THE SELECTION AND RECORDING OF BODY MEASUREMENTS IN NUTRITION WORK

REVIEW OF THE LITERATURE

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The object of taking body measurements in nutrition work is to provide a practical basis for the evaluation of nutritional status. The evaluation rests on a comparison of the body measurements of groups of comparable age and of the growth patterns of infants and children. The recording of body measurements usually forms part of a programme that includes clinical examination, biochemical investigations, and dietary survey.

Observations can be made by longitudinal or cross-sectional studies. If suitable numbers of individuals in different age groups are examined simultaneously, the study is cross-sectional, while if the same group of individuals is examined at intervals over a period of time the study is longitudinal. Cross-sectional data can be obtained with relative ease and rapidity, whereas longitudinal studies must be made over a period, e.g. of several years.

Cross-sectional investigations are a valuable tool for the speedy establishment of population 'norms' or standards of reference, and are of the utmost importance in the study of the state of nutrition of different populations or socio-economic groups. The value of body measurements is, however, increased if they are repeated on the same individuals, especially during the active phase of growth, and valuable inferences can be made by comparing the results so obtained with similar data for other groups.

Whether the data under consideration are longitudinal or cross-sectional, lower values for one group than for another in the same age range give cause for suspecting nutritional inadequacy. However, when interpreting differences, it should be borne in mind that various factors, e.g. socio-economic, regional, racial, and seasonal, may affect growth.[1-10]

An effective means of recognizing whether or not a child has been growing satisfactorily is to record each measurement on a graph from time to time.[11] Such longitudinal studies also give an indication of the irregular nature of individual growth patterns, which are characterized by marked fluctuations in growth rate, even before the adolescent growth spurt.[12, 13] The age at onset and duration of the acceleration of growth that occurs during adolescence also show very wide variation and it must be

remembered that the averaging of data will tend to flatten the peaks produced by individual growth spurts.[12]

In the evaluation of the nutritional status of individuals somatometry has a limited value; in group studies of children, however, and especially if modern techniques are employed in order to determine body build and 'composition', somatometry is probably the most important of the approaches used in the evaluation of nutritional status. It has the advantage of providing data that are objective and easily obtained and reproduced.

METHODS AND MEASUREMENTS USED IN THE CHARACTERIZATION OF BODY BUILD

The methods used and the number of measurements chosen (from a more or less infinite number) will depend on their practicability under given circumstances and the aims in view. In field work and school health programmes the number must usually for practical reasons be reduced to the minimum necessary for satisfactory evaluation of body build and 'composition'.

Certain measurements, for instance bi-acromial diameter, are less accurately reproducible than others (e.g. bi-cristal diameter), because they are readily affected by changes in position (shoulder movements in the case of the bi-acromial diameter). Some measurements, however, that are not so accurately reproducible may be closely correlated with height or weight or some other measurement, and should therefore not be eliminated in favour of another solely on the grounds of their inferior reproducibility.

All measurements used should be taken in a manner in accordance with accepted standards and as precisely as possible. The techniques used in a survey should be clearly described in the report.

Body measurements should include not only height and weight, but also, as far as practically possible, other measurements that will yield information on skeletal framework, muscle mass, and degree of adiposity.[12] Considerations that will influence the choice of measurements are: the particular purpose of the investigation (e.g. school health programme, growth study, field study, etc.); the fact that different approaches may be needed at different age levels; and the practicability of the proposed measurements, which will depend on the particular circumstances and their accuracy of reproducibility.

The recording of height and weight forms the basis of somatometric tests and no extensive enquiry is conceivable in which these two fundamental measurements are not noted, together with age and sex.

Skeletal Framework

Apart from height, a number of measurements can be made to evaluate the characteristics of the skeletal framework. Hip width (bi-iliac diameter) and shoulder width (bi-acromial diameter), for instance, are good measures of lateral development.

Sitting height and cristal height indicate the proportions of the total height contributed by the trunk and legs respectively. Chest circumference, depth and diameter indicate the characteristics of the thoracic cage. Bi-epicondylar diameter of the humerus and femur, wrist and ankle girth, and ulnar length, are used to characterize the extremities.

Muscularity

It is not generally appreciated that nearly half of the normal body weight is made up of muscle.[14] Muscularity can be assessed by the following means:

(*a*) X-ray photographs—by which differentiation can be made between bone, muscle and subcutaneous tissue.
(*b*) Somatometric measurements.
(*c*) The creatinine coefficient, which has been suggested as a measure of muscularity, has been shown to be unreliable and only a very rough guide.[15, 16]

Muscular development can be estimated from the limb circumference, provided that the thickness of the subcutaneous layer is determined at the same site by skinfold measurement and corrected for. Thus D, the diameter of the upper arm corrected for subcutaneous fat, may be calculated from the arm circumference (C) and the skinfold (S) according to the equation $D=\frac{C}{\pi}-S$, and serves as a criterion of muscularity.[17]

Leanness-fatness

No direct method for measuring the proportion of fat in the intact body is available. The following indirect methods can be applied:

(i) *Specific gravity of the body.* This is determined by underwater weighing or gas displacement in a specially constructed chamber.[18-23] It was thought to be an excellent measure of body fat until questioned and criticized recently by Tanner.[24]

(ii) *X-ray photographs.* As stated above, these can be used to distinguish between muscle, bone and subcutaneous tissue (fat). This method has mostly been used on the calf, where, however, in the adult, fat does not specially tend to accumulate. The correlation of calf fat with fat in other areas and with total body fat has not yet been ascertained, but it is likely to be low. Consequently, the data for subcutaneous fat in this region are at present of uncertain value for the calculation of general fatness or leanness.[14] The method could, however, be adapted for application to other regions of the body.

(iii) *Caliper measurement of skinfold thickness.* Skinfold measurements have the advantage of simplicity and can be rapidly taken. Their validity as a measure of subcutaneous fat does not seem to be in doubt.[20, 25, 26] There is general agreement that the skin proper varies little in thickness and that differences in the thickness of skinfolds are due to differing thicknesses of the subcutaneous layer.[14] In fat people about two-thirds of the excess adiposity is located just beneath the skin.[20]

(iv) *Abdominal circumference and gross body weight.* These measurements provide a rough guide to leanness-fatness. The difference between abdominal and thoracic circumference tends to parallel the specific gravity and can serve as a gross measure of leanness-fatness.[18, 27]

Measurements in Childhood

Different measurements must be considered in infants and young children. Height must be taken as crown-heel length, and skull circumference is an important additional measurement to characterize head development and growth. Head circumference may be omitted from 3 years onwards,[28] although some workers[29] have recorded it as a routine measurement until adulthood. By the time the age of 2 years is reached, standing height is to be preferred to supine length, since the errors in supine length may be considerable,[12] especially if the child struggles. Some workers, however, use supine length up to the age of 6 years. It should be noted that higher values are obtained for supine length than for standing height.[12]

RECOMMENDED TECHNIQUES IN FIELD STUDIES AND SCHOOL SURVEYS

The techniques described below are recommended for use in nutritional status surveys and the data obtained from them should supplement those from clinical examinations, biochemical tests, and dietary surveys.

The metric system is the most widely used and it should be adopted for purposes of comparison with other workers' findings.[28] The measurements can always be converted to the English system.

Skeletal measurements such as height and bi-acromial and bi-cristal diameter should be recorded to the nearest 0·1 cm. This may seem impracticable, but a reading to the nearest 1 cm. would be too inexact. After the various calculations have been made, the results can be brought to the nearest 0·5 or 1 cm., as desired.

Weight is taken to the nearest 0·1 kg. ($\frac{1}{4}$ lb.),[12] skinfold caliper measurements to the nearest 0·1 mm.,[24] and limb circumference to the nearest 1 mm.

1. *Height*

This should be measured as follows: The subject should be without shoes and standing with his heels and back in contact with an upright wall. His head should be held so that he looks straight ahead with the lower borders of his eye sockets in the same horizontal plane as his external auditory meati—that is to say, the head must not be tipped with the nose upwards.[12] The wall should not have a prominent skirting board; otherwise the heels will be too far forward and the body will lean backward.

Care should be taken that the subject does not exaggeratedly thrust his shoulders backward or hunch them upward, thus forcing shoulders, upper thorax and arms out of their usual anatomical relationship. The arms should be held freely (or loosely) at the sides, in an extended position; the palms should be held inward, facing the lateral surfaces of the thighs. The feet, with the heels touching or at the most half an inch apart, should be held so that their respective longitudinal axes form a 45° angle with each other (this is a comfortable standing position).

In postpubertal females, buttock development may be so exaggerated that the heel and shoulder contact will be strained. In such cases the subject should be allowed to stand free in the 'standard erect position',[39] i.e. she should be requested to stand as erect, or as 'tall" as possible, but comfortably so, supporting the weight equally on both feet.

The recording of the measurement is best done with a Martin anthropometer. As a second choice, Baldwin's paper measuring scale may be used.[39] In order to make effective contact with the top of the head, slight pressure should be applied to minimize the effect of the hair. Care must be taken to prevent the heels from coming off the ground. Ribbons, pins, etc., should be removed from the hair. Tanner[12] recommends that during the measurement the subject should be told to take a deep breath and stretch to be as tall as possible, his argument being that stretching minimizes the variation in height seen between morning and evening, which may otherwise be as much as 2 cm. This, however, does not seem to be a generally adopted method and if the measurements were always taken at about the same time of day the argument would fall away.

2. *Weight*

Beam balances with attached weights should be used and the scale should be checked regularly. Weighing of subjects in their ordinary clothing is strongly to be deprecated. Young children should be weighed in the nude if possible.[12] Older children and adults should wear a standard garment and the scale should be adjusted to zero with the garment resting on it, so that the recorded weight is the nude weight. Personal ornaments and accessories should be removed.[28]

3. *Skeletal Framework*

Cristal height. The value of this measurement is questioned by some,[28] but the Rowett Research Institute[30] found that cristal height was of more value than total height or weight in distinguishing different expenditure groups. It constitutes the distance from the sole of the feet to the highest point of the ilium and is obtained with the subject standing erect. Adequate pressure should be exerted on the contact surface in order to minimize the effects of the subcutaneous fat that may overlie the iliac crest.[28] Care should be taken that the hips are kept in a horizontal position.[28]

Bi-cristal diameter. This measurement is an index of the width of the pelvic girdle, and is obtained by measuring the greatest distance between the lateral margins of the iliac crests. When necessary, strong pressure should be exerted on the contact surface so as to minimize the effect of the overlying soft tissue.[28] Bi-cristal diameter is a good measure of the lateral development of the skeletal frame, and it is recommended as a standard item in the 'minimal' set of anthropometric measurements.[28]

Bi-acromial diameter. This represents the width of the shoulder girdle, and it is next in importance to bi-iliac diameter as a measure of the lateral development of the skeletal frame.[28] It is taken with the subject standing erect, but relaxed so as to give the *maximum* distance between the lateral margins of the acromion process of the scapulae; i.e. the shoulders must be neither hunched nor thrust back.[28]

4. *Skinfold Measurements*

Skinfold measurements are recommended as measures of subcutaneous fat. At present there is fairly unanimous agreement on the value of two sites, namely the upper arm and the scapular regions.[28] A third skinfold measurement, on the abdomen next to the umbilicus, is also recommended by certain workers.[17, 31]

Hammond[31] compared estimates of subcutaneous fat obtained by means of X-rays with estimates based on skinfold caliper measurements and found a very high degree of correlation. He stated that the pattern of fat distribution that characterized any one site applied closely in all other sites. Of the six sites he used for skinfold caliper measurements Hammond found every one to be highly representative of total fat. He considered that the measurements that could best be combined for estimating total fat were those taken in the triceps (or biceps), subscapular and abdominal regions.

Technique. The calipers used should be one of the standard instruments in general use nowadays. They should have a constant pressure of about 10 G./sq. mm. irrespective of gap, and a contact surface of 20 - 40 sq. mm.[28] The most accurate of the skinfold calipers available is probably the Harpenden instrument.[24] The skin should be lifted by grasping a fold firmly between the thumb and forefinger at a distance of about 1 cm. from the site at which the skinfold is to be measured, care being taken not to include underlying muscle or fascia.[22] It should be remembered that the intention is to measure a complete skinfold (double thickness of skin plus tela subcutanea) and the degree of stretching applied should be adjusted accordingly.[17] The calipers should be applied at a depth about equal to the thickness of the fold.[22]

Some investigators use the right-hand side of the body but, since all anthropometry has been carried out on the left side for the last 70 years by international agreement, there would seem to be no point in departing from this custom.[24]

(a) *Triceps (upper arm) skinfold.* The arm is allowed to hang freely in a vertical plane and the forearm is flexed to an angle of 90°. The site measured is at the back of the left upper arm over the triceps, midway between the tip of the acromial process of the scapula and the tip of the olecranon. The direction of the skinfold should be parallel to the long axis of the arm.[28]

(b) *Subscapular skinfold.* This skinfold is measured below the tip of the left scapula, with the subject in a relaxed standing position. The lines of Langer require the fold to be taken in a diagonal plane ascending medially at an angle of about 45° from the horizontal, that is to say in the direction of the ribs.[22, 32] The thickness of the subcutaneous tissue is fairly uniform in this area and small differences in the location of the site would matter less here than in the arm or abdominal region.[22]

(c) *Abdominal skinfold.* The site is 1 inch to the left of and 1 inch below the umbilicus.[31] The skinfold is lifted in the horizontal plane, with the subject in a standing position.

5. *Muscularity*

For the estimation of muscularity the measurement of limb circumference is the simplest and most rapid method. The recommended measurements are the circumferences of the upper arm and calf (lower leg).[10, 28] A steel tape should be used.

The upper-arm circumference is measured at a right angle to the long axis of the arm at the level of the upper-arm

skinfold (see section 4), with the arm hanging freely at the side. The steel tape should be applied lightly to the skin without deforming its contour.[28]

The calf circumference is taken so as to represent the maximum circumference of the left calf at right angles to the long axis of the limb. Contact should be definite but slight, without indentation of the skin. The measurement should, according to Stuart and Meredith,[11] be taken with the subject standing with his feet several inches apart and his weight evenly distributed on the lower limbs.

6. *Other Measurements*

Various other measurements such as wrist and ankle girth, bi-epicondylar diameter of humerus and femur, ulnar length, arm length, chest girth and diameter, etc., can be taken. Their value, however, is not clearly proved, nor are they generally recommended by authorities for inclusion in the minimum set of anthropometric measurements to be used in school and field studies.

Of these other measurements, chest girth is probably the one most frequently included by workers in their sets of measurements. Bigwood,[10] however, preferred not to include it because it is very difficult to obtain accurate measurements of chest girth for comparative purposes and the value is doubtful because soft tissues are included in the measurement. In taking chest diameter some workers have compressed the soft tissue and others not, thereby confusing the issue.

INTERPRETATION OF MEASUREMENTS

Various mathematical indices based on body measurements have been recommended in the past for the numerical expression of the 'score' of the individual. These indices have usually purported to be adequate or reliable measures of nutritional state, but most of them have been shown to be unreliable or to yield no more information than less complicated methods, and they have fallen into disfavour. For reference to them other sources may be consulted.[1, 10, 11, 33, 34] Suffice it here to say that a single set of body measurements cannot as a rule be relied upon to indicate clearly the state of nutrition of individuals,[1, 10, 11, 35] nor can 'grids', 'channel systems', etc., be regarded as satisfactory measures of individual growth.[11, 36]

As stated above, the chief value of body measurements is that they provide a basis for comparing different groups and for measuring and comparing the progress of groups or individuals. When serial measurements are recorded on the same group of children, a sudden drop is sometimes seen in the percentile position held by a specific child. Such a regression often coincides with illness, and may occasionally be the first evidence of it. On the other hand, the fact that a consistent position is held cannot be taken as a guarantee of good health.

A single body measurement cannot as a rule be correlated with nutritional status; for instance, the single observation that weight has been gained fails to indicate whether bone, muscle or fat has been predominantly developed. More definition is obtained when weight is combined with height, but the picture is still ambiguous. Excessive weight for height may, for instance, be indicative either of flabbiness or of a stocky, muscular build. Measurements such as bi-acromial and bi-cristal diameter may help to characterize the extent to which excessive weight for height is dependent on breadth of skeleton, while skinfold thickness and limb circumference may help to distinguish adiposity from muscular development.

Of the individual anthropometric measurements used for throwing light on the nutritional state, the importance of skinfold thickness is underlined.[37, 38] The thickness of the subcutaneous layer, whether determined by skinfold calipers or X-ray measurement, is considered to provide a more satisfactory index of relative fatness and nutritional status than the body weight.[37, 38]

PRESENTATION OF DATA AND RECOMMENDATIONS

Group findings can be represented in different ways and the choice of a suitable method should be guided by the characteristics of the data, i.e. by the 'spread' or distribution of the variable under consideration.

As with all biometric observations, somatometric findings show a considerable range of variation even when the groups studied exclude or minimize known sources of variation (e.g. age and sex). The values for a particular variable tend to cluster round a point within the range of variation (usually near the middle) and, when each value is plotted graphically against the frequency with which it occurs, a curve is obtained which ascends to a peak (the mode or most 'popular' value) before descending again as the upper limit of the range is approached.

When the frequency distribution curve is symmetrical and unimodal, the distribution is said to be 'normal'. In such a case the mode (i.e. the value of the variable corresponding to the peak of the curve) coincides both with the mean and with the median (i.e. the central value). The mean of a normally distributed set of values is therefore in every sense the 'expected' value of the population and can justifiably be presented as such. Its usefulness is limited, however, unless an indication is also given of the range of the values. This is usually done by giving the standard deviation (S.D.), which defines a range about the mean within which roughly two-thirds of the values fall.

Extreme values at one end of the distribution curve not balanced by correspondingly extreme values at the other will cause the mean to shift away from the mode or 'popular' value in the direction of the more extreme values. The position of the median, however, is affected only when the *number* of values is greater on one side of the mode than on the other. Even then, the median deviates from the mode less than the mean does.

Because a skew or asymmetrical distribution (which is encountered more frequently than a symmetrical distribution) detracts from the value of the mean, it has become customary to represent somatometric findings by means of percentile tables or graphs and this method is recommended for general use. The median, above and below which equal numbers of values fall, corresponds to the 50th percentile. The 90th percentile is that value below which 90% of the values fall, the 10th percentile that value above which 90% of the values fall, and so forth.

Percentile graphs that represent the different population norms are extremely useful not only for comparing populations but also for comparing the status or progress of an individual with that of the rest of the population. Population norms are, however, continually changing because of the 'secular trend' and, according to Tanner,[12] should be re-established every 10 years.

In South Africa there is a conspicuous lack of somatometric data representative of the country's population, and a great need exists for large-scale studies on representative

samples in order to establish norms for the different population groups.

SUMMARY

The place of somatometry in the evaluation of nutritional status and growth is discussed. Certain measurements and techniques are recommended for school and field studies. These recommendations are supported by references to authorities.

It is suggested that data be presented in percentile tables or graphs.

A plea is made for large-scale studies on representative groups for the establishment of population norms, data on which are conspicuously lacking in South Africa.

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