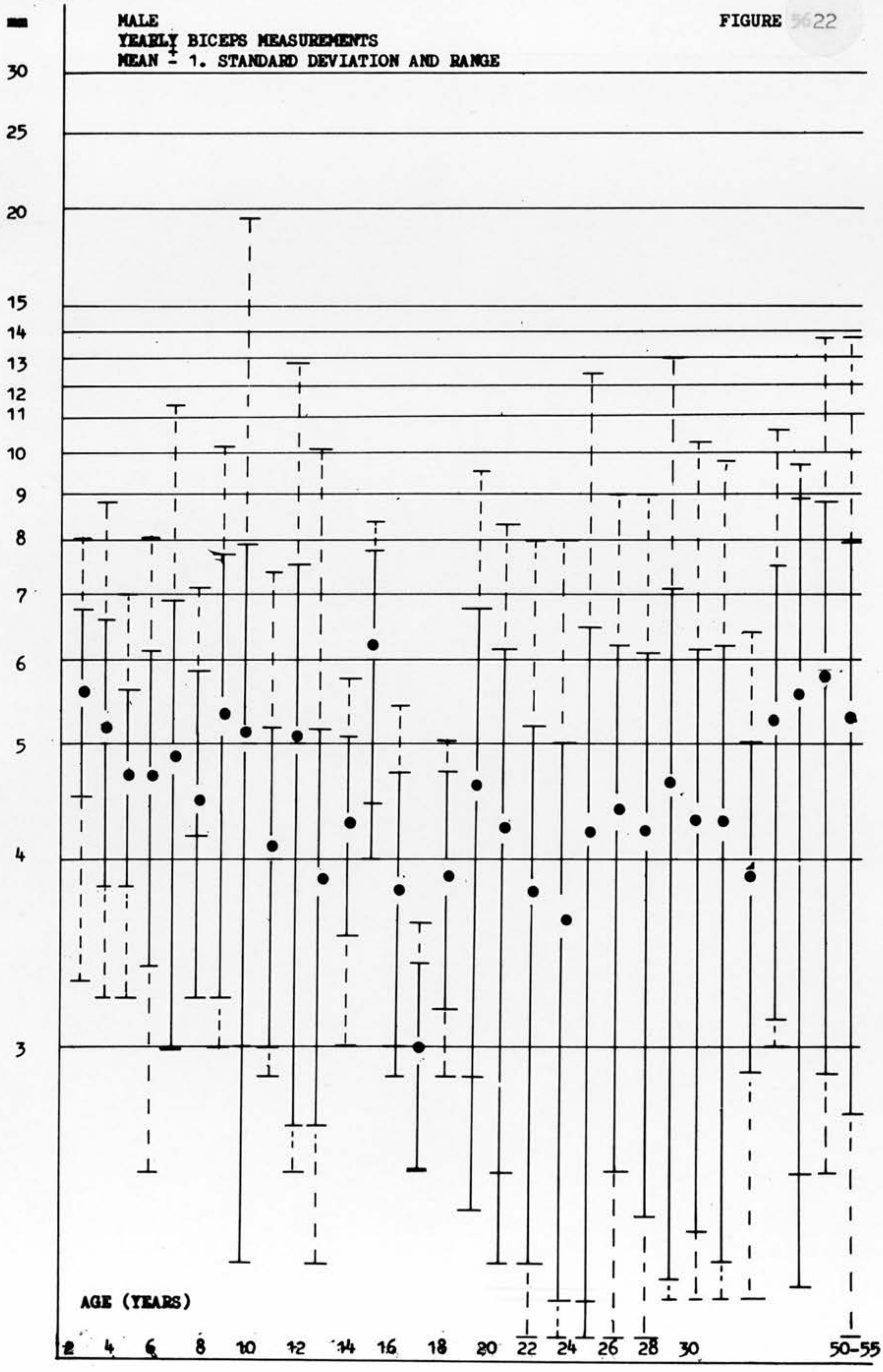
FIGURE 20



MALES
YEARLY SUBSCAPULAR MEASUREMENTS
MEAN ± 1. STANDARD DEVIATION AND RANGE

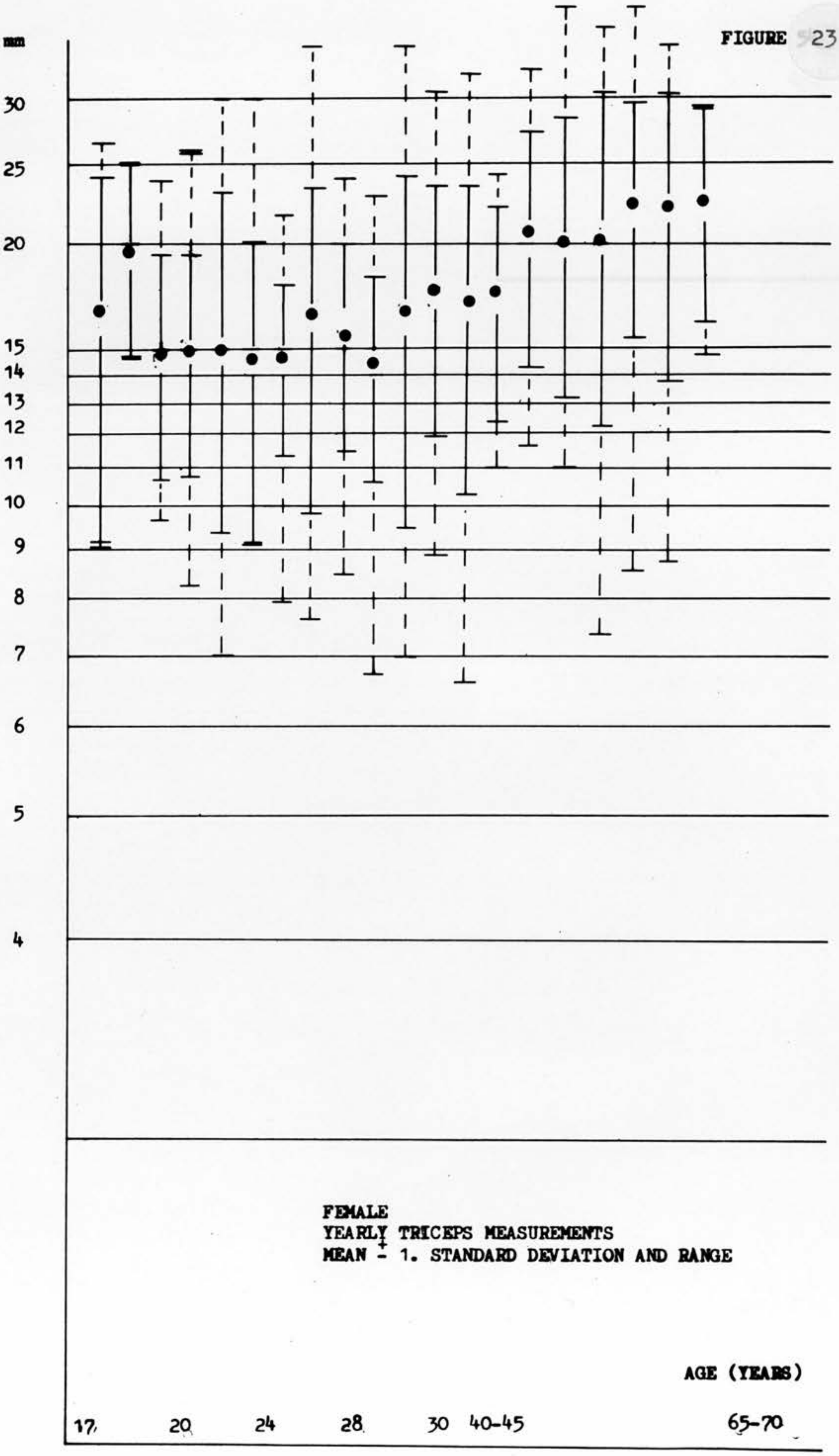
FIGURE 21


mm
30
25
20
15
14
13
12
11
10
9
8
7
6
5
4
3
MALE
YEARLY SUPRAILIAC MEASUREMENTS
MEAN ± 1. STANDARD DEVIATION AND
RANGE
AGE (YEARS)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 40-45 60-65



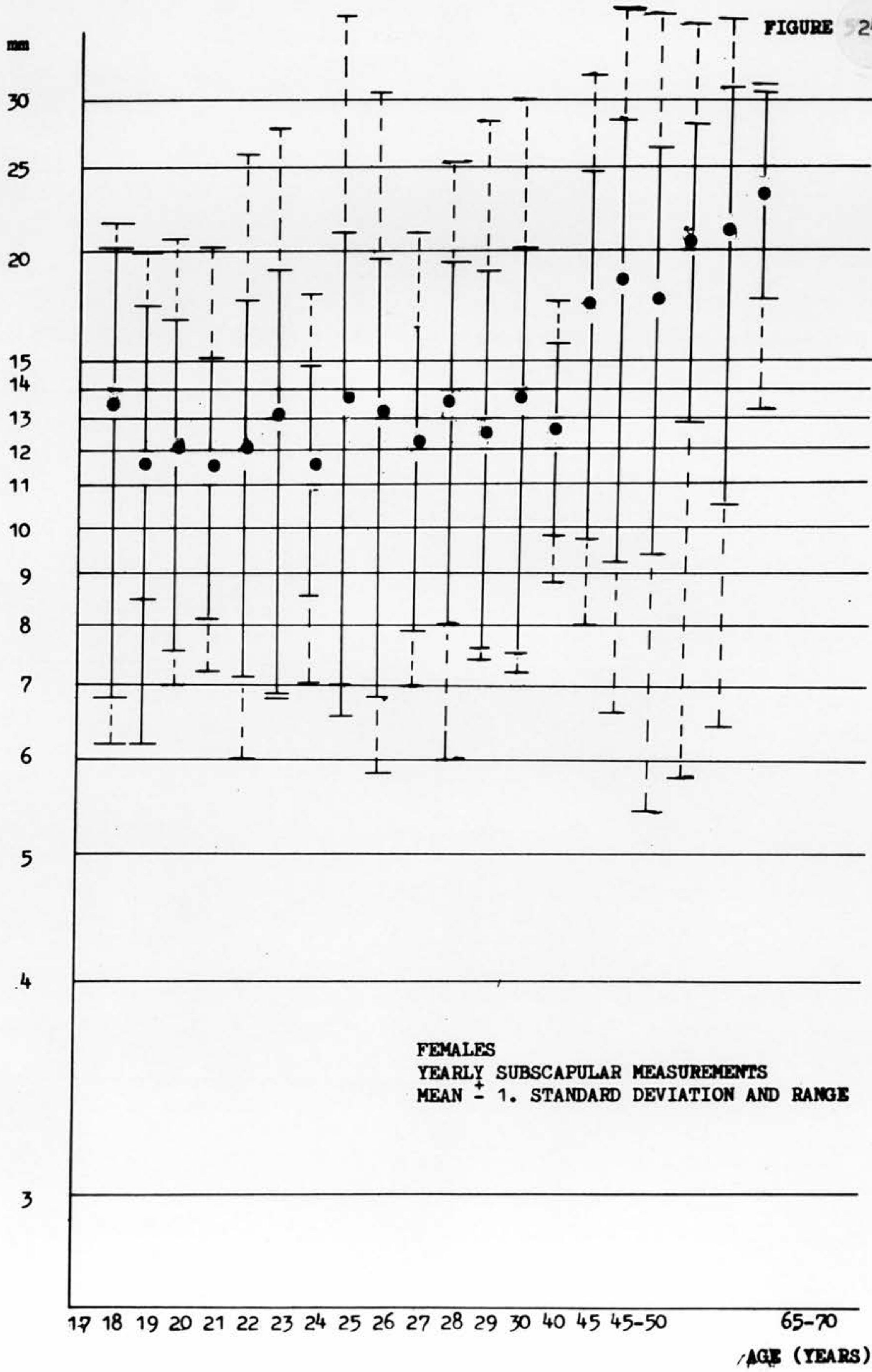
mm
MALE
YEARLY BICEPS MEASUREMENTS
MEAN ± 1. STANDARD DEVIATION AND RANGE
FIGURE 22
30
25
20
15
14
13
12
11
10
9
8
7
6
5
4
3
AGE (YEARS)
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
50-55

FIGURE 23



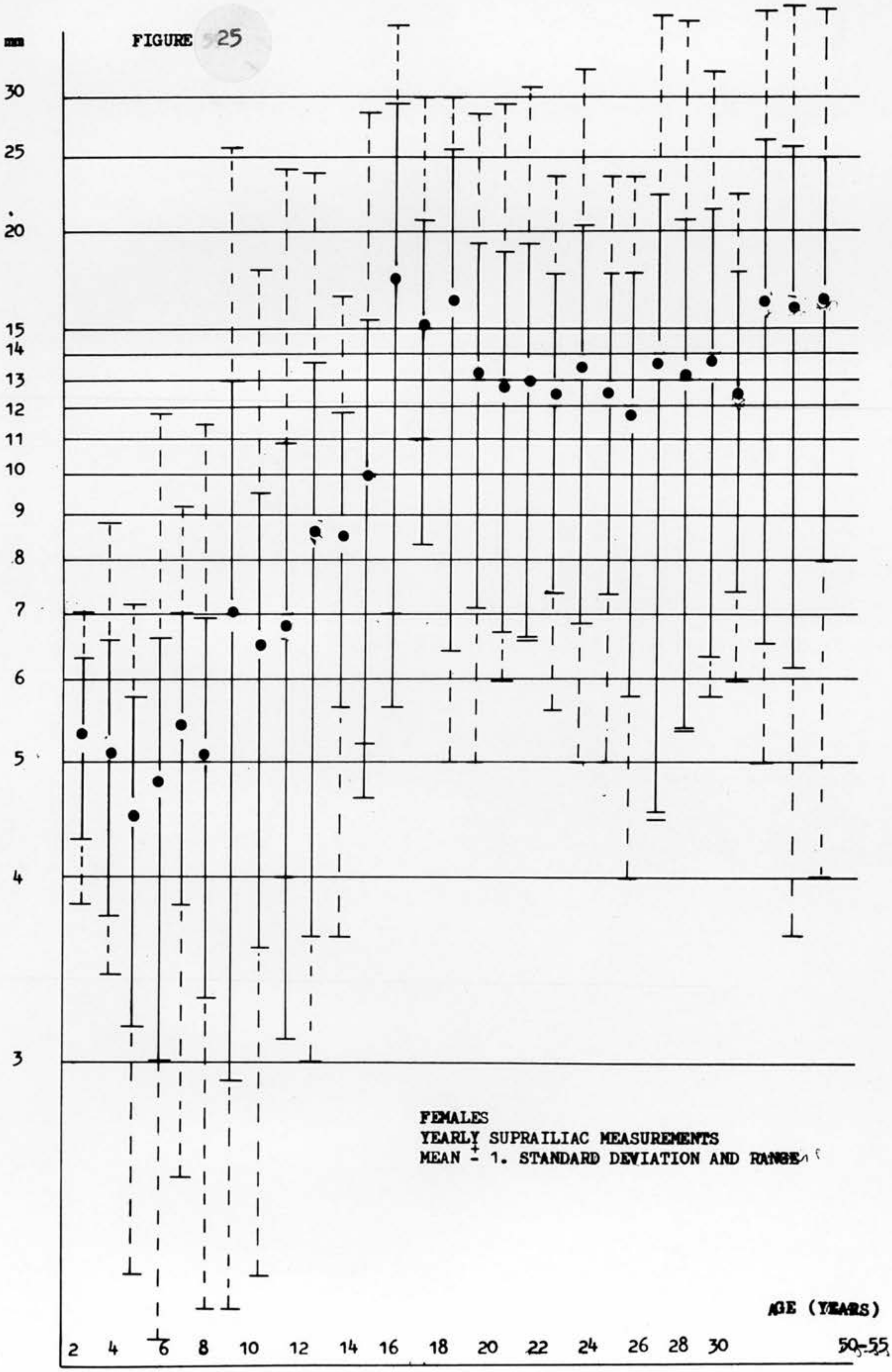
FEMALE
YEARLY TRICEPS MEASUREMENTS
MEAN ± 1. STANDARD DEVIATION AND RANGE

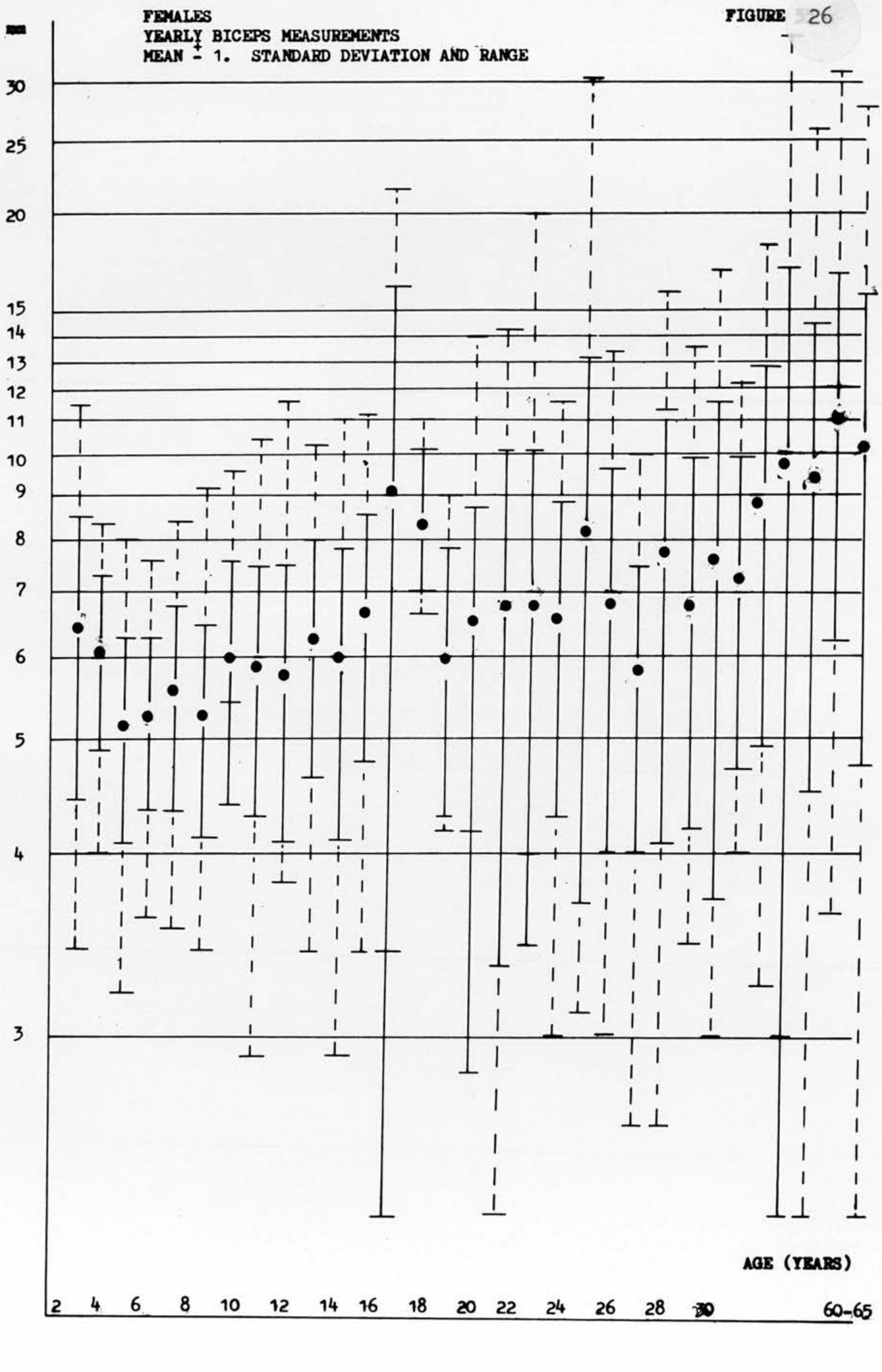
FIGURE 24



FEMALES
YEARLY SUBSCAPULAR MEASUREMENTS
MEAN ± 1. STANDARD DEVIATION AND RANGE

FIGURE 25


mm
30
25
20
15
14
13
12
11
10
9
8
7
6
5
4
3
FEMALES
YEARLY SUPRAILIAC MEASUREMENTS
MEAN ± 1. STANDARD DEVIATION AND RANGE
AGE (YEARS)
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
50-55


FEMALES
YEARLY BICEPS MEASUREMENTS
MEAN ± 1. STANDARD DEVIATION AND RANGE
FIGURE 26
mm
30
25
20
15
14
13
12
11
10
9
8
7
6
5
4
3
AGE (YEARS)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 60-65

Comparison of Twins and Siblings

	ADULT HEIGHT	ADULT WEIGHT	ADULT TBSS LOG TRANSFORMED
Sisters (105)	164.2 ± .52	58.1 ± .72	260.4 ± 1.76
Female Twins (236)	164.0 ± .42	56.6 ± .46	257.5 ± 1.11
'P'	N.S.	N.S.	N.S.
Non-Identical Girls (184)	164.3 ± .47	57.0 ± .53	257.6 ± 1.25
Identical Girls (52)	163.3 ± 1.41	55.2 ± 1.30	256.8 ± 2.55
'P'	N.S.	N.S.	N.S.
Brothers (109)	179.6 ± .69	72.7 ± 1.05	252.9 ± 2.24
Male Twins (236)	176.7 ± .46	68.5 ± .55	243.2 ± 1.50
'P'	.001	.001	.001
Non-Identical Males (176)	176.7 ± .51	69.2 ± .64	254.8 ± 1.73
Identical Males (60)	176.4 ± 1.01	66.5 ± 1.11	235.5 ± 2.85
'P'	N.S.	N.S.	.001

Male Twins - Childhood

	Height			Weight			TBSS			
3-4	100.3	S.D.	4.7	15.9	S.D.	1.8	22.9	S.D.	4.8	16
4-5	104.7	S.D.	4.1	17.5	S.D.	2.0	23.4	S.D.	6.1	21
5-6	111.2	S.D.	6.1	18.9	S.D.	2.5	22.1	S.D.	3.4	38
6-7	117.1	S.D.	5.6	21.0	S.D.	2.5	21.2	S.D.	5.5	26
7-8	124.4	S.D.	7.9	24.0	S.D.	3.6	22.2	S.D.	10.0	20
8-9	128.7	S.D.	8.4	26.7	S.D.	3.9	21.8	S.D.	6.4	21
9-10	137.9	S.D.	5.8	32.1	S.D.	3.9	26.5	S.D.	11.8	21
10-11	141.6	S.D.	5.7	33.9	S.D.	9.3	23.8	S.D.	7.2	28
11-12	147.4	S.D.	7.5	37.3	S.D.	4.6	23.1	S.D.	7.4	13
12-13	149.9	S.D.	8.5	38.4	S.D.	7.6	24.9	S.D.	11.1	24
13-14	157.0	S.D.	7.5	44.1	S.D.	6.0	19.6	S.D.	2.5	26
14-15	165.4	S.D.	5.9	50.1	S.D.	3.8	22.9	S.D.	2.9	4

Brothers - Childhood

	Height			Weight			TBSS			
3-4	103.1	S.D.	0.33	17.1	S.D.	0.8	25.7	S.D.	4.9	6
4-5	107.3	S.D.	5.4	18.4	S.D.	2.6	23.7	S.D.	2.9	8
5-6	115.1	S.D.	3.0	21.3	S.D.	1.8	22.2	S.D.	1.2	3
6-7	120.3	S.D.	6.6	23.0	S.D.	2.2	21.7	S.D.	3.9	5
7-8	123.5	S.D.	5.6	23.6	S.D.	2.7	23.4	S.D.	7.1	7
8-9	130.2	S.D.	4.0	26.3	S.D.	2.4	20.9	S.D.	3.7	15
9-10	136.4	S.D.	5.2	30.5	S.D.	3.5	22.1	S.D.	4.7	12
10-11	142.2	S.D.	5.8	33.7	S.D.	6.4	26.1	S.D.	14.7	12
11-12	143.8	S.D.	10.6	33.9	S.D.	5.0	19.6	S.D.	1.9	8
12-13	156.6	S.D.	10.2	47.1	S.D.	10.3	31.2	S.D.	15.3	11
13-14	161.5	S.D.	10.3	51.0	S.D.	14.7	29.8	S.D.	21.1	10
14-15	166.0	S.D.	7.1	53.7	S.D.	7.8	24.6	S.D.	4.3	8

Female Twins - Childhood

AGE	HEIGHT	WEIGHT	T+B+S+S	NUMBER
	Mean ± S.E.	Mean ± S.E.	Mean ± S.E.	
3-4	97.1 ± 4.5	14.0 ± 1.2	27.9 ± 5.3	18
4-5	103.7 ± 4.8	16.3 ± 1.6	27.1 ± 7.4	9
5-6	110.9 ± 4.1	18.3 ± 1.7	24.7 ± 4.9	28
6-7	115.9 ± 5.6	20.5 ± 2.7	25.7 ± 6.3	27
7-8	127.1 ± 5.4	25.0 ± 2.5	26.4 ± 5.1	22
8-9	129.4 ± 7.2	26.8 ± 4.1	25.3 ± 6.2	28
9-10	134.3 ± 66.3	28.4 ± 3.5	29.5 ± 10.6	19
10-11	143.0 ± 7.5	32.1 ± 4.1	29.3 ± 8.5	36
11-12	148.8 ± 10.3	37.3 ± 6.2	30.2 ± 9.4	16
12-13	153.7 ± 5.8	43.3 ± 7.3	35.3 ± 14.3	20
13-14	160.2 ± 5.2	47.4 ± 8.3	32.9 ± 10.1	21
14-15	158.1 ± 4.5	49.1 ± 10.2	37.3 ± 17.3	6

Sisters - Childhood

	Height			Weight			TBSS			
3-4	97.2			15.1			33.0			1
4-5	104.5	S.D.	4.7	18.1	S.D.	1.4	28.3	S.D.	1.8	5
5-6	112.2	S.D.	3.7	19.3	S.D.	1.9	24.0	S.D.	2.8	6
6-7	118.7	S.D.	4.3	21.5	S.D.	2.1	26.4	S.D.	4.6	9
7-8	123.4	S.D.	6.8	24.9	S.D.	3.9	28.9	S.D.	7.9	9
8-9	130.5	S.D.	6.2	27.4	S.D.	4.1	25.0	S.D.	4.2	9
9-10	132.4	S.D.	4.9	28.3	S.D.	6.8	30.6	S.D.	16.0	5
10-11	137.1	S.D.	6.1	31.8	S.D.	5.1	29.2	S.D.	3.3	9
12-13	155.1	S.D.	9.4	43.0	S.D.	9.2	31.5	S.D.	12.0	11
13-14	160.6	S.D.	5.8	48.5	S.D.	4.2	35.9	S.D.	10.7	12
14-15	164.3	S.D.	4.9	53.3	S.D.	5.5	37.2	S.D.	10.4	16

FIGURE 27

YEARLY MEAN HEIGHTS IN CHILDHOOD OF BROTHERS AND OF MALE TWINS

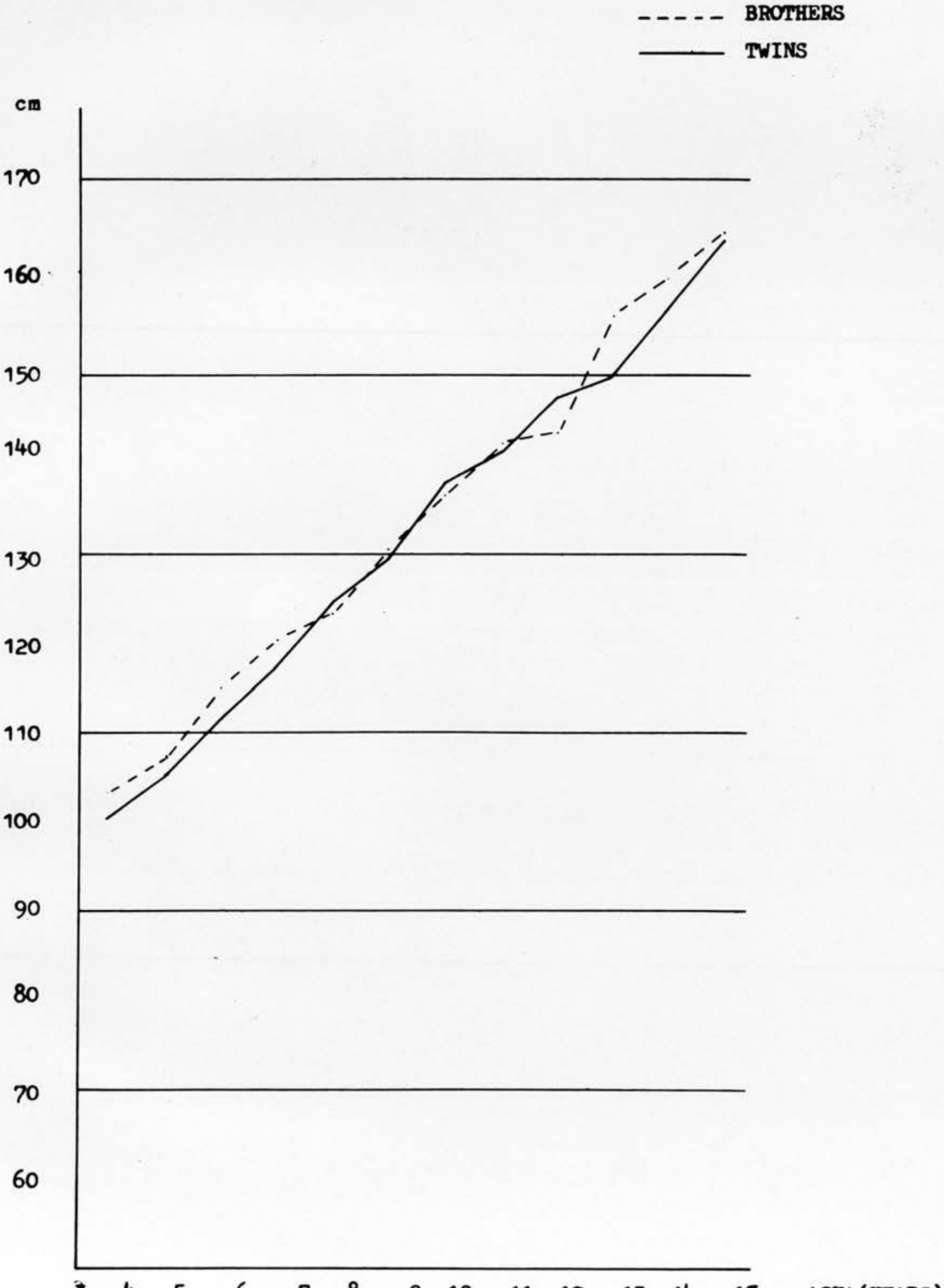


FIGURE 28

YEARLY MEAN HEIGHTS IN CHILDHOOD OF SISTERS AND OF FEMALE TWINS

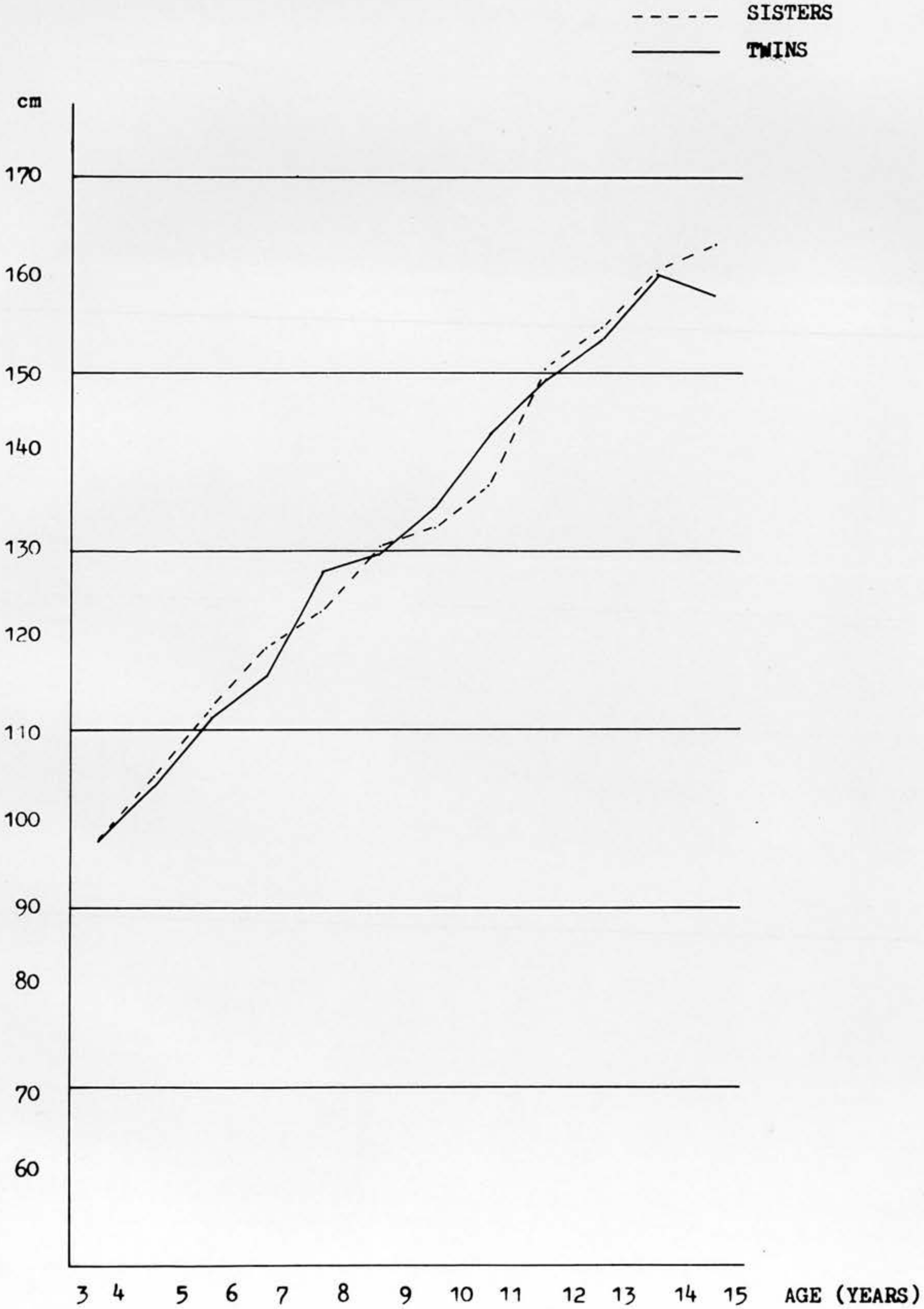


FIGURE 29

YEARLY MEAN CHILDHOOD WEIGHTS OF BROTHERS AND MALE TWINS

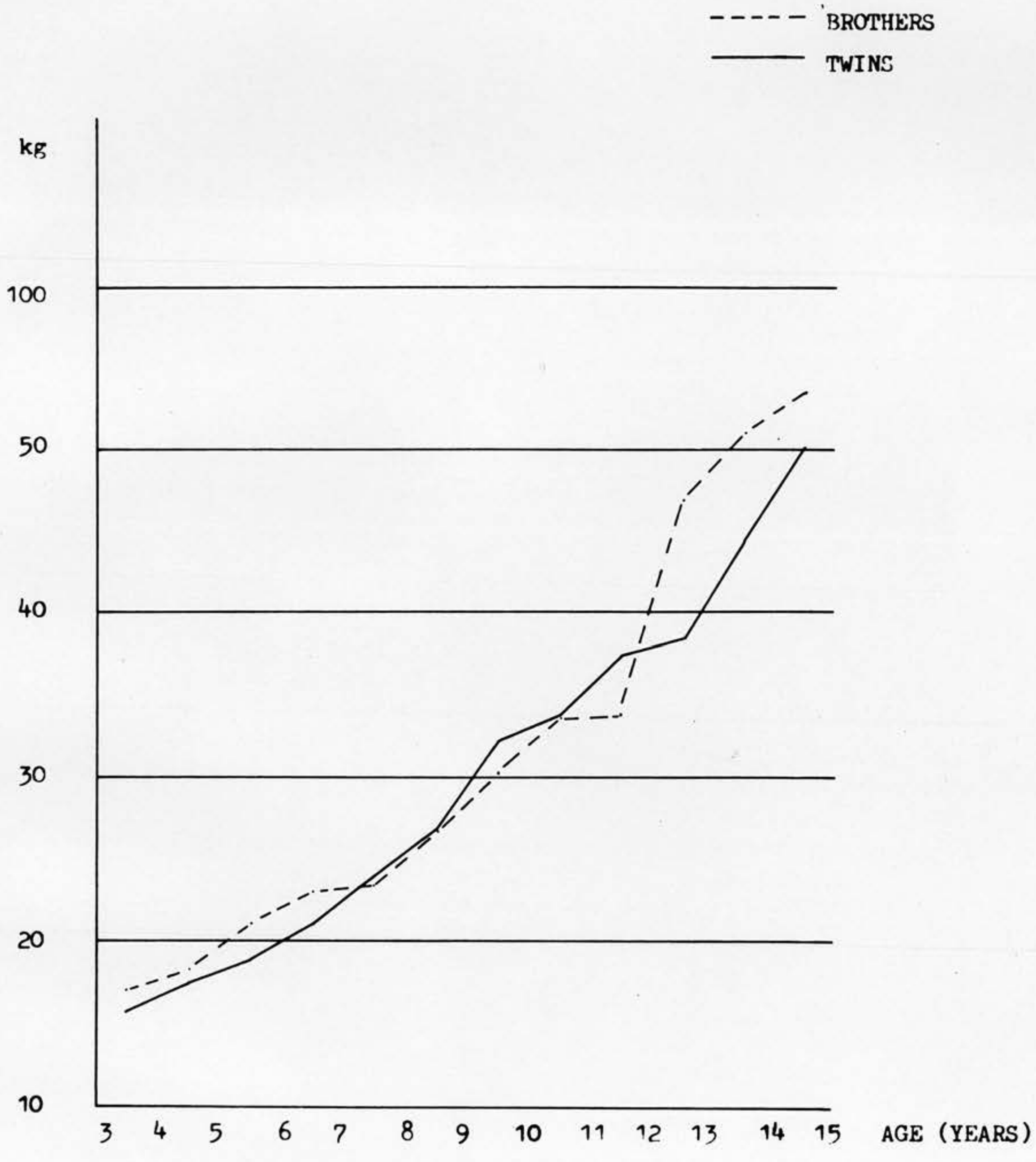


FIGURE 30

YEARLY MEAN CHILDHOOD WEIGHTS OF SISTERS AND FEMALE TWINS

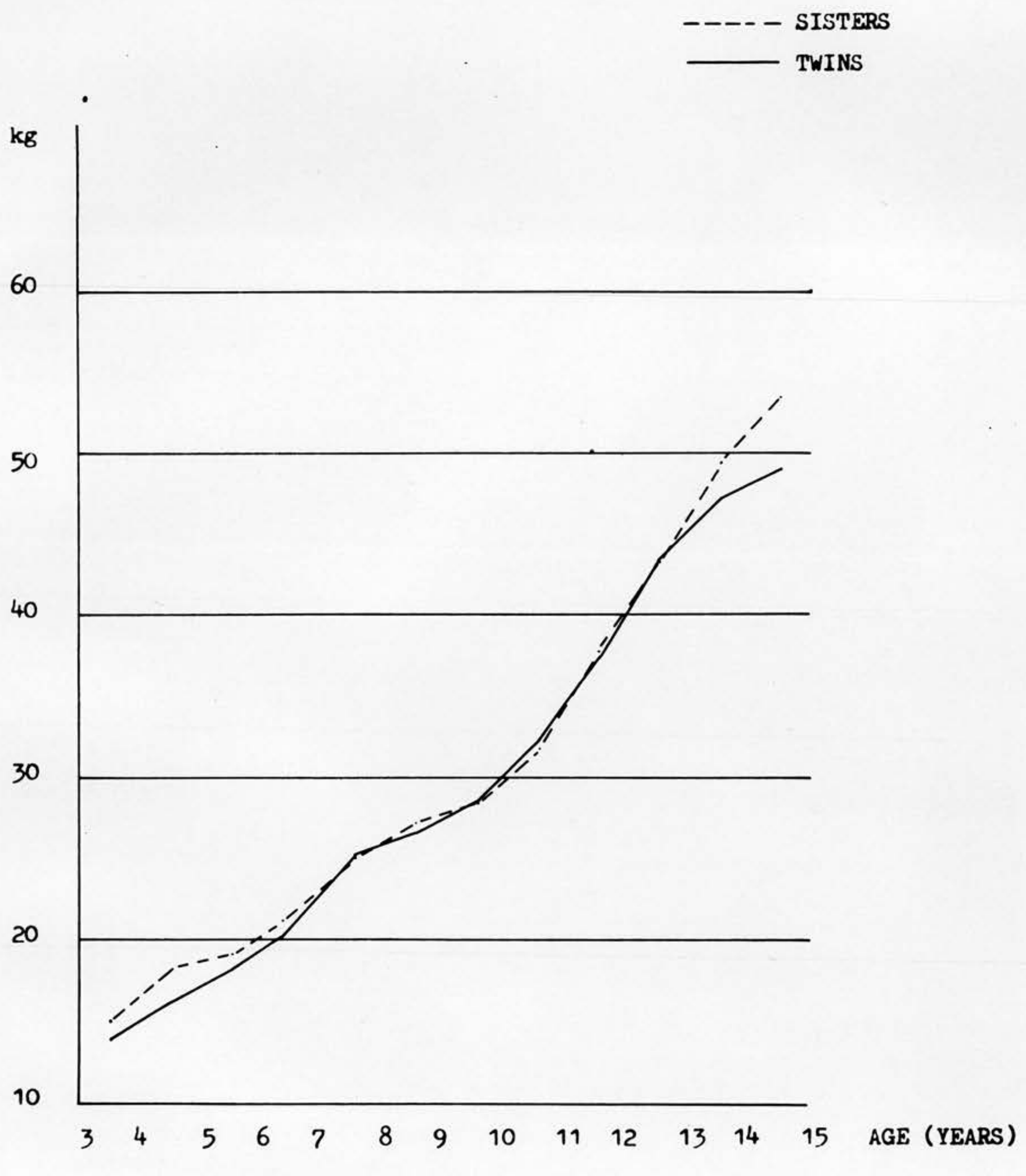


FIGURE 31

YEARLY MEAN CHILDHOOD COMBINED SKINFOLD MEASUREMENTS (TRICEPS + BICEPS + SUBSCAPULAR + SUPRAILIAC) OF BROTHERS AND OF MALE TWINS

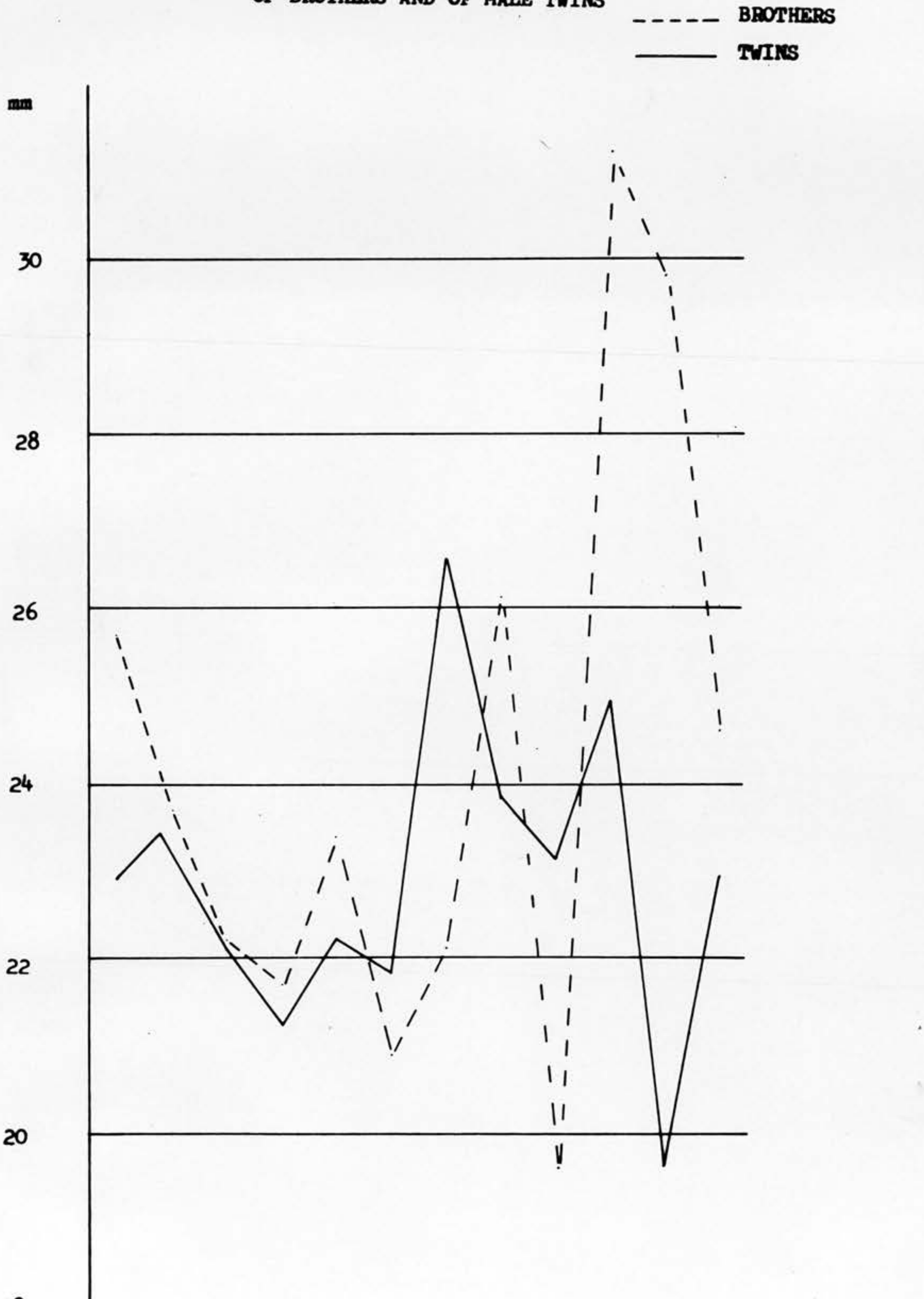
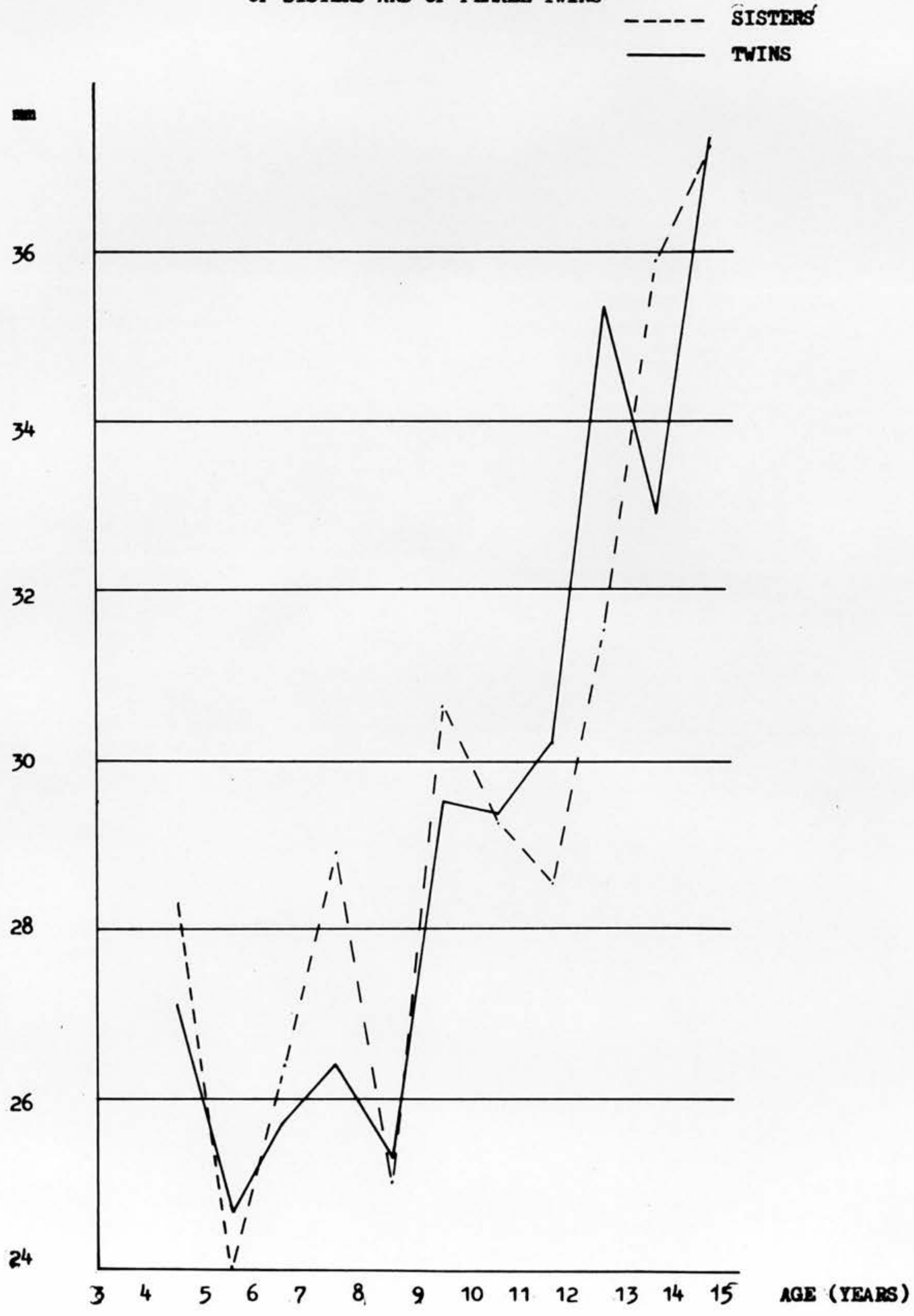


FIGURE 32

YEARLY MEAN CHILDHOOD COMBINED SKINFOLD MEASUREMENTS (TRICEPS + BICEPS + SUBSCAPULAR + SUPRAILIAC) OF SISTERS AND OF FEMALE TWINS



Acknowledgements

I should like very much to thank Dr. C.G.D. Brook for providing me with the opportunity to carry out this work and for the invaluable advice he gave throughout the project. This study was financed by a grant from the Department of Health and Social Security.

Miss Veronica Trigg, Mrs. Robyn Gard and Miss Lynette Napper provided much appreciated secretarial assistance. Professor J.W. Stewart kindly arranged the twin blood analyses.

This manuscript was typed by Miss Shobhna Shah. I specially thank her for her remarkable tolerance of the multiple shapes this thesis took before final completion.