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The presentation and use of height and weight data for comparing the nutritional status of groups of children under the age of 10 years

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This paper presents recommendations for the analysis and presentation of height and weight data from surveillance or surveys involving nutrition and anthropometry in young children up to the age of 10 years. These recommendations are only for the analysis of data collected on a cross-sectional basis. The basic indices recommended are height for age and weight for height, each considered either in terms of centiles or in a cross-classification scheme using standard deviation scores. It is hoped that these methods of analysis and presentation will prove widely acceptable, so that international comparisons will be made easier.

In the past, the nutritional status of groups of children has been most frequently assessed by using a classification based on a deficit in weight for age, originally proposed by Gomez and modified by Jelliffe (*1, 2, 3*). The Eighth Joint FAO/WHO Expert Committee on Nutrition (*4*) emphasized the importance of distinguishing between acute and chronic, or present and past, malnutrition. Several authors have suggested methods for the classification of nutritional status, based on measurements of height and weight, which take into account this distinction (*5, 6, 7*). Recently, an FAO/UNICEF/WHO Expert Committee on Nutritional Surveillance (*8*) recommended the use of height for age and weight for height as primary indicators of nutritional status in children.

The results of surveys made in different regions, or in the same region at different times, should be analysed and reported in such a way that comparisons are facilitated. This paper suggests methods of classification that we hope will be widely acceptable and thus make international comparisons possible. The classifications are intended for use in analysing data from cross-sectional surveys made as part of nutritional monitoring or surveillance programmes. In the context of this paper, nutritional monitoring includes the cross-sectional collection of measurements of height and weight on a continuous basis as part of regular health care services (surveillance) as well as the making of periodic studies of population samples (surveys).

These recommendations, although specifically for use in the analysis of cross-sectional data from groups of children, do not conflict in any way with the use of weight and height for following the progress of individual children in clinics. The reader should recognize, however, that there are specific problems related to the evaluation of growth of an individual child that are not discussed in this paper.

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THE REFERENCE POPULATION

It is frequently convenient to compare measurements made in different places, or in the same place at different times, by relating them to a single reference population. The anthropometric data to be used in the development of such a reference population should fulfil the following criteria.

1. Measurements should relate to a well-nourished population.

2. The sample should include at least 200 individuals in each age and sex group.

3. The sample should be cross-sectional, since the comparisons that will be made are of a cross-sectional nature.

4. Sampling procedures should be defined and reproducible.

5. Measurements should be carefully made and recorded by observers trained in anthropometric techniques, using equipment of well tested design and calibrated at frequent intervals.

6. The measurements made on the sample should include all the anthropometric variables that will be used in the evaluation of nutritional status.

7. The data from which reference graphs and tables are prepared should be available for anyone wishing to use them, and the procedures used for smoothing curves and preparing tables should be adequately described and documented.

At present, there are three bodies of data that may be considered for use as an international reference. These are: the measurements of Dutch children reported by van Wieringen (*9*); those of US National Academy of Sciences (*10*); and those of British children reported by Tanner et al. (*11*).

Although none of these sets of measurements meets all the criteria listed above, we suggest that the data recommended by the US National Academy of Sciences are, on balance, most suitable for use as an international reference. These data are drawn from a defined sample of American children which contains between 300 and 1600 children in each yearly age group. In addition to height and weight, other anthropometric variables are available including measurements of skinfold thickness, limb circumference, and head circumference. A detailed analysis and description of the reference population and the sampling procedures is obtainable from the US National Center for Health Statistics and will be published as a monograph of that agency. The data from this reference population are available for both sexes as centile curves of weight for age and height for age up to 18 years, and of weight for length or height up to the age of puberty (*12*). The data are also available as tabulations of centiles and mean ± SD of height and weight for each month of age up to the age of 18 years, and of weight for height for each 0.5 cm height interval up to 145 cm for boys and 137 cm for girls. These tabulations are available from the Chief Medical Officer, Nutrition, World Health Organization, who will also offer facilities for consultation on the computer analysis of results for presentation in the ways recommended below.

Anthropometric measurements are being made, or are in the process of being analysed, on large groups of children in other countries, e.g., Cuba and United Kingdom (*13, 14*). When these analyses are complete, a detailed comparison of all the results should be undertaken to determine how far the reference data that we are recommending are representative of well-nourished children in different countries.

When the reference population data are being used, a distinction must be made between the concept of a reference and that of a standard or target. The question of whether all child populations throughout the world have the same genetic potential for growth in size is still unresolved (*15, 16*). Clearly, if there were differences dependent on different gene distributions, then the target for one population would not be the same as the target for another. This does not, however, affect the use of the reference data for comparisons between populations.

We suggest that there are in effect two stages in the analysis of data from cross-sectional surveys. The first stage is recording and grouping the observations in such a way that they are internationally intelligible and comparable. It is for this purpose that a reference base is needed, and it is immaterial from what population that base is drawn, provided that it is large enough for proper statistical definition.

Because the reference population cannot be used as a universal target, the question of what is a realistic goal in any particular situation does become important. If it is felt that the growth of children in an industrialized country is not a realistic target in another country in which the population has a different genetic and environmental background, two courses are possible: the first is to construct a local standard, although this may present considerable difficulties; the second is to make an arbitrary and perhaps temporary adjustment in the cut-off points derived from the reference population that are used for grouping the data and making value judgements about them (see below). For example, if it is felt that in a particular population even well-nourished children are shorter in stature than the children of the North American reference population, then it might be reasonable to set the target for height as 95% of the reference height rather than 100%. Decisions of this kind have to be taken locally, and it is not possible to make international recommendations about them.

ANALYSIS AND PRESENTATION OF DATA

Indicators

We recommend that for the assessment of nutritional status in cross-sectional studies, primary reliance should be placed on weight for height as an indicator of the present state of nutrition and on height for age as an indicator of past nutrition. Although weight for age has for many years been a mainstay in the evaluation of nutritional status, it has the disadvantage that it does not distinguish between acute and chronic malnutrition. On the other hand, weight for age as well as height for age are useful indices when serial measurements are made, as in clinics for children under 5 years of age. Weight for age is particularly useful in children under 1 year old and, if length measurements are not performed accurately, weight for age may be the most valid index.

Both the Dutch data of van Wieringen and the American data show that in these populations weight for height is nearly independent of age between 1.0 and 10.0 years. This means that, at a given height, both median weight and range of weight are independent of the age of the children concerned. Weight for height is probably also relatively independent of ethnic group, particularly in the age groups between 1 and 5 years (*15*, *17*, *18*). At ages of less than 1 year, at a given height (or length) the older child tends to be heavier. This source of error, which in any case is not very great (*19*), is minimized if in the first year of life children are classified in fairly narrow age ranges, as recommended below. Neither weight for age nor height for age can be determined when ages are unknown, and in these situations the use of weight for height for the assessment of nutritional status is particularly advantageous.

Age groups

In many contexts, children up to the age of 5 years are considered to be a homogeneous group and are referred to under the heading of preschool children. This leads to errors because the pattern of malnutrition tends to change as children grow older (*6*). At 1–2 years of age the deficit in weight for height is often very marked; by 3–4 years this deficit may be made up, but the child remains with a deficit in height for age and weight for age. For this reason it is recommended that data be presented in the age groups shown in Table 1. If the numbers of children are large enough (at least 100 in each age group) we strongly recommend the groupings in column A. In many situations the age groups shown in column B will be the most useful. The wider groupings in column C should be used only when numbers are small; we believe that such data will have limited value.

Table 1. Recommended age groups for the presentation of anthropometric data

A Highly recommended	B Recommended	C Permissible
0 – 2.99 months		
3.0 – 5.99 months	0 – 5.99 months	
6.0 – 8.99 months		
9.0 – 11.99 months	6.0 – 11.99 months	0 – 11.99 months
1.0 – 1.99 years	1.0 – 1.99 years	1.0 – 1.99 years
2.0 – 2.99 years		
3.0 – 3.99 years	2.0 – 3.99 years	
4.0 – 4.99 years		
5.0 – 5.99 years	4.0 – 5.99 years	2.0 – 5.99 years
6.0 – 6.99 years		
7.0 – 7.99 years	6.0 – 7.99 years	
8.0 – 8.99 years		
9.0 – 9.99 years	8.0 – 9.99 years	6.0 – 9.99 years

Analysis and presentation of results for each age and sex group

In all cases an accurate description of the population from which the results were obtained, including the numbers of children, should be provided in tabular or graphic form. Suppose, then, that measurements have been made on a number of children of one sex between the ages of 1 and 2 years; this forms a specific age and sex group. The set of measurements from this group can be analysed in two ways: by centiles, or by standard deviations from the mean (SD score).

Centiles

Data for an individual child (sex, age, height, and weight) are used to place the child in the appropriate centile of weight for height (or length), height for age, and weight for age. Under the age of 1 year, weight for age centiles are particularly useful. The specific centile into which a child falls can be determined by calculation; alternatively, the range within which each child lies can be obtained from graphs such as the examples (based on the National Center for Health Statistics/CDC reference population) shown in Fig. 1–6 or from appropriate tables. In these graphs and tables the weight for height, height for age, and weight for age centiles of the reference population are shown at selected intervals, including the third, fifth, ninety-fifth, and ninety-seventh centiles, which are presented so that the extremes can be better characterized.

Height and weight data for a group of children can be summarized in a table or a figure. Examples

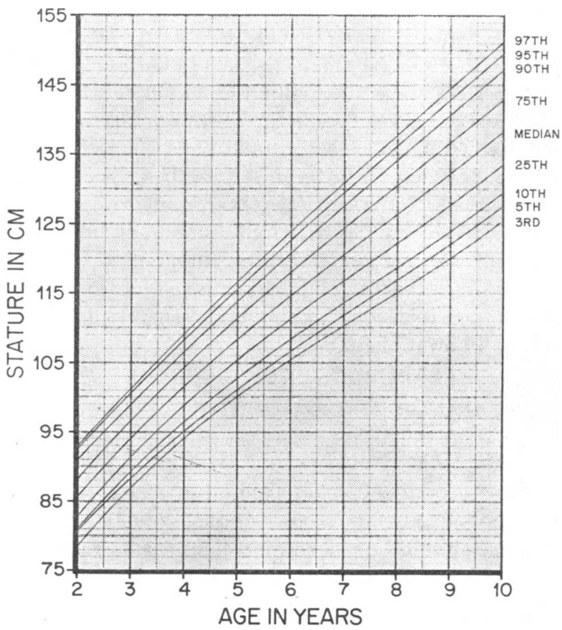

Fig. 2. Girls, 2–10 years, stature by age, percentiles (reference population).

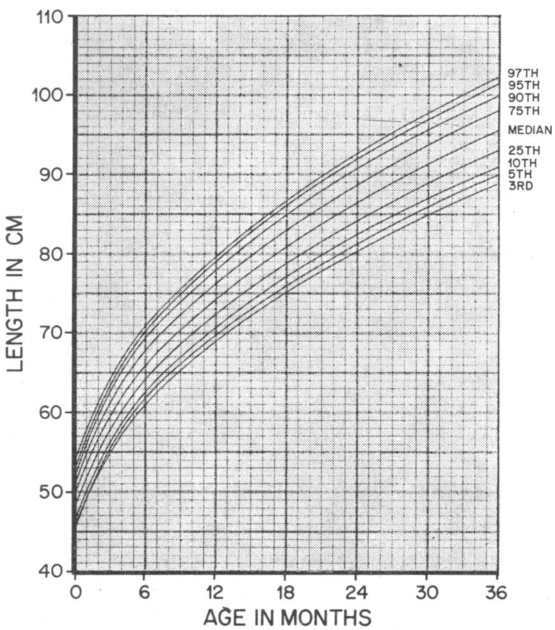

Fig. 1. Girls, 0–36 months, supine length by age, percentiles (reference population).

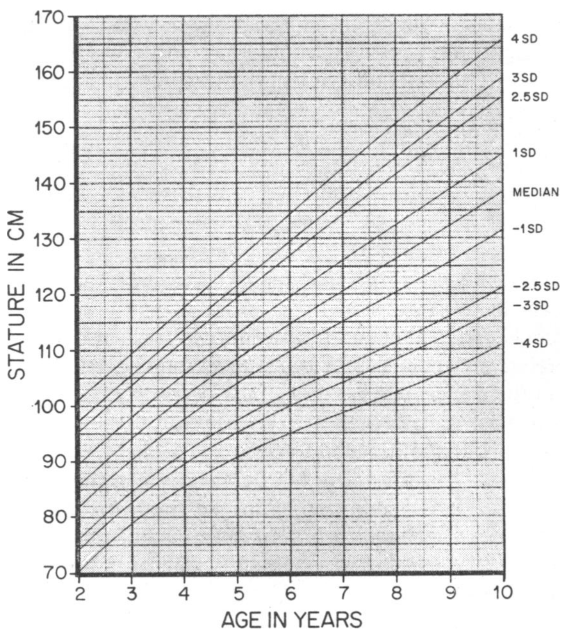

Fig. 3. Girls, 0–36 months, supine length by age, standard deviations (reference population).

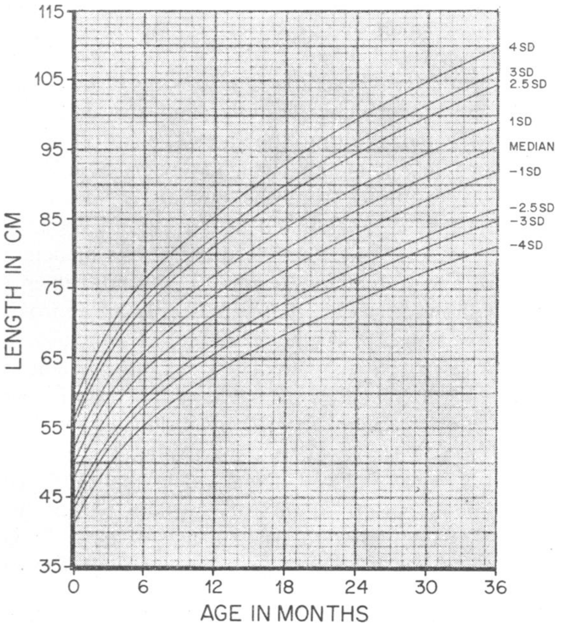

Fig. 4. Girls, 2–10 years, stature by age, standard deviations (reference population).

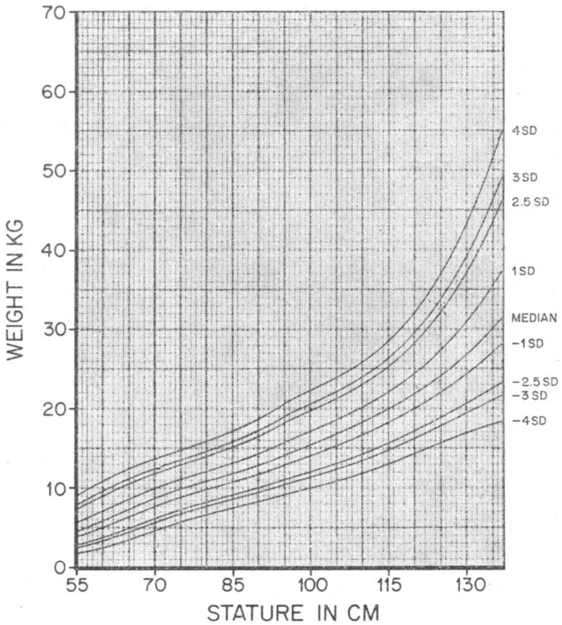

Fig. 6. Girls, weight by stature, standard deviations (reference population).

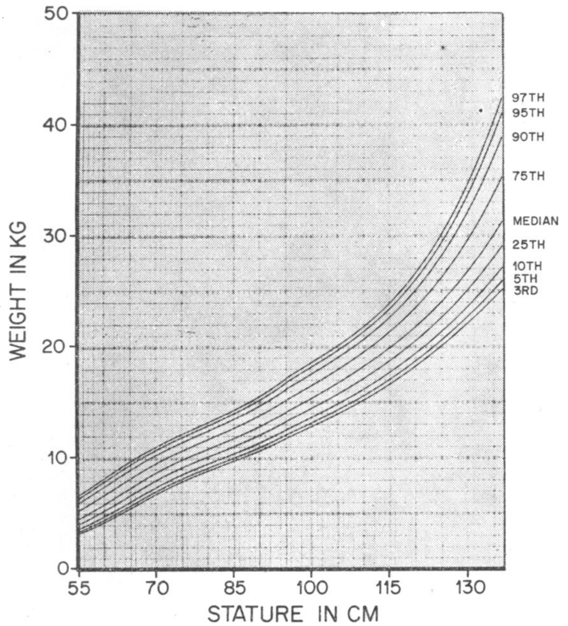

Fig. 5. Girls, weight by stature, percentiles (reference population).

of the presentation of height for age are shown in Table 2 and Fig. 7; similar presentations are appropriate for weight for height and weight for age. Fig. 7 shows that the sample contains an excess of children whose height for age lies in the lower centile ranges of the reference population. The advantage of relating results to centiles is that no error arises from the fact that weight for height in the reference population, and probably in all populations, has a skewed distribution. This skewness makes direct calculation of standard deviations inappropriate. The disadvantage of the method is that extremes of variation are less easy to characterize than in the standard deviation method. There are many populations in less developed countries where large numbers of children are so far outside the range of the reference population that they cannot be accurately classified by centiles.

Standard deviation score

In populations where many children lie outside the extreme centiles of the reference population, classification has usually been based on percentage deviation from the median of the reference population (*2*, *6*, *19*). In such classifications it has been usual to

Table 2. Example of presentation of the centile distribution of height for age in a sample group of children (aged between 1 and 2 years) as compared to the reference population

Centile		Male	Female	Total
00.0 – 02.9	n	15	23	38
	%	2.4	3.4	2.9
00.0 – 04.9	n	86	59	145
	%	13.9	8.7	11.2
00.0 – 09.9	n	211	208	419
	%	34.0	30.6	32.3
10.0 – 19.9	n	77	107	184
	%	12.4	15.8	14.2
20.0 – 29.9	n	81	100	181
	%	13.1	14.7	13.9
30.0 – 39.9	n	67	54	121
	%	10.8	8.0	9.3
40.0 – 49.9	n	48	46	94
	%	7.7	6.8	7.2
50.0 – 59.0	n	45	47	92
	%	7.3	6.9	7.1
60.0 – 69.9	n	26	41	67
	%	4.2	6.0	5.2
70.0 – 79.9	n	25	29	54
	%	4.2	6.0	5.2
80.0 – 89.9	n	18	23	41
	%	2.9	3.4	3.2
90.0 – 99.9	n	22	24	46
	%	3.5	3.5	3.5
95.0 – 100.0	n	10	9	19
	%	1.6	1.3	1.5
97.0 – 100.0	n	2	4	6
	%	0.3	0.6	0.5

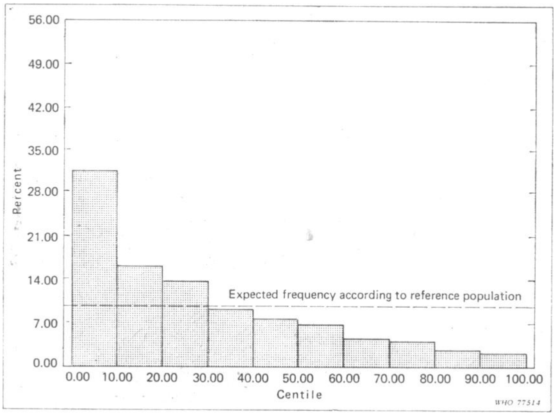

Fig. 7. Height for age distribution of a sample population in centiles as compared to the reference population; total number in sample = 4780.

distinguish grades of deficit (mild, moderate, and severe) by establishing arbitrary cut-off points.

Waterlow and others (*5*, *6*, *19*, *20*) have pointed out the additional usefulness of looking at the deficit in weight for height (wasting) and the deficit in height for age (stunting) together. The cut-off points proposed in this system, which were based on percentage deviations from the median, were chosen because they were assumed to correspond approximately to 1, 2, and 3 standard deviations of height for age and weight for height. Fig. 8 and Tables 3 and 4 show, however, that this is only an approximate relationship. As an example, at a height of 65 cm (girls) 90% of median weight for height is equal to 1.00 SD below the median (—1 SD) whereas at 85 cm, it is equal to 1.30 SD below the median (the 17th and 10th centiles respectively). The relative proportions of children diagnosed as malnourished by using a cut-off of 80% of median weight for height as compared to using a cut-off of —2 SD changes somewhat with increasing age and size of children. For this reason it is recommended that in those populations where large numbers of children fall above the upper or below the lower centiles, their weight for height and height for age should be expressed as multiples of the standard deviation of the reference population rather than as percentages of the median.

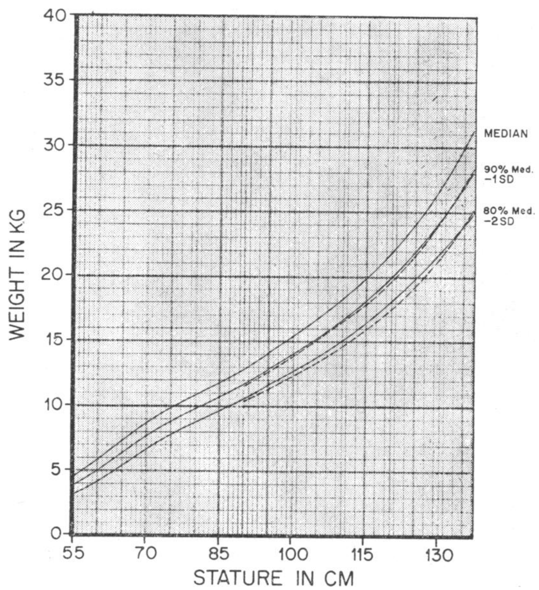

Fig. 8. Girls, weight by stature, standard deviations and percentages of median curves (reference population).

Table 3. Relationship of selected levels of percentage of median to SD scores and centiles for weight for height at various heights (girls)

Height (cm)	Weight for height (girls)					
	120% of median		90% of median		80% of median	
	SD score	centile	SD score	centile	SD score	centile
65	+ 1.9	97th	− 1.0	17th	− 2.0	3rd
85	+ 2.5	99th	− 1.3	10th	− 2.5	0.6th
95	+ 1.7	96th	− 1.1	13th	− 2.3	1st
105	+ 1.9	97th	− 1.1	13th	− 2.3	1st
115	+ 1.9	97th	− 1.2	12th	− 2.3	1st

Table 4. Relationship of selected levels of percentage of median to SD scores and centiles for height for age at various ages (boys)

Age (months)	Height for age (boys)					
	95% of median		90% of median		85% of median	
	SD score	centile	SD score	centile	SD score	centile
6	− 1.3	10th	− 2.5	0.6th	− 3.8	0.008th
12	− 1.4	8th	− 2.8	0.2nd	− 4.2	0.002th
24	− 1.3	10th	− 2.6	0.5th	− 3.9	0.005th
48	− 1.2	12th	− 2.4	0.8th	− 3.6	0.02nd
72	− 1.2	12th	− 2.4	0.9th	− 3.6	0.02nd

Because the weight for age and weight for height distributions were highly skewed at the upper centiles, different estimates of the standard deviation for values above and below the median were made for these variables. This was done by fitting empirical centiles of each half distribution with half of a Gaussian curve. In the case of height for age, which is normally distributed, standard deviations were calculated in the normal fashion.

Charts showing selected multiples of the standard deviation in the reference population are reproduced in Fig. 3, 4, and 6. Since in many situations there are obese as well as undernourished children, provision should be made for excess weight for height as well as for deficits. The determination for each child of the appropriate standard deviation score for weight for height, height for age, and weight for age can be done by calculation or by comparison with these graphs. The formulae for calculating the standard deviation score for a child, as well as a number of examples using weight for height, are shown in Table 5. Similar calculations to determine the standard deviation score for height or weight for age can be made by substituting the age of the subject, the height or weight of the subject, the median height or weight for age, and the appropriate ±1.00 SD value as required. It is then a simple matter to summarize the results by giving, for each age and sex group, the number and proportion of children in specified standard deviation ranges. However, as each child may in varying degrees be both under weight for height (acutely malnourished) and under height for age (chronically malnourished), it is an advantage to get a more complete picture of the various combinations. For this purpose a 4×4 table was originally introduced (*6, 19*). If account is to be taken of children who are overweight and of more than average height, the number of cells in the table should be increased.

Table 5. Examples of calculation of standard deviation scores

Height of subject (boys) (cm)	Weight of subject (kg)	Median weight for height (kg)	± 1.00 SD (kg)	Subjects' SD score
60	5.1	5.8	− 0.643	− 1.1
70	9.3	8.5	+ 0.841	+ 1.0
90	15.1	13.0	+ 1.069	+ 2.0
110	15.3	18.7	− 1.610	− 2.1

Formula for calculation of the SD score of subjects with a weight below the median weight for the subject's height:

$$\text{SD score of subject} = \frac{\text{median weight for height} - \text{weight of subject}}{\text{1.00 SD lower}}$$

Formula for calculation of the SD score of subjects with a weight above the median weight for the subject's height:

$$\text{SD score of subject} = \frac{\text{weight of subject} - \text{median weight for height}}{\text{1.00 SD upper}}$$

Applications

In presenting height and weight data to describe the nutritional status of children from relatively well-nourished populations, centile distributions of height for age and weight for height are the most appropriate (see Table 2 and Fig. 7). In relatively undernourished populations the cross-tabulation of height for age against weight for height is recommended using standard deviation scores instead of percentage deviations from the median. The approximate relation-

Table 6. Example of cross tabulation in SD scores of weight for height and height for age, in a developing country, of children aged between 1 and 5 years (number in sample = 6482)

SD score of weight for height	SD score of height for age (percentage of population)				
	More than − 2.00	− 2.00 to − 2.99	− 3.00 to − 3.99	− 4.00 or less	Total
More than − 2.00	24.3	24.8	21.3	15.1	85.5
− 2.00 to − 2.49	2.3	2.6	2.3	1.7	8.9
− 2.50 to − 2.99	0.8	1.2	1.1	0.7	3.7
− 3.00 or less	0.4	0.5	0.5	0.4	1.8
Total	28.0	29.0	25.1	17.9	100.0

Table 7. Example of cross tabulation in SD scores of weight for height and height for age, in a developed country, of children aged between 1 and 5 years (number in sample = 9448)

SD score of weight for height	SD score of height for age (percentage of population)				
	More than − 1.50	− 1.50 to − 1.99	− 2.00 to − 2.99	− 3.00 or less	Total
+ 2.00 or more	5.3	0.4	0.5	0.5	6.7
1.99 to + 1.00	13.4	0.9	0.8	0.4	15.5
+ 0.99 to − 1.99	66.6	5.0	3.8	0.9	76.3
− 2.00 or less	1.3	0.1	0.0	0.0	1.4
Total	86.6	6.4	5.2	1.8	100.0

ships between SD scores, deviations from the median and centiles for weight for height (girls) and height for age (boys) are shown in Tables 3 and 4. With such information, appropriate classification limits and numbers of cells can be chosen.

Previous use of this system has shown that 80% of median weight for height and 90% of median height for age in undernourished populations are useful classification limits for identifying significantly malnourished groups of children. In deciding on appropriate classification limits in both undernourished and overnourished populations, the following principles should be observed.

1. It is desirable to include ±2.0 SD units for both height for age and weight for height in the classification scheme.

2. In undernourished populations, −2.0 SD weight for height corresponds approximately to 80% of the median weight for height and 90% of the median height for age. If further extension below —2.0 SD units is desired, it should be done in units of 0.5 or 1.0 SD, and the classification points at —3.0 SD, —4.0 SD units, respectively, should be maintained.

3. In populations where overnutrition is a problem, the same principle should be applied in extending upwards or downwards from +2.0 SD units for weight for height particularly. It should be noted from Table 3 that +1.0 SD corresponds approximately to 110% of median weight for height and +2.0 SD corresponds approximately to 120% median weight for height.

4. In practice this will usually mean analysing the population data in 0.5 SD units and later grouping these data into appropriate SD groups. It is recommended that in most cases classification points at —2.0 SD or +2.0 SD units be included, depending on whether the population is basically undernourished or overnourished. When data are put together using these principles, it will usually not be necessary to have more than a 4 × 4 cross-tabulation.

Examples showing the appropriate use of these principles in populations of developing and developed countries are given in Tables 6 and 7. The systems of analysis and presentation so far discussed have dealt with the distribution of height for age and weight for height (length) in population groups. It may sometimes be useful to present a single figure to describe the extent to which a population differs from the reference population. For this purpose, the average of the standard deviation scores for children in specific age and sex groups can be calculated. Such averages can be used for comparing the overall position of different groups.

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RÉSUMÉ

PRÉSENTATION ET UTILISATION DES DONNÉES RELATIVES À LA TAILLE ET AU POIDS POUR LA COMPARAISON DE L'ÉTAT NUTRITIONNEL DE GROUPES D'ENFANTS DE MOINS DE 10 ANS

Dans le présent article sont formulées des recommandations pour l'analyse et la présentation des données relatives à la taille et au poids fournies par la surveillance ou des enquêtes nutritionnelles et anthropométriques chez des enfants jusqu'à l'âge de 10 ans. Ces recommandations sont destinées uniquement à l'analyse des données recueillies sur une base transversale. Les indicateurs fondamentaux recommandés sont la taille pour l'âge et le poids pour la taille, chacun étant présenté soit en centiles soit sous une forme de classement à plusieurs entrées utilisant les valeurs des écarts-types. On espère que ces méthodes d'analyse et de présentation pourront être largement acceptables et rendront ainsi plus faciles les comparaisons sur le plan international.

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