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# Underweight or stunting as an indicator of the MDG on poverty and hunger

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## Underweight or stunting as an indicator of the MDG on poverty and hunger


*Abstract*

*The prevalence of underweight among underfives, based on anthropometric surveys is used as one of the two hunger related indicators for tracking progress towards MDG-1. The measurement of height in addition to weight allows a more refined classification of anthropometric failure, which dissects underweight in its two components (stunting and wasting).*

*Because height captures long term growth performance more specifically than weight, an international consensus is emerging to favour stunting among underfives over underweight as the indicator of choice to monitor MDG-1. This paper looks into the interconnectedness of the three indicators and proposes new methods of charting results. First, for plotting z-score values for individual children and/or for groups a so-called 'Anthro Graph' is proposed. Secondly, for plotting prevalence percentages (for groups) a so-called 'Anthro Prevalence Graph' is useful. And lastly, the basic idea behind these graphs leads to a special type of cross-tabulation (called 'Antro Table') for the presentation of various kinds of results by anthropometric categories. This table can be used to present in a disaggregated manner either the prevalence percentages of undernutrition themselves or the results of an explanatory or concomitant variable.*

*Application of the 'Anthro Prevalence Graph' to various levels of survey data is shown to be useful in charting trends or comparisons of undernutrition. Application of the 'Antro Table' to survey data from Kenya confirms the reliability of underweight as a sound overall indicator of child growth, while the prevalence of stunting (low height) remains a useful additional indicator that can help attribute any trends in underweight to chronic and/or acute undernutrition.*

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**Introduction**

Of the eight Millennium Development Goals, the first goal addresses poverty and hunger. One of the two quantified targets is to halve, between 1990 and 2015, the proportion of people who suffer from hunger[1]. To measure progress towards achieving this target, two indicators have been selected by the United Nations (box 1). The first indicator is the proportion of children below five years of age whose weight for age is below the WHO cut-off point for malnutrition[2]. The second indicator is the proportion of the population whose food consumption is below minimum requirements.

Contrary to the measurement of undernourishment, which is, an indirectly derived indicator based on data and estimates from many different sources (national food balance sheets, household food consumption and income surveys) and using many assumptions[3], the measurement of underweight in children is a relatively straightforward approach in which anthropometric information (age, sex and body weight) is collected from a sample of children[4].

***Box 1***. *Millennium Development Goals*

*Goal 1. Eradicate extreme poverty and hunger*

**Target 2.**
Halve, between 1990 and 2015, the proportion of people who suffer from hunger

**Indicators**
**4**. Prevalence of underweight children under five years of age (UNICEF-WHO)
**5.** Proportion of population below minimum level of dietary energy consumption (FAO)

Source: United Nations Statistics Division - Millennium Development Goal Indicators Database (http://unstats.un.org/unsd/mi/mi_goals.asp)

This working paper5 has a closer look at this first indicator (prevalence of children with a body weight which is too low for their age). The main question addressed is to what extent information based on anthropometric surveys among young children provides reliable information on the actual prevalence rates of undernutrition, and therefore whether underweight prevalence can be considered an appropriate indicator for monitoring the Millennium Development Target of halving between 1990 and 2015 the proportion of people suffering from hunger.

In standard nutrition surveys the ages covered are either children under-five or children under-three years old. A child's actual body weight expressed in terms of international reference values for its actual age represents an index of its attained weight-for-age (WA). When this index falls below an internationally agreed value (i.c. more than 2 standard deviations below

[1] The other target of MDG1 is to "Halve, between 1990 and 2015, the proportion of people whose income is less than one dollar a day"
[2] The cut-off point used internationally is median minus 2 standard deviations (m-2sd). This is explained in detail at the end of section 1.1).
[3] See first part in Klaver & Nubé (2008), pp. 273-283. See also Nubé (2001); Wesenbeeck et al (2009).
[4] See also Nubé & Sonneveld (2005)
[5] This working paper was developed in preparation for a paper entitled "The MDG on poverty and hunger: How reliable are the hunger estimates?" by Klaver & Nubé (2008).

the expected median), it serves as an indicator of underweight in this child. In technical terms: the weight-for-age Z-score (abbreviated:*WAZ*) <-2. The percentage of children in a population or sample with values of WAZ<-2 expresses the prevalence of underweight.
Already in the 1970s, it was realized that the index WA (and thus the indicator of underweight) combines the effects of two distinct dimensions of child growth: (i) growth in body stature with age, and (ii) fluctuations in body proportions. Each of these dimensions of child growth has an indicator of its own: (i) attained length or height which is too low for the child's age (called 'stunting'), and (ii) body weight which is too low for the child's height (called 'wasting'). These two dimensions are reflected by the indices HAZ and WHZ, respectively. The former is the cumulative result of growth in stature, while the latter is the result of concurrent fluctuations. In other words: low HAZ is seen as indicating 'chronic' undernutrition, while low WHZ is seen as indicating 'Acute' undernutrition. In most of the survey practice, the three indicators are presented each in their own right. Sometimes a cross-tabulation of wasting by stunting is used, but an accepted methodology to present the results of the three indicators in an interconnected way is only recently emerging.
In addition, a recent international discussion has been raised that prevalence of stunting would be a better indicator for monitoring MDG-1 than the prevalence of underweight. The reason is that height-for-age indicates the long term process of child growth and thus would correspond most closely with chronic hunger and poverty. In the currently used indicator of underweight, the wasting component which it harbours, might exaggerate or dilute the effects of stunting. Investigating this hypothesis is another reason to lay the the indicator of underweight under the microscope for dissection.

Section 1 sketches the history of the development of the three main indices and indicators to assess child growth and shows how they are interrelated. Ways are explored to capture the three indices/indicators of child growth in two dimensions and a proposal is made for the display of WHZ by HAZ showing WAZ (so-called 'Anthro Graph'). This graph can be used for plotting individual or group data.
Based on this idea, section 2 proposes a new form of graphical display of one form of group results, namely prevalence percentages of undernutrition ('Anthro Prevalence Graph'). This graph shows prevalences of stunting and wasting, each in their own right, by prevalences of underweight. In order to align this 'Anthro Prevalence Graph' with the previous 'Anthro graph', it uses in fact the complement of the prevalences of undernutrition, i.e. prevalences of good nutrition. This form of graphical display is applied to different cases: the comparison between different age groups in Ghana, between continents in the world, between regions in Africa and between different national surveys in Kenya.
Section 3 proposes a special table ('Antro Table') to represent survey results in terms of prevalences disaggregated by combinations of stunting and underweight, visualizing the prevalence of wasting in an implicit way. This section also explores the relationships of these indicators with indicators for other development targets and background conditions over time. The reason is that the monitoring of MDG targets should serve a purpose, namely the appropriate interpretation of national trends, including the attribution of changes to likely explanatory factors (such as the impact of various policies, of economic opportunities or constraints and of both natural and man-made changes or disasters). Thus, using DHS survey data from Kenya, the 'Antro Table' is used for the presentation of prevalence percentages of undernutrition, of relative risk of diarrhoea and of the relative odds of belonging to a household in the poorest wealth quintile. The full extent of the relationships between undernutrition and explanatory factors are beyond the scope of this paper, which intends to be a first stepping stone to developing a new approach and new tools as a basis for further analysis of the indicators of undernutrition prevalence *per se*.
Conclusions are drawn in section 4.

## 1 The prevalence of undernutrition

### *1.1 The conventional way of charting and classifying young child growth*

The growth of a young child can be judged from its increase in body weight and/or height over time. When a child does not grow well, it lags behind in the development of its bodily dimensions. Weight and height can be measured at any age and converted into indices of attained growth: weight for age and height for age, respectively. In working out such an index, the attained weight or height of the growing child is compared to the expected weight or height for a child of that age, as judged from reference tables or charts that have been established in the scientific literature. The procedure for the anthropometric index weight for age (W/A) is as follows. Weight for age is the classic index and has been in use since its introduction in the 1950's by Gomez in Mexico (Gomez, 1956). Until the early 1970's anthropometric assessment of the nutritional status of children was mainly based on weight-for-age, in relation to a supposedly normal standard or reference curve.

The classic way to visualize this concept of attained body weight was and is the growth chart, which is widely used in clinical practice for growth monitoring of young children (see Figure 1). The weight of a child at a certain age is indicated in this graph with a dot. A series of dots form the child's growth curve, that can be compared to the reference curves in the chart.

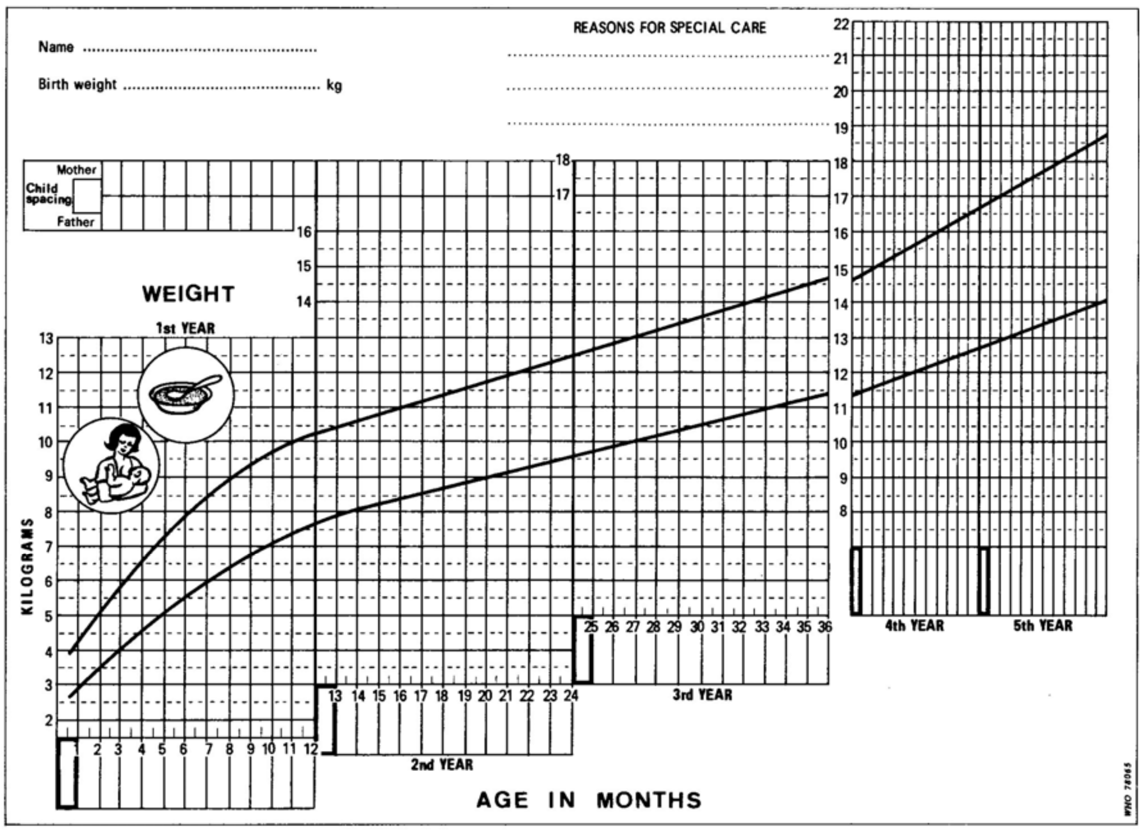


**Fig. 1**. Growth chart of weight (in kg) by age (in months)
Legend: The upper line is the $50^{th}$ percentile of the WHO/NCHS reference value for boys, and the lower line the $3^{rd}$ percentile for girls. For the explanation of these percentiles, see text.

Growth charts have curves that indicate average growth and sub-normal growth. As there is biological variation in growth, there is a range of values around the average that can be accepted as normal. When values are below a lower limit, they are considered 'subnormal'.

Conversely, when values are above an upper limit, they are considered ‘Above normal’. Such curves have been derived from reported studies among a reference population. The World Health Organization has established reference data which are widely used by many countries and organizations[6]. Some countries use reference data based on their own research or borrowed from other sources.

For example, a girl of 12 months is weighed in a clinic and her observed body weight is 7.9 kg. In order to evaluate that weight, it is compared to the range of weights that are expected for girls of that age. The WHO/NCHS reference tables (WHO, 1983) gives key figures that describe the frequency distribution of weights for each age. In this case, the tables indicate that 3% of the girls of 12 months have a weight below 7.6 kg, 20% below 8.6 kg, 50% below 9.5 kg , 80% below 10.4 kg and 97% below 11.5 kg. These values are referred to as the 3rd, 20th, 50th, 80th and 97th percentile[7], respectively (also written as P3, P20, P50, P80 and P97). P50 is the so-called median value. The frequencies are always highest around the middle value and lowest towards the ‘tails’ of the distribution[8]. Within the percentile system average growth is represented by the median value (50th percentile, P50)[9]

The weight of a child can conveniently be expressed as a percentage of the median. In the case of the girl of 12 months her weight-for-age index (W/A) is 100*7.9/9.5 = 83%. A percentage below 100% means that weight is below average. Moverover the percentage tells how far that girl is below average, in this example: 17%. One cannot readily judge whether this is too low, unless a criterion is given, a cut-off value. In the case of weight-for-age of underfives, values below 80% are considered to be underweight (and values below 60% severe underweight). Conventionally, values within the range of the median ± 20% are considered to represent ‘Acceptable’ growth status[10], at least within the percentage-of-the-median system of expression. According to these cut-off values, the girl of 12 months weighing 7.9 kg has a normal W/A.

In the 1970’s the way of classifying anthropometric results in terms of selected percentages of the median was challenged as being not very rigorous, because it assumes across different age values one and the same fixed cut-off level of 80% (i.e. a deviation of 20% below the median). In fact, in the reference population this normal deviation due to biological variation varies according to age. A better way is then to characterize an observed anthropometric measure in terms of its location in the frequency distribution. One way to do this is to indicate between (or at) which percentile values the observed value is. In the above example, the WHO/NCHS table tells that 5% of the girls of 12 months have a weight below 7.8 kg and 10% below 8.2 kg. So the observed weight of 7.9 kg at 12 months is within the range of the 5th to the 10th percentile (P5-P10), a value low in the distribution, but still within the ‘Acceptable range’ (which is P3-P97). This percentile system is useful, but has limitations when it comes to very low values. Also it does not allow arithmetic calculations of group

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[6] In 1983, the World Health Organization adopted international reference values for weight-for-age, height-for-age and weight-for-height (WHO, 1983), based on tables of the North-American National Centre for Health Statistics (NCHS). In 2006 the World Health Organisation published new growth standards for international use (WHO, 2006b).

[7] A percentile describes the value below which a certain percentage of the total frequencies is located, e.g. the fiftieth percentile (P50) is the value halfway the frequency distribution and is also referred to as the median value. For a symmetrical distribution, the median coincides with the arithmetical average…..

[8] This can be gleaned from the above data: most frequent are the values between the median ± 0.9 kg, namely 80%-20%=60%, while values up to twice the distance ( median ± 1.9 kg) come from an extra 34% only (97%-80% plus 20%-3%).

[9] For technical reasons (some skewness in the frequency distribution of weights), not the arithmetical mean, but the median value (also referred to as 50th centile or P50) at each age was taken as the ‘average’ for reference purposes. Across the ages, these values form the 100% reference line in the chart.

[10] Also referred to as attained growth at a given moment. This has to be distinguished from growth velocity, which is the change in weight between two moments in time.

results (such as mean and standard deviation). Hence in the 1970's a new system was proposed to express an anthropometric measure, not in terms of its position (location) among the *frequencies* - as in the percentile system -, but in terms of its position on the scale of *values* - as in the old percentage system, but now in a more standardized way. The position of a child that is actually measured, is described quantitatively by a score that tells how far it is from the median, while that actual distance (or: deviation) is expressed not in kg, but in units of the standard deviation of the reference distribution. This is called the 'Standard Deviation Score' or 'Z-score', where values between -2 and +2 are considered by convention to be within the so-called 'normal range'. The average reference value has a Z-score of zero (i.e. the *deviation* from that average reference point is zero).
The Z-score system is more precise than the percentage system in two ways: (i) it does not round off the cut-off level (such as 80%, being a convenient multiple of 10%) and (ii) it does not imply a *fixed* relative width of the frequency distributions (such as ± 20% across all ages). To express the observed weight of 7.9 kg as an SD score, one needs to find from the WHO/NCHS table, in addition to the P50, also the standard deviation (sd). According to the reference tables, the median minus 2 sd is 7.4 kg for a 12 months old girl. The median is 9.5 kg. The sd can be recalculated to be (9.5-7.4)/2 = 1.05 kg. The weight-for-age Z-score (WAZ) is (7.9-9.5)/1.05 = -1.52. It is a dimensionless score. A negative value means that the weight is below average. Values below -2.0 are classified as underweight. Although this girl with a WAZ of -1.52 is relatively light for her age, she is still within the 'normal range' for attained W/A.

### *1.2 Three anthropometric indices*

Some 30 years ago, Latham (Seoane & Latham, 1971) and Waterlow independently proposed that low weight-for-age combines the effects of two different aspects: a child can be underweight because it is too short for its age or because it is too thin for its height, or a combination of the two. Thus a distinction is made between low height-for-age (H/A) and low weight-for-height (W/H). Latham called these chronic and acute malnutrition, respectively (Waterlow, 1973): body stature (length, height) at a given age is the result of the cumulation of linear growth since the child was conceived and born and thus is a measure of chronic undernutrition (called 'stunting'), while weight-for-height is the result of concurrent or recent episodes of fluctuation in body 'fill' (called 'wasting'). Waterlow proposed a two by two cross-classification of wasted+stunted, wasted only, stunted only and normal[11] – see layout of this cross-classification in Table 1a. He proposed the following cut-off values to define subnormality: 80% of the median reference value in the case of W/A and W/H, and 90% in the case of H/A. That the percentages for height are not the same as for weight follows from the frequency distributions of the reference values: weight has a higher variation than height. The lower limit of the acceptable range of W/A or W/H is 20% below the median, while for H/A it is only 10% below the median. These percentages are rounded figures (multiples of 10%), which makes them convenient to use.
As was discussed in section 1.1, since the 1970's the recommended way to express anthropometric indices is in terms of SD-scores (Z-scores). Table 1a gives an example of the Waterlow classification from a recent DHS survey in Kenya, which uses Z-scores as cut-off values of undernutrition.

[11] This group includes children with values above the normal range, so strictly speaking this group is not sub-normal, i.e. not wasted and not stunted (see also note 21).

**Table 1a.** Example of the classification of undernourished children according to Waterlow.

| Prevalence (numbers and percentages) of children under five years of age | | | |
|---|---|---|---|
| | Wasted (WHZ<-2) | Not wasted (WHZ>=-2) | Total |
| Not stunted (HAZ>=-2) | **Wasted only**: 190 (3.9%) | **'Normal'***: 3190 (65.3%) | 3380 (69.2%) |
| Stunted (HAZ<-2) | **Wasted and stunted**: 88 (1.8%) | **Stunted only**: 1417 (29.0%) | 1505 (30.8%) |
| Total N = | 278 (5.7%) | 4607 (94.3%) | 4885 (100%) |

Source of prevalence data: Kenya Demographic and Health Survey 2003 (Measure DHS+, 2004), cases weighted.
Notes: The nationally representative sample survey covered 4885 under-fives from 400 sample points (clusters) in rural and urban areas of Kenya. To obtain the numbers in the above table, cases were weighted using the sampling weights in the SPPS data file to correct for any differences in sampling probabilities.
The anthropometric categories are defined by combinations of HAZ and WHZ above or below Z = -2. The figures refer to the number of children in that category and the percentage of all children is shown in brackets.
Formatting: The shading is an indication of the severity of the condition: light shading is for either wasted or stunted, and darker shading is for both wasted and stunted.
* This group may include children with values above the normal range (Z-scores>+2.0), which may represent overweight or abnormal height. When the term 'normal' is used in this chapter, it should be understood as meaning 'not sub-normal'. In Waterlow's classification, 'normal' means neither wasted nor stunted.

Table 1a shows prevalence percentages for Kenya's recent Demographic and Health Survey (DHS). In this example, 30.8% of the under-fives were stunted and 5.7% were wasted, but there was an overlap of 1.8% (wasted and stunted) such that the prevalence of children with normal height-for-age and normal weight-for-height was 65.3%. The much higher prevalence of stunting compared to the prevalence of wasting is a normal finding in nutrition surveys: the former is the accumulated result of a chronic process or trend, while the latter can be seen as the result of variation in this trend. Under non-emergency conditions, the prevalence of wasting is generally of a much smaller magnitude than the prevalence of stunting.

The mean Z-score values for the four categories are shown in Table 1b. The mean HAZ of the two categories in each row of Table 1a can be verified, and although not exactly the same, they are quite close. In the same vein, the mean WHZ of the two categories in each column of Table 1a are almost the same. Interestingly, the mean WAZ in Table 1b can be seen to exhibit three instead of two levels: normal children (-0.4), those with only one failure (around -2) and those with a double failure (-3.6). This is consistent with the intensity of the shading shown in Table 1a.

**Table 1b**. Mean Z-score values of Waterlow's four nutritional status categories

| | mean HAZ | mean WHZ | mean WAZ |
|---|---|---|---|
| Normal | -0.56 | -0.03 | -0.40 |
| Wasted, non-stunted | 0.05 | -2.65 | -2.10 |
| Stunted, non-wasted | -2.90 | -0.12 | -1.85 |
| Wasted and stunted | -3.08 | -2.53 | -3.64 |

The example of the girl of 12 months (see the end of section 1.1) is expanded with a length[12] measurement of, say, 70 cm. The median H/A and m-2sd for girls of 12 months old are according to the WHO/NCHS tables: 74.3 cm and 68.6 cm, respectively; the standard deviation being half of the difference, i.e. 2.85 cm. The observed value of 70 cm is 94.2% of the median and has a height-for-age Z-score (HAZ) of (70-74.3)/2.85= -1.51. Although this girl is relatively short for her age, she is still within the 'normal range' for attained H/A.
To judge about the relation between body weight and height, the WHO/NCHS tables also give key figures for the frequency distributions of weight-for-height (W/H). The median W/H and m-2sd for girls of 70 cm long are according to the WHO/NCHS tables for weight-for-length: 8.4 kg and 6.8 kg, respectively; the sd being 0.8 kg. The observed weight of 7.9 kg is 94.0% of the median. The weight-for-height Z-score (WHZ) is (7.9-8.4)/0.8= -0.63. Although this girl is slightly thinner than average, she is well within the 'normal range' for W/H. In the Waterlow classification (Tables 1a and 1b) this girl is within the category labelled 'normal'.

Waterlow's classification (Table 1a) invites questions it cannot answer about under-weight children. Are all the wasted children underweight? Are all the stunted children underweight? And can there be underweight children who are not wasted or stunted? A more refined classification of undernutrition has recently been proposed by Peter Svedberg (2000), who extended Waterlow's classification with a third dichotomy based on WAZ. Before giving the details of that innovation (see section 1.6), it is necessary to prepare some more ground by discussing prevalence percentages (see section 1.3) and the interrelationships between the three anthropometric indices (see sections 1.4 and 1.5).

### *1.3 Cut-off values and prevalence percentages*

Results for a group or sample of children can be given in two ways: (i) standard statistics (such as mean and standard deviation) and (ii) percentage of cases with values within a given range. The most widely used expression follows the latter option. For a group or sample of children, the frequency of individual results is expressed in terms of prevalence percentages: (i) the prevalence of underweight (i.e. children with a below-normal weight for their age), (ii) the prevalence of stunting (i.e. children with a height below normal for their age), and (iii) the prevalence of wasting (i.e. children with a below-normal weight for their height). The type of cut-off values used (percentage of the median or median minus 2sd) has a discernable impact on the resulting prevalence percentages. Details are given in Annex 1. However these differences do not invalidate what follows below and are therefore outside the scope of this paper.

### *1.4 Interrelationships between the three anthropometric indices*

The idea of Latham and Waterlow to distinguish wasting from stunting as factors of underweight (see 1.2) was embraced by the nutrition community and for some time in the 1970s the 'Waterlow classification' was even held to replace the old classification based on weight for age. In actual practice, it did not go to that point. In most anthropometric surveys weight is taken in the first place (so one can calculate W/A) and if resources allow, height is taken as well (so one can calculate H/A and W/H)[13]. Usually the three anthropometric indices

[12] Body stature of children below 24 months is measured as they lie down on a measuring board. Children above 24 months are preferably measured while they are standing, unless they cannot yet stand. The NCHS reference has two data sets: one for children 0-3 years (length measured while lying down) and one for children 2 years and above (stature measured as standing height). In order not to complicate the explanation, in the text the term 'height' will be used both for supine length and for standing height, whichever is the case.

[13] Incidentally, for rapid assessment surveys there is an alternative measure that can be taken in stead of weight, namely arm circumference, either alone or in combination with height. There are separate tables with reference values for these indicators. In an anthropometric survey in which height and/or weight are taken, arm

are reported each in their own right: low W/A as underweight, low H/A as ‘chronic’ undernutrition and low W/H as ‘Acute’ undernutrition. The following schematic notation illustrates the logic of this interconnection:

$$W/A \approx W/H * H/A$$

The right hand portion of this ‘formula’ would work out algebraically as follows: W/~~H~~ * ~~H~~/A = W/A. One has to be warned though, that the three anthropometric indices are not simple arithmetical divisions of W and H by A or H, respectively. In reality, the arithmetics involved are much more complex[14]. Yet, the schematic ‘formula’ has the merit to convey at a glance the ‘logic’ behind the Waterlow classification.

### *1.5 The three indices in one two-dimensional graph*

The above introduction about cut-off values and prevalence percentages contained two perspectives. The first was about the way to classify one child by comparison with international reference data. To do that, the weight, height and age of a child are converted into the three anthropometric indices. Cut-off values serve to classify that child as being in the normal range, or below normal or above normal for any of those indices (see below). The second perspective is the calculation of a result for a group: the number of children below normal values is expressed as a percentage of all children in the group. This is the prevalence percentage. In the rest of this introduction, a way is sketched to represent the combined results of one or any child in one graph: the ‘Anthro Graph’. In section 2.1 a method wil be proposed to represent prevalence data in a similar way: the ‘Anthro Prevalence Graph’.

**Table 2.** Example of anthropometric measures and derived indices for a girl

Example: Girl A

| Age (months) | Weight (kg) | Stature (cm) | Weight-for-age (WAZ) | Height-for-age (HAZ) | Weight-for-height (WHZ) | Under-weight | Wasted | Stunted |
|---|---|---|---|---|---|---|---|---|
| 6 | 7.0 | 68 | -0.2 | 0.8 | -1.1 | no | no | no |
| 12 | 7.6 | 76 | -1.8 | 0.6 | -2.6 | no | yes | no |
| 24 | 8.5 | 81 | -2.7 | -1.7 | -2.6 | yes | yes | no |
| 36 | 10.0 | 82 | -2.8 | -3.2 | -1.1 | yes | no | yes |

The usual way to represent growth data is in a time graph. This type of display is most useful if one wants to compare positions in time in order to see trends. Figure 2 visualizes the development of weight and stature. It shows that as the child grows older, its weight and

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cicumference can also be measured and used to corroborate the other findings. Further discussion of arm circumference is outside the scope of this paper.

[14] In fact, the anthropometric indices are not obtained by a simple arithmetical division of W by A (or H) and of H by A, respectively, but by a much more complex procedure involving the expression of an observed W or H in terms of its position compared to reference values. The resulting anthropometric indices are expressed as Z-score values: WAZ, WHZ and HAZ. The above notation is just for illustrative purposes. The true WAZ is not simply obtained by multiplying WHZ and HAZ but is calculated in its own right. A Z-score value indicates how far a child’s observed value is above or below the median value of the international reference data for children of the same age (in the case of WA and HA) or height (in the case of WH). The distance of the observed value from the median reference value is expressed in terms of standard deviation units of the same reference population. The result has no measurement units, as it is obtained as cm/cm or as kg/kg. According to statistical theory, the ‘range of normal variation’ of Z-score values is between -2.0 and +2.0.

height increase. Height seems to lag behind at 2 and 3 years of age. Graphing the absolute measures as such does not tell, whether the girl was growing well, as reference lines are lacking. Moreover, the fact that the two measures almost coincide at the start, should not be interpreted as something meaningful, because it is just arbitrary: stature was expressed here in units of 10cm, simply in order to allow convenient plotting of the two graphs in one figure.

A sharper insight into the growth performance of the child is given by plotting the anthropometric indices in stead of the absolute measures (see Figure 3). These indices express the position of this child in comparison to expected growth according to the international WHO/NCHS growth reference. In this case, it is clear that child A passed through a period of wasting at the ages of 1 and 2 years, from which it was recovered at 3 years. H/A dropped steadily and the girl became stunted at age 3. W/A dropped also steadily, but more rapid at an early age than H/A and the girl became underweight from age 2. One can see that the W/A graph is the result of the H/A and W/H trends: it has the downward trend of H/A and compared to that trend the 'bowl' shape ofW/H, although a bit less pronounced.

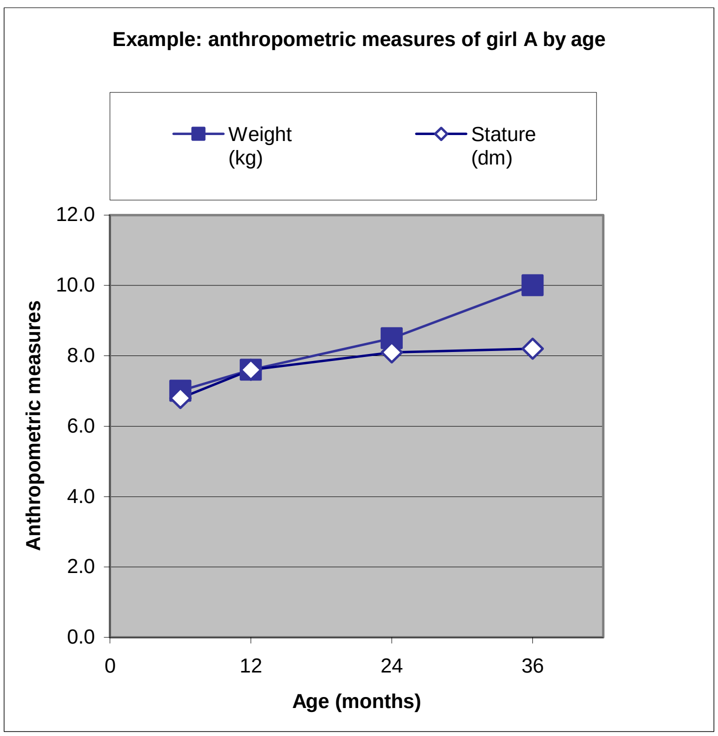


**Fig. 2**. Time graphs of the two anthropometric measures (example as in Table 2)

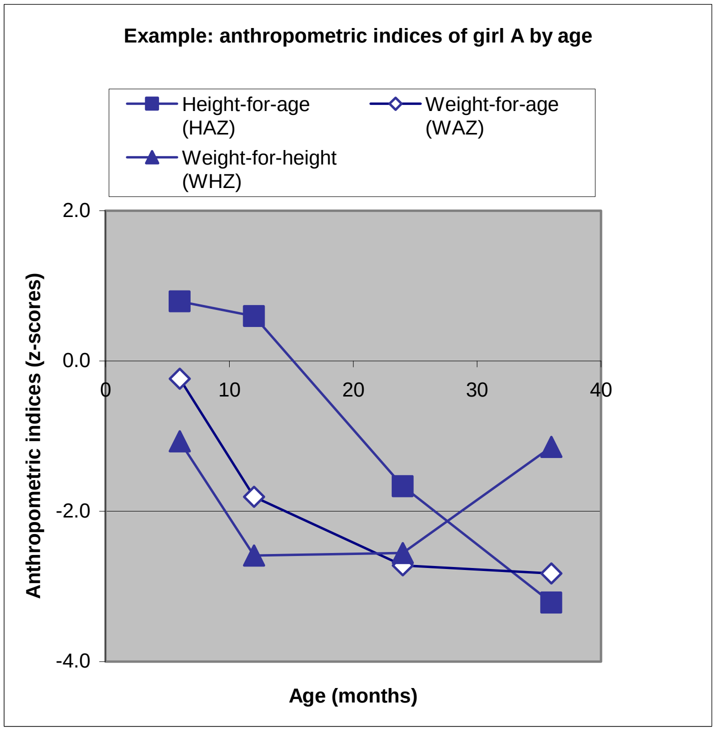


**Fig. 3**. Time graphs of the three anthropometric indices (example of Table 2)

With some imagination, one can have a general idea about the relative contribution of H/A and W/H, respectively, to W/A, namely relatively more wasting at a younger age and relatively more stunting at an older age. However, the graph does not reflect these relative contributions of H/A and W/H to W/A in a straightforward way, and more indirectly than directly at that. Alternative ways of graphing are possible, that plot two anthropometric indices against each other, in stead of plotting one anthropometric index at a time against the time axis. One such alternative is shown in Figure 4. It was first published in the landmark publication 'Measuring change in nutritional status' (WHO, 1983). This graph was based on the WHO/NCHS reference data[15] for boys of 18 months[16] and can serve as the 'canvas' on which the position of any observed child is 'projected': the position of a child at a certain moment can be indicated in this graph with a dot.

[15] In 2006 the World Health Organisation published new growth standards for international use (WHO, 2006b). The way in which the z-scores are calculated has been refined, due to a new way of dealing with skewness in the frequency distributions. Results using the new standards are bound to result in somewhat different values for the indices and for prevalence percentages. In order to compare future results with historical data, these need to be calculated using both the new and the old reference values. Historical data may need to be recalculated using the new standards. The interrelationships discussed in this paper are not affected.

[16] Admittedly, the relationship between the three anthropometric indices, although being very strong, is not perfect: there is some minor influence of age on the exact position of the iso-WAZ curves. Yet using one curve for all ages is good enough for practical purposes. Reasons for this slight age effect are as follows: some distortion is due to the fact that the WHZ reference values are not specified by age group and that the reference values were derived by smoothing techniques applied to each index independently, not taking the 3-dimensional perspective into account. In addition, reference values at the low and high ends of age or height ranges available in the data sets appear to be less robust. Then there is the problem of the length-height transition around 2 years of age, before which stature is measured while the baby is lying down and after which while the baby is standing upright. In the NCHS references, the data for length are from a longitudinal data set (FELS), while the data for height are from a cross-sectional data set (NHANES).

It visualizes WHZ by HAZ. The limits of the 'normal ranges' (+2 and -2, respectively) of these two anthropometric indices are indicated with horizontal and vertical lines inside the body of the graph. The horizontal lines are 'iso-WHZ lines' and the vertical lines are 'iso-HAZ lines'[17]. Values in between these two lines represent the normal range. The median value is exactly halfway the normal range. Thanks to the strong interrelationship between the three anthropometric indices (see 1.4), it is possible to indicate also in the same graph the limits of the 'normal range' of WAZ: see the diagonal 'iso-WAZ curves' in Fig. 4[18]. As one can see, the normal ranges of WHZ and HAZ form central bands in the form of a cross, while the normal range of WAZ runs as a band diagonally from the upper left to the lower right of Figure 4. In the middle these three normal ranges overlap in such a way, that the normal ranges of WHZ and HAZ form a square, between data points (-2,+2), (-2,-2), (+2,-2) and (+2,+2), and that the normal range of WAZ does not intersect the square at the data points (-2,-2) and (+2,+2), but at points closer to the origin, so that there are two triangular areas where WHZ and HAZ are in the normal range, but WAZ is not.
In Figure 4 child A from Table 2 has been plotted with circular dots. The size of the dots indicates the different ages and the dots are connected to show the child's progression over time. At 6 months the child has normal values for attained growth. At 12 months, its WHZ has fallen below -2., at 24 months also its WAZ has fallen below -2 and at 36 months, while its WAZ is still equally low, WHZ has improved but HAZ deteriorated.

The fact that the three indices are so strongly interrelated (discussed above in section 1.4) means that two of the three indices exhaust (practically all) the information there is in the data: given two of the three indices, the third is implied or is just another way to express the same information. The alternative way of visualizing the data does not add any information that cannot be gleaned from the time graphs, but it represents the same data from another angle. It is more parsimonious, as the information contained in three graphs in Fig. 3 has been condensed into one graph in Fig. 4 that 'tells it all'. Fig. 4 also allows a sharper description of the time trends in terms of the relative contributions of W/H and H/A to the resulting W/A: at 6 and 12 months, child A is somewhat thinner than it is short, at 24 months it is more or less as thin as it is short and at 36 months it is shorter than it is thin. One could draw an imaginary diagonal line from the left lower corner through the data points (-2,-2) and (+2,+2) to the right upper corner of Fig. 4, to indicate states of 'balance' in the deviation from normal in terms of both W/H and H/A. Points to the left of this diagonal represent states of 'shorter and/or moreplump' and points to the right of this diagonal states of 'thinner and/or taller'.
It is also interesting to imagine, how a growing child will move through Fig. 4. A child which grows well, will follow a growth trajectory somewhere in the middle box. Normal growth is not smooth, but occurs in bouts or *'saltation'* followed by periods of stagnation or *'stasis'* (Lampl et al, 1992). This means that a spurt in body stature tends be accompanied by some degree of apparent thinning. In a next period these tendencies may become reversed: linear growth stagnates somewhat, while weight growth catches up. In Fig. 4 such growth spurts may be seen as modest movements around the child's starting position: a move to a lower position more to the right during a growth spurt and a move to a higher position more to the left during the period of stagnation. In this vein, the growth of child A between 24 and 36 months can be characterized as an example of 'stasis'. What happened between 6 and 24 months can be characterized as progressive growth failure (retarded weight growth first, followed by retareded height growth).

[17] 'Iso' means equal. This terminology has been borrowed from geography. For example, an 'iso-hyet' is a curve that connects points on a map with equal rainfall. They are also known as 'contour lines'. Between a higher and a lower contour line there exists a gradient (gradual decrease in values).
[18] These 'iso-WAZ curves' indicate all value combinations of WHZ by HAZ that produce a same WAZ value.

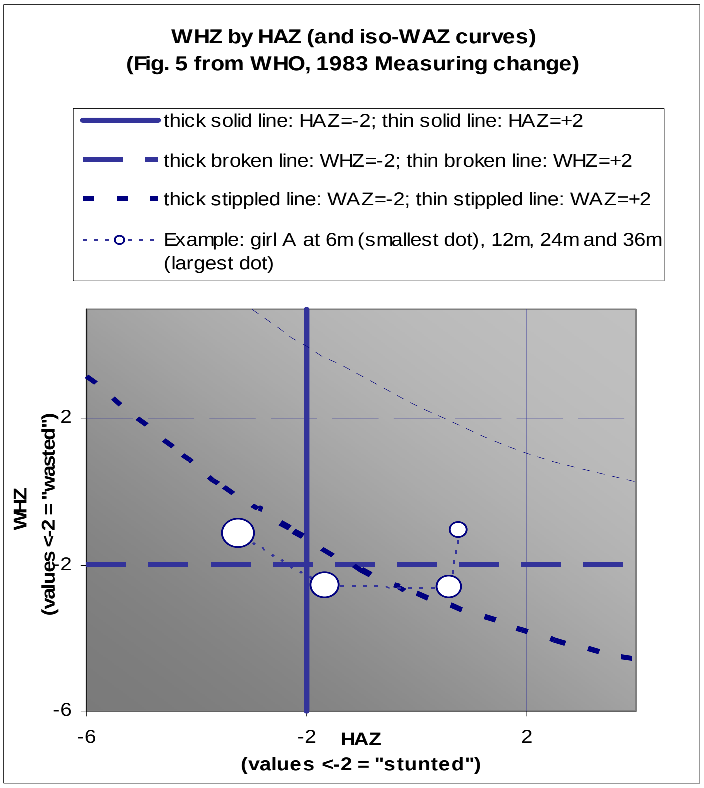


**Fig. 4**. Graph of WHZ by HAZ
Legend: Straight lines indicate the upper and lower limits of the normal ranges of weight-for-height and height-for-age (the horizontal and vertical lines, respectively). Curved diagonal lines indicate the upper and lower limit of the normal range of weight-for-age. The four connected dots serve as an example of a young child at different ages (see text).

### *1.6 The meaning of different areas in the two-dimensional graph*

The Waterlow classification can be recognized as the basis of Figure 4. It suffices to transpose Figure 4 (i.e. interchange the two dimensions) to get the same layout as in Table 1a. This invites the question as to how weight-for-age runs through the Waterlow classification. From Figure 4 we can infer the answer: diagonally.

Recently a more refined classification of undernutrition has been proposed by Peter Svedberg (2000), who extended Waterlow's classification with a third dichotomy based on WAZ. He proposed six different combinations of the 3 anthropometric indicators, which he labelled A to F. Nandy et al (2005) applied this classification to survey data from India and rediscovered[19] one combination that Svedberg did not mention (and which they labelled group 'Y')[20]. Thus there are seven possible categories based on the combinations of the 3 indices (see Table 3)[21]. For ease of reference we propose group labels that are abbreviations of the

[19] In fact, this classification was already given in WHO (1983) based on its Figure 5 (here: Fig. 9).
[20] This is the combination of being underweight (be it slightly), but not wasted (although close to it) and not stunted (although also close to it).
[21] Cross-tabulating three dichotomies produces eight (=2*2*2) combinations. A theoretical eighth combination, ('wasted and stunted, but not underweight': SW), is empty, as the anthropometric values that should give rise to that possibility cannot co-exist, at least not with the standard cut-off values of -2. As the cut-off values of WHZ and HAZ are relaxed, while keeping WAZ at -2.0, a point may be reached where group U becomes impossible and a new category SW will appear.

category descriptions. This has the added advantage that the number of digits in a label indicates whether one is dealing with a single, double or triple failure.
Svedberg further proposed combining the prevalences of the various possible combinations of wasting and/or stunting and/or underweight into one ‘composite index of anthropometric failure’ (CIAF), which is equal to 100% minus the prevalence of the group without failure (i.e. 100% minus Svedberg’s group A, labelled N in this paper). The CIAF is always a higher figure than each of the prevalences of wasting, stunting or underweight.

**Table 3.** Classification into seven groups of undernourished children according to Svedberg (2000), expanded by Nandy et al (2005).

| Group name (Svedberg & Nandy) | New proposed group label (this paper) | Description | Wasting | Stunting | Underweight |
|---|---|---|---|---|---|
| A | N | **No failure**: Children whose height and weight are above the age-specific norm (i.e. above –2 z-scores) and do not suffer from any anthropometric failure. | No | No | No |
| F | S | **Stunting only**: Children with low height for age but who have acceptable weight, both for their age and for their short height. | No | Yes | No |
| E | SU | **Stunting and underweight**: Children with low weight for age and low height for age but who have acceptable weight for their height. | No | Yes | Yes |
| Y | U | **Underweight only**: Children who are only underweight. | No | No | Yes |
| C | UW | **Wasting and underweight**: Children with above-norm heights but whose weight for age and weight for height are too low. | Yes | No | Yes |
| B | W | **Wasting only:** Children with acceptable weight and height for their age but who have subnormal weight for height. | Yes | No | No |
| | Not possible | **Wasting and stunting, but no underweight**: | Yes | Yes | No |
| D | SUW | **Wasting, stunting and underweight**: Children who suffer from anthropometric failure on all three measures. | Yes | Yes | Yes |

### *1.7 Proposal for a new ‘Anthro Graph’*

As shown above, in a graph of two of the three indices the third is implied. While Fig. 4 was constructed with H/A and W/H as the two main axes, there are two other options to choose two out of three indices. As W/A is the summary value and H/A and W/H its components, there is a point in selecting W/A as the first dimension, to represent the total (which has also been selected for monitoring MDG-1), and either H/A or W/H as the second dimension, that tells how that total is made up from its two ‘building blocks’. For monitoring the MDG, it makes sense to select H/A as the second dimension, as it is the indicator of chronic undernutrition. Thus the ‘Anthro Prevalence Graph’ proposed in this paper has the indicator (W/A) on the x-axis (horizontal coordinate = abscissa) and (H/A) on the y-axis (vertical coordinate = ordinate). These positions have no particular causal meaning, as if W/A would cause or explain H/A. They are rather interdependent, H/A being a component of W/A. Yet it makes mnemonic sense to represent the H/A dimension literally as ‘standing’. When this is done for the individual values (z-scores), the third index (W/H) is more or less fixed and can be indicated as iso-WHZ lines that run obliquely (practically as straight lines) through the graph (see Fig. 5).

The stunted children are below the thick solid horizontal line, the underweight children are to the left of the vertical thick stippled line and the wasted children are above the upper diagonal thick broken line. That wasting and stunting should point into different directions in this graph is caused by their antagonistic relationship for a given WAZ[22].

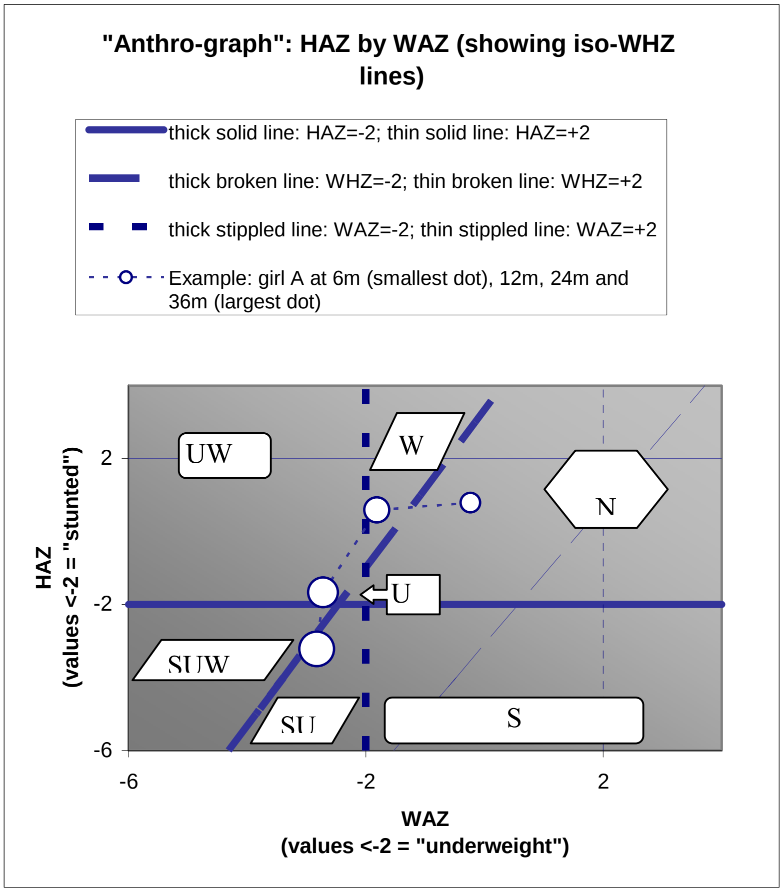


**Fig. 5**. ‘Anthro Prevalence Graph’ for plotting height-for-age by weight-for-age z-score values of a child or of a group of children.

Legend: The vertical and horizontal lines indicate the upper and lower limits of the normal ranges of weight-for-age and height-for-age, respectively. The diagonal lines indicate the lower and upper limit of the normal range of weight-for-height. Children with HAZ by WAZ values above and to the left of the broken heavy diagonal line are wasted, either (UW) or not (W) in combination with underweight, or even in combination with stunting (SUW). Children with HAZ by WAZ values below and to the right of the broken heavy diagonal line are ‘normal’ in the sense of no failure[23] (N), underweight only (U), stunted only (S) or stunted with underweight (SU). The four connected dots serve as an example of a young child at different ages (see text).

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[22] Incidentally, one can visualize in this graph, into what direction results shift if there is an error in the original observations. An overestimate in a weight recording will force a child horizontally to the right. An age underestimate will force a child diagonally upward parallel to the direction of the iso-WHZ lines (thus flattering any stunting and underweight). An underestimate in a height reading will force a child vertically downward (away from wasting).

[23] In a strict sense, the term ‘normal’ applies to values that lie within the normal range (i.e. between -2 and +2). Z-score values above +2 are not really normal, but are exceptional, such as exceptionally heavy (WAZ>+2), exceptionally tall (HAZ>+2) or exceptionally plump (WHZ>+2). In this paper the focus is on undernutrition and within that context the term ‘normal’ should be interpreted to mean: not sub-normal. In the rest of this paper we prefer to use terms like ‘non-stunted’, ‘non-underweight’ and ‘non-wasted’ over terms like ‘normal H/A’, ‘normal W/A’ and ‘normal W/H’, respectively. We will refer to Group N with the term ‘no failure’ rather than ‘normal’. For the Waterlow classification (see Table 2), the use of the term ‘normal’ is continued, because ‘no

Just as Fig. 4, this graph represents the values of the WHO reference population, which is the 'canvas' on which the position of any observed child is projected. Child A has moved to an other position, due to the change of axes (HAZ from horizontal to vertical position and WAZ in stead of WHZ at the horizontal position). The lower left iso-WAZ curve of Fig. 4 has become the left vertical line at WAZ=-2 in Fig. 5, while the horizontal line at WHZ=-2 of Fig. 4 has become the upper diagonal iso-WHZ line in Fig. 5. Please note that lower WHZ-values are found *above and/or to the left* of that line. For instance, child A at 12 months is 'wasted only'. It is so to say 'too tall for its weight'; if it would have been somewhat shorter, it could have fallen in the category 'no failure'. At 24 months child A is still wasted, but also underweight. At 36 months is is no longer wasted, but 'underweight and stunted'.
In Fig. 5 the new proposed group labels of Table 3 have been indicated as well. The category 'underweight only' is still a small triangle[24] between the opposites N ('no anthropometric failure') and SUW (3 anthropometric failures combined).

The areas SU and UW are double failure categories. The total of anthropometric failures according to Svedberg is S+SU+SUW+U+UW+W. Each type of anthropometric failure can also be viewed in its own right: the total wasted is then made up of W+UW+SUW, the total stunted of S+SU+SUW and the total underweight by SU+SUW+U+UW.

In Figure 5 again child A from Table 2 has been plotted with circular dots. Like in Fig. 4, in Figure 5 growth spurts may be seen as modest movements around the child's central position. A child that does not gain enough weight while growing older will show a movement to the left; if it suffers from linear growth retardation (stunting), it will move down. If it suffers from both, it will move in the direction of the lower left corner of the graph.
An imaginary diagonal line that one could draw to indicate states of 'balanced undernutrition' (in which the deviation from normal would be attributed to both W/H and H/A), would run through the data points (-2.45,-2) and (+2.65,+2), i.e. the lower left and upper right corners of the diamond shape around the centre. Points to the left of this diagonal now represent states of 'thinner and/or taller' and points to the right of this diagonal states of 'shorter and/or more plump'.

The proposed Anthro Prevalence Graph of Fig. 5 is for plotting children: any child can be represented by a dot in this graph. If one deals with results for a group, Fig. 5 can also be used to plot the mean z-scores. However, to plot group results which are in terms of prevalence percentages, one needs a graph with modified scales. Below we propose an 'Anthro Prevalence Graph' for plotting the prevalence of good H/A (and good W/H) by the prevalence of good W/A.

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failure' would be confusing, since Waterlow's 'normal' includes groups N and U of the anthrograph, and U is one of the forms of anthropometric failure.

[24] That a group U exists at all, depends on the cut-off levels used for the classification of undernutrition, in this case -2 for WAZ, -2 for HAZ and -2 for WHZ (see note 20). Theoretically, by relaxing one of those values, group U can be made to disappear.

## 2 Applications of the H/A by W/A analysis using the ‘ Anthro Prevalence Graph’

### *2.1 ‘Anthro Prevalence Graph’ – the example of Ghana*

The following presentation and discussion of the results of 2 national nutrition surveys held in Ghana serves as an example of how the results are plotted in the usual way (as a time series) and how they can be plotted in a new way (using an ‘Anthro Prevalence Graph’). The surveys selected were held more or less in the same period of the year. This is important, because anthropometric values have a tendency to fluctuate throughout the seasons. Such fluctuations with the seasons have been observed elsewhere (a.o. in the Kenya Coast, see Hoorweg et al, 1995 and Niemeyer et al, 1991).

**Table 4:** Results of two national nutrition surveys held in Ghana (age groups made comparable)

| Survey number | Survey year | Period | Age group (years) | N | Percentage low W/H (wasted) | Percentage low H/A (stunted) | Percentage low W/A (underweight) |
|---|---|---|---|---|---|---|---|
| *3* | *1993–94* | *SEP-FEB* | *0-2.99* | *1819* | *11.3* | *25.9* | *27.3* |
| 4 | 1998-99 (full data) | NOV-FEB | 0-4.99 | 2570 | 9.5 | 25.9 | 24.9 |
| *4* | *1998-99 (part of data)* | *NOV-FEB* | *0-2.99* | *1638* | *12.9* | *20.0* | *24.9* |

#### *2.1.1 Influence of children’s age*

The usual way to represent such results graphically is as a time series (such as in Fig. 3). The anthropometric results by age group of survey 4 held in 1988-99 are depicted in Fig. 6. One can see, that infants below 6 months are well protected against malnutrition. Acute undernutrition (wasting) is most prevalent from 6 months to 2 years of age (the weaning period, when children are particularly vulnerable) and subsides afterwards. Chronic undernutrition (stunting) starts to affect the children somewhat later than the acute malnutrition. Stunting results from the cumulative effect of growth failure over the years. Figure 6 shows, that it does not subside, but continues to increase after 2 years.

The comparison of the full results of surveys 3 and 4 would suggest that there was a decrease in the prevalence of underweight, attributable to a decrease in the prevalence of wasting. However, the two surveys differ in their age ranges. This needs to be corrected before a fair comparison can be made. When the children of 3 and 4 years old are excluded from the results of survey 4 (see row labelled ‘part of data’ in Table 4), the prevalence of wasting increases from 9.5 to 12.9 and the prevalence of stunting decreases from 25.9 to 20.0. So the same decrease in the prevalence of underweight appears to be attributable to a decrease in the prevalence of stunting, not wasting. This is consistent with a younger child population.

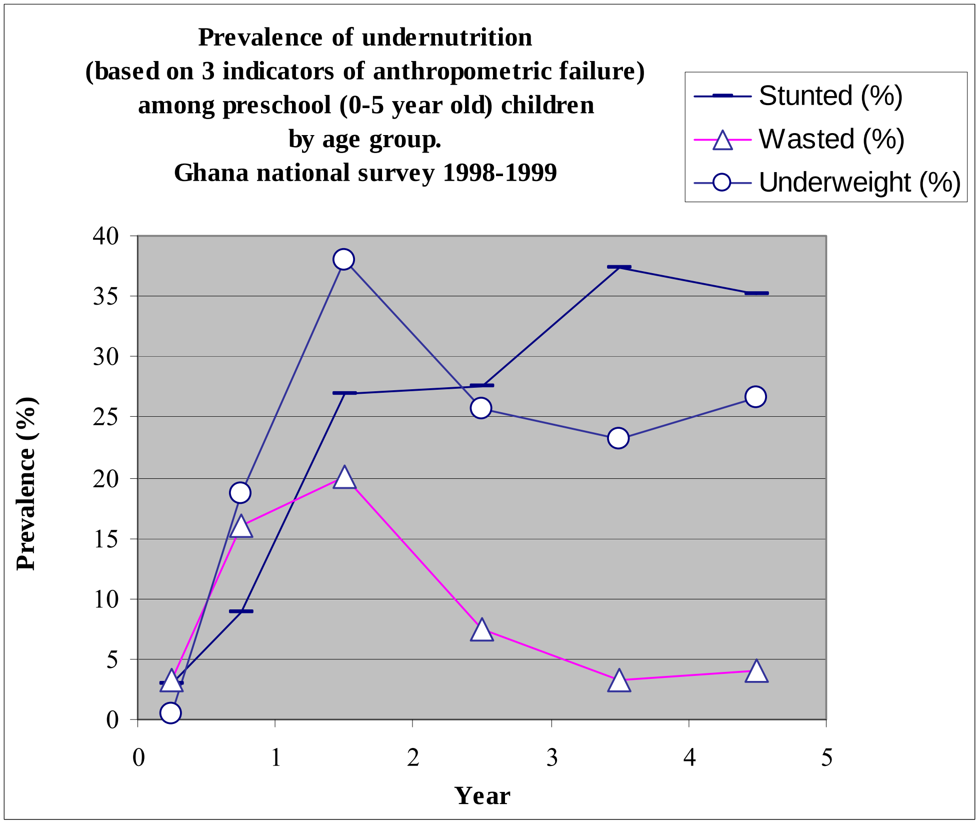


**Fig. 6**. Prevalence percentages of anthropometric failure by age group (Ghana, Nov. 1999-Feb. 1999)

*2.1.2 Trends in underweight dissected*

What was explained in section 1.4 for the anthropometric indices (z-scores) is also valid for the corresponding prevalence percentages: the three graphs as in Fig. 6 are interrelated, because the prevalence of low W/A is the combined effect of the prevalence of low H/A and the prevalence of low W/H. In Fig. 6 one can see, that the peak in the prevalence of wasting is reflected in the peak in the prevalence of underweight and that the steady rise in stunting makes that underweight can no longer become as normal at 3 and 4 years of age as wasting does. At more careful inspection, one can see evidence of a compensatory relationship between W/H and H/A: at 9 months and 3 years the W/H graph and the H/A graph move somewhat away from each other compared to their general trend.

In line with the anthrograph proposed above (1.7), we could plot the prevalence of low H/A by the prevalence of low W/A. However, if we plot their complements (i.e. 100% minus that prevalence), we obtain a graph that is more in line with the Anthro Prevalence Graph of Fig. 5, more favourable outcomes getting higher positions on the x- and y-axes and less favourable outcomes getting lower positions. In order to explore how the prevalence of normal W/H behaves, it is shown as a second ancillary graph in Figure 7.

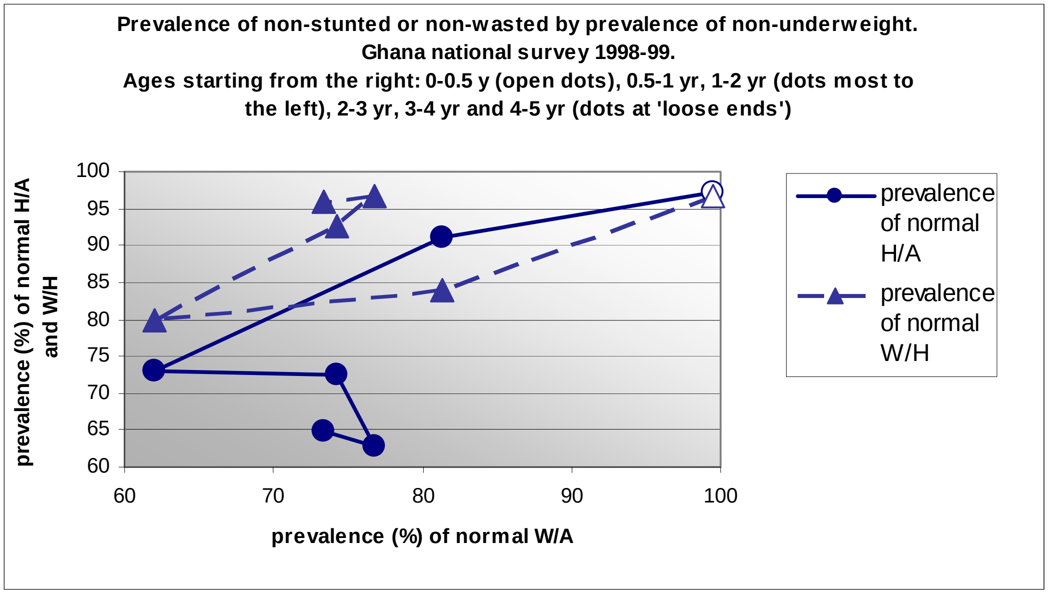


**Fig. 7**. 'Anthro Prevalence Graph: percentage of normal anthropometry by normal W/A (Ghana, Nov. 1998- Feb. 1999).

The time scale is now indicated by the sequence of the dots. The youngest age group is found in the most favourable right upperhand corner of the graph, because it was as yet hardly affected by undernutrition. The graph shows that undernutrition, esp. wasting, started to affect children in the second half of the first year. Around 1 year, stunting 'wins' from wasting. From 1-2 to 2-3 years the prevalence of stunting remained high; the increase in W/A was only due to an improvement in W/H (decrease of wasting). Between 3 and 5 years, the graph shows less dynamics, it is as if the state of undernutrition has more or less stabilized itself: around one quarter of the children is underweight and around one third is stunted.
Looking at the general trend of the graphs, the H/A graph shows a decreasing trend with age (going downward when one moves from right to left in the graph). This is consistent with the cumulative character of stagnation in length growth: catch-up in H/A does hardly occur. The W/H graph does not have this cumulative character: catch-up in W/H does occur. A movement of the H/A prevalence graph (and by implication the W/H prevalence graph) away from its trend constitutes a change in the relative preponderance of chronic versus acute undernutrition. In Fig. 6 one can verify that at 0.5-1 years of age there is a preponderance of acute undernutrition and from 1-2 years of age onwards an increasing preponderance of chronic undernutrition.

As is apparent in Figure 7, fluctuations around the trend of height for age and of weight for height mirror each other: when H/A fluctuates upward compared to its overall trend, W/H fluctuates downward compared to its overall trend. It is as if the W/H prevalence graph is a 'ghost image' of the H/A prevalence graph. This in consistent with the 'formula' discussed above in section 1.1: for given W/A, if H/A goes up, W/H goes down. This is consistent with what happens during child growth. As discussed above (1.4), normal growth is not smooth, but occurs in bouts followed by periods of stagnation. This means that a spurt in body stature tends be accompanied by some degree of apparent thinning. In a next period these tendencies may become reversed: linear growth stagnates somewhat, while weight growth catches up. This holds for individual children. But it is also a recurrent observation in survey findings of groups of children. At first reflection, it may be surprising that such fluctuations in individual

children do not cancel each other out over the many children in a survey. The likely explanation is, that to some extent many children are 'in phase' with each other. A strong candidate for an external factor that has such an influence on a group of children is seasonality (Hoorweg et al, 1995; Niemeijer et al, 1991), but the existence of other causes of fluctuations at group level cannot be excluded.
The strong mirror-wise shapes of the H/A and W/H prevalence graphs is due to the fact discussed above (see section 1.4), that the three anthropometric indices are strongly related. The graph even suggests that there could be a line that connects H/A prevalences that go together with low levels of wasting, such that most of the underweight is due to stunting. Such a line would roughly run from the lower left corner to the upper right corner of the graph. Because of the compensatory nature of the H/A and W/H prevalences, redundancy of the information can be further reduced by ignoring the W/H prevalence graph and focusing attention on the H/A prevalence graph. In doing so, there would not be much loss of information, because in the H/A prevalence graph itself both the cumulative downward trend and the fluctuations (mirrorwise with W/H) are preserved: 'one graph tells it all' [25].

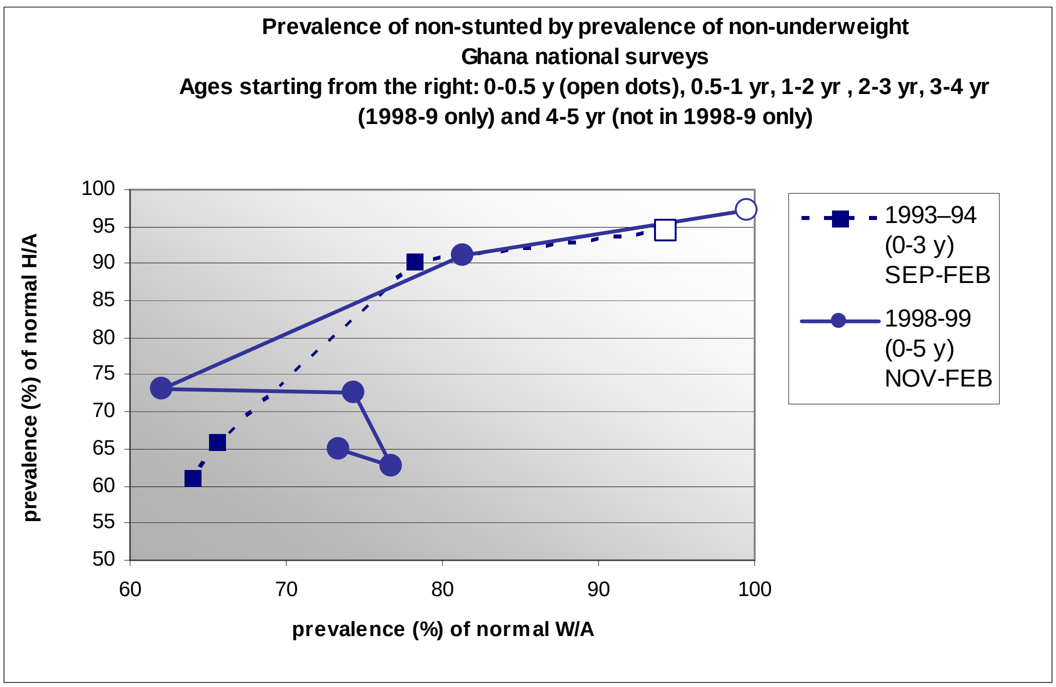


**Fig. 8**. 'Anthro Prevalence Graph': percentage of normal height-for-age by normal weight-for-age (Ghana, National surveys of Sep. 1993 - Feb. 1994 and of Nov. 1998- Feb. 1999).

[25] Admittedly, plotting the W/H prevalences is meaningful in a first analysis, to verify that the fluctuations with H/A prevalence are mirrorwise indeed. If not, it is wise to check the results for errors in the calculations. Some remaining distortion may not be caused by errors in the calculations, but is probably due to imperfections in the reference data set. Some distortion may be caused by the fact that the WHZ reference values are not specified by age group and that the reference values were derived by smoothing techniques applied to each index independently, not taking the 3-dimensional perspective into account. In addition, reference values at the low and high ends of age or height ranges available in the data sets appear to be less robust. Finally, there is the problem of the length-height transition around 2 years of age, before which stature is measured while the baby is lying down and after which while the baby is standing upright. In the NCHS references, the data for length are from a longitudinal data set (FELS), while the data for height are from a cross-sectional data set (NHANES).

If we wish to compare the two surveys of Table 4, the two Anthro Prevalence Graphs can be plotted together in one figure (see Fig. 8). What stands out in Fig. 8 is the similarity in level and pattern of child growth between the surveys, which were held 5 years apart. In both graphs the youngest infants are relatively well nourished and the rapid deterioration during the weaning age stands out in both cases. There are also some differences: in the earlier survey the children of 1-3 years showed more stunting (and less wasting – not shown) than in the later survey, and no catch-up in W/A at 2-3 years (children above 3 years were not included in the earlier survey).

The ‘Anthro Prevalence Graph’ has the following advantages compared to the conventional prevalence graphs: (i) it is a more condensed representation of the data (one or two graphs in stead of three); (ii) it gives a sharper view of any stagnation in growth (see the proximity of the prevalences between 2 and 5years of age); (iii) a rapid change over time is visible clearly as a larger distance between consecutive dots; (iv) it shows clearly the compensatory relationship between W/H and H/A.

### *2.2 Application of the ‘Anthro Prevalence Graph’ to the comparison between continents*

The 5th Report on the World Nutrition Situation – RWNS 2005 (SCN 2004), presents aggregate results by continent and sub-continental region. These results were obtained by linear regression analysis of multi-country data. In the following analysis the estimates for 1995 and 2005 are used. The results are for young children, ages combined. They are presented in ‘Anthro Prevalence Graphs’ of normal H/A by normal W/A. In order to see, how the prevalences of normal W/H behave in relation to differences or changes in the prevalences of normal H/A, they are also shown in the graphs. To facilitate interpretation, the prevalence percentage of normal W/H is connected by a line to the corresponding prevalence percentage of H/A for the same (sub)continent and the same year of the estimate. In Figure 9 empirical trendlines have been drawn that show what prevalences of normal W/H and H/A would be ‘expected’ for a given prevalence of normal W/A.

The anthropometric position of Latin-America is in the favourable right upperhand corner with low prevalences of all 3 types of anthropometric failure. The situation in South-Central Asia as well as in the whole of Asia was worse than in Africa in 1990. The situation and trend over the past decade for Asia as a whole (not shown in Fig. 9) is similar, but more to the right:. In the graph one sees at a glance how South Asia and the whole of Asia have moved to the right: while their level of wasting remained considerable, their level of stunting decreased and as a consequence also its level of underweight. In 2005 Asia as a whole had reduced its level of underweight to that of Africa. Africa shows a rather stagnant performance over the past decade. This stagnation in Africa resulted in higher absolute numbers of malnourished in 2005 (34.5 million, as against 27.8 million in 1995), while in the other continents the absolute numbers decreased (92 million, as against 120 million in 1995).

One can observe in Fig. 9 that undernutrition in Africa is comparatively more of the chronic type than ‘expected’ for its prevalence of underweight. Alternatively one could say that Africa has comparatively less underweight than ‘expected’ for its prevalence of stunting. In South-Central Asia on the contrary, undernutrition was more of the acute type (lower prevalence of not-wasted, i.e. higher prevalence of wasted children). In 2005 after the strong improvement over the past decade, the level of chronic undernutrition both in Asia as a whole and in South-Central Asia was comparatively less than ‘expected’ for its prevalence of underweight. The latter can be concluded from the (vertical) positions of the big icons, as well as from the distance between corresponding big and small icons (length of the vertical connecting dotted lines). Ten years ago, Ramalingaswami et al (1996) drew attention to the fact that just over 30% of Africa's children were underweight, but that the corresponding figure for South Asia was over 50%. Because of their population size, half of the world's

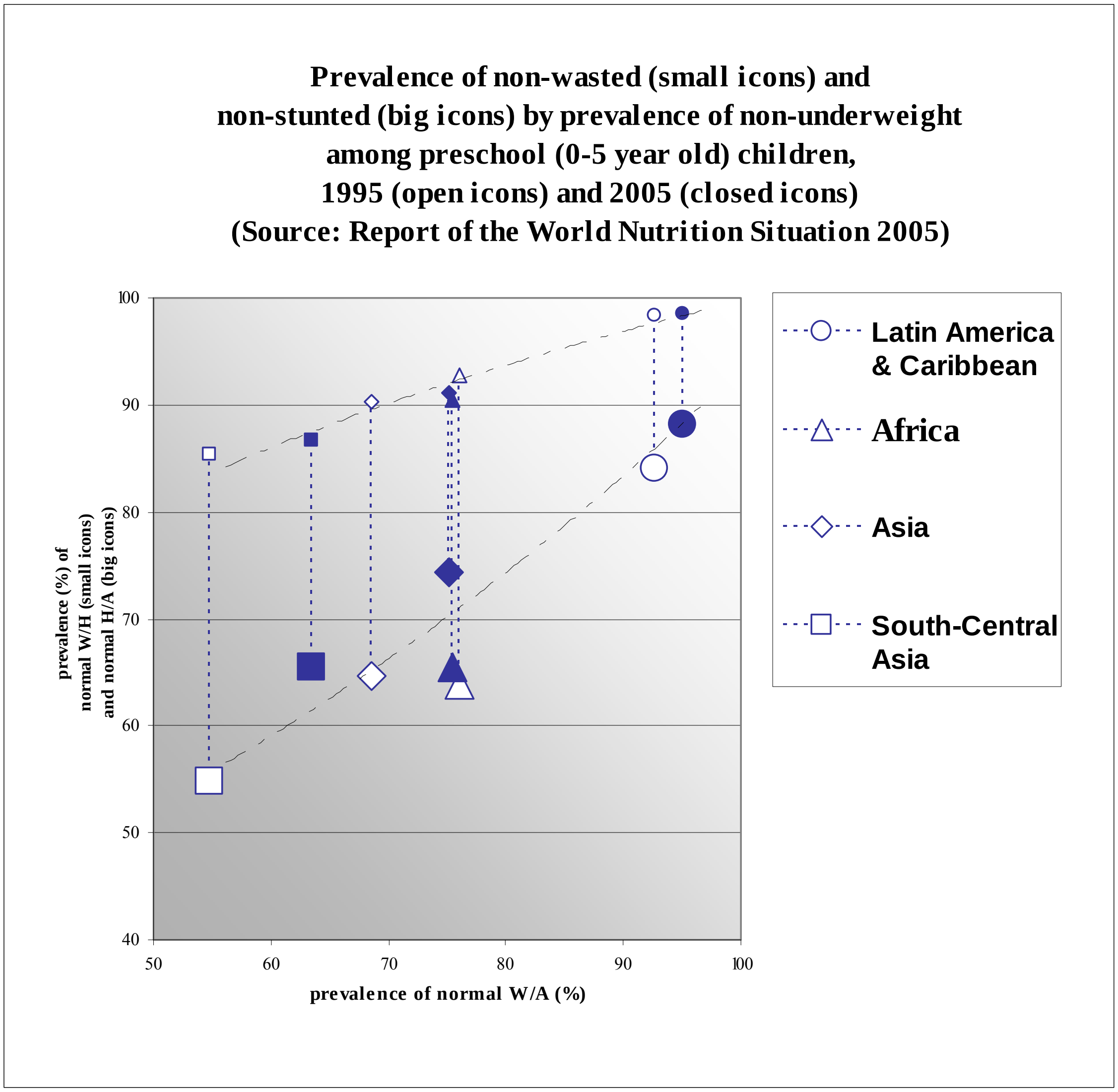


**Fig. 9**. 'Anthro Prevalence Graph': percentage of normal anthropometry by normal W/A, overall results for 3 continents, estimates for 1995 and 2005.

malnourished children were to be found in just three countries - Bangladesh, India, and Pakistan. They called this the 'Asian Enigma': they could not find an explanation for this difference between South Asia and Africa in differences in poverty, income inequality, agricultural performance, the vegetarian diet, neglect by government or genetic differences in growth potential. They came to a consensus that the exceptionally high rates of malnutrition in South Asia are rooted deep in the soil of inequality between men and women. Apparently, the cohort of children born one decade later has grown up under more favorable circumstances in that subcontinent. By now we are faced with an other enigma: what are the barriers to progress in Africa? This paper proposes new plotting tools that can be used to raise questions for deeper analysis. For instance, a shortening of the distance between W/H and H/A is what we also expect to occur in an individual child during a growth spurt. The three (sub)continents considered in this analysis all showed such a contraction over the past decade, but in Asia and Latin America & The Caribbean did it occur with a movement to the right (less underweight). In Africa there was stagnation in the prevalence of underweight. One can also say that in 1995 Africa had a comparatively anomalous position, as if its level of normal weight was flattered considering its level of stunting. In 2005 this was still the case: the lower marks are lower than 'expected'. If it was an individual child growing, one might suspect that there was something particular in terms of its body composition (e.g. a large worm load or a systematic underestimation of its body stature for some reason). The above results are very much aggregated, so there is a need to study the results at more disaggregated level.

### *2.3 Application of the 'Anthro Prevalence Graph' to the comparison between regions within Africa*

Figure 10 portrays the prevalences of normal anthropometry by normal W/A for regions within Africa. In Fig. 10 the vertical lines have been suppressed in order not to overload the graph. Within Africa, the higher prevalence of stunting than expected for its prevalence of underweight, as highlighted above, stands out for Eastern Africa, while in Western Africa it is the reverse: lower prevalence of stunting than expected for its prevalence of underweight (see Fig. 10).

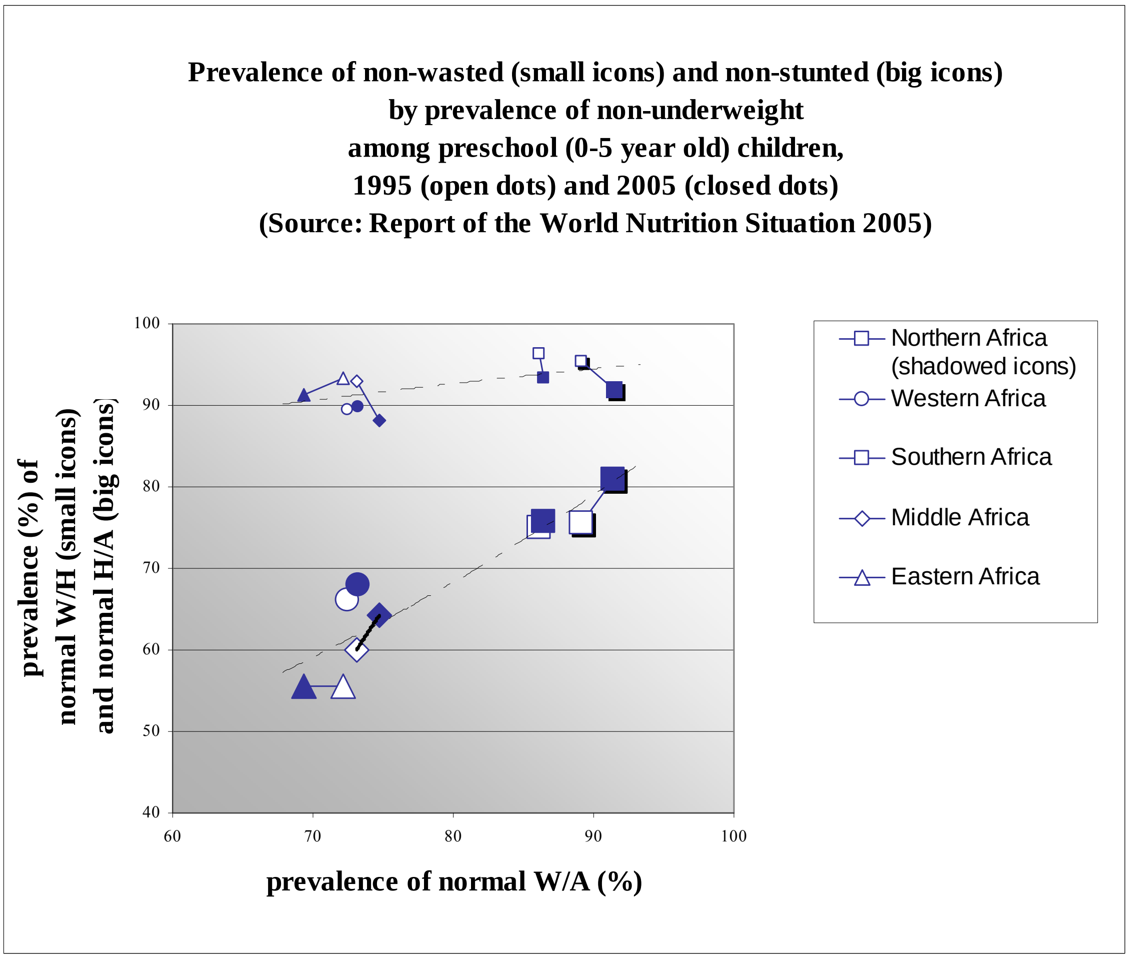


**Fig. 10**. 'Anthro Prevalence Graph': percentage of normal anthropometry by normal W/A, overall results for regions in Africa, estimates for 1995 and 2005.

The trend in the past decade is clearly positive for Middle and Northern Africa (diamonds and shadowed squares, respectively, in Fig. 10): less underweight and less stunting. It is noteworthy though that the rate of wasting increased, as if it was driven upward by the greater

growth in stature. The nutritional situation in Western and Southern Africa (circles and non-shadowed squares in Fig. 10) improved only marginally. Finally, nutritional conditions worsened in Eastern Africa (triangles in Fig. 10): more underweight due to more wasting. Fortunately the already high level of stunting did not increase further there.
It is interesting to note that the vertical distances between the prevalences of normal W/H and normal H/A were consistently smaller in 2005 than a decade earlier. In all regions but Western Africa the level of wasting increased and in all regions but Eastern Africa the level of stunting decreased. This may remind us of what happens during a growth spurt in an individual child (see 2.1.2). Yet other explanations cannot be ruled out, notably the comparability of the aggregate data over time: were there any differences in seasonality or in age composition of the samples? For instance, it can be noted that for Western Africa the prevalence of normal H/A is relatively high for its position in terms of W/A. If it were results for an individual child, one would wonder if these results concern a younger child population (e.g. children under 3 in stead of under 5 years of age). For Eastern Africa this is the opposite.

### *2.4 Application of the 'Anthro Prevalence Graph' to the comparison between national surveys – the example of Kenya*

Kenya has one of the longest series of national nutrition surveys (see Table 5).

**Table 5**. Prevalence percentages of undernutrition in Kenya (national surveys)

| Year of survey | Months | | Age group | Wasting (%) | Stunting (%) | Under-weight (%) |
|---|---|---|---|---|---|---|
| 1978-79 | NOV-JAN | Rural + urban | 0.5-4.99 | 5.3 | 35.4 | (na) |
| 1982 | | Rural | 0.25-4.99 | 4.6 | 38.2 | (na) |
| 1987 | | Rural | 0.5-4.99 | 4.5 | 32.2 | (na) |
| 1993 | FEB-AUG | Rural + urban | 0.5-4.99 | 6.0 | 35.7 | 24.4 |
| 1994 | JUN-AUG | Rural + urban | 0.5-4.99 | 7.8 | 33.6 | 22.5 |
| 1998 | FEB-JUL | Rural + urban | 0.5-4.99 (*) | 6.20 | 35.8 | 24.2 |
| 2000 | SEP-OCT | Rural + urban | 0.5-4.99 (*) | 6.20 | 35.3 | 21.1 |
| 2003 | APR-SEP | Rural + urban | 0.5-4.99 (*) | 5.78 | 32.74 | 21.8 |

(*) Prevalences recalculated from total results minus children 0-0.49 years
(na) = not available

In the 1980's W/A was not reported and the early surveys in 1982 and 1987 did not cover urban areas. In Fig. 11 prevalences of normal W/A were assumed by these authors.

The general picture is one of rather stagnating nutritional conditions, with signs of a slight improvement in weight and height growth since 2000. From survey to survey, results describe somewhat erratic movements back and forth, with a jump to better W/A about every decade (compare the changes between the periods 1982-1987, 1993-1994 and 1998-2000). The decade of the 1990's had less (variation in) stunting than the decade of the 1980's. If our assumptions about W/A in the 1970s are correct, the level of underweight did probably not change much over the 2 last decades of the past century. Since 2000 the performance in terms of underweight seems to have improved. The slight increase in underweight prevalence in 2003 is somewhat puzzling, as it was accompanied by less wasting and less stunting. This suggests the need for deeper analysis. From these results is not very well possible to predict by extrapolation where Kenya will be at the next survey[26]: will the general improvement be maintained, or will the statistics revert to lower values as they did in 1982, 1993 and 1998?

These overall results (all ages groups combined) hide quite some internal dynamics. For example, if we compare the results of the survey of 1993 to those of the survey of 1994 by age group (not shown in this paper), the move to the right in the graphs (2% less underweight) is mainly due to 6% less underweight among the children 1-2 years of age. The 2% less stunting in 1994 is the result of 7% more stunting among the children in the second semester of their first year of life and 4.5 % less stunting among the children 2 years and over. In 1994 there was 2% more wasting, which was the result of 3% more wasting among all age groups except 1-2 years.

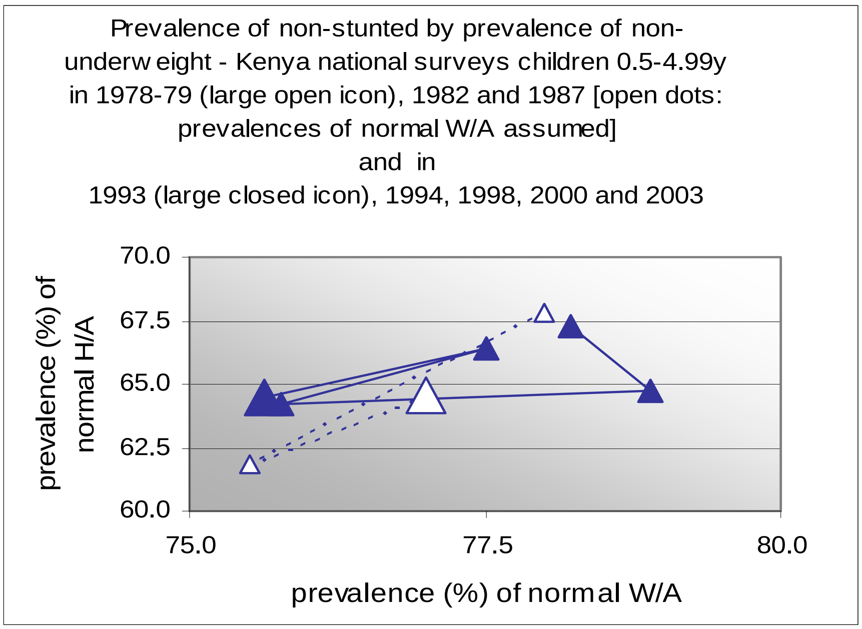


**Fig. 11.** 'Anthro Prevalence Graph'. Percentage of normal anthropometry by normal W/A among underfives, Kenya national surveys.

[26] The results of the Kenyan national surveys of 2000 and 2003 are now also available in recalculated form (WHO, 2007) using the new WHO child growth standards (WHO, 2006b). Curiously, the sample sizes have increased, which makes the comparison difficult. One possible explanation is that with the new standards, less child values are flagged to be rejected. Roughly the new standards result in 5-10 percentage points more stunting, around 1 percentage point more wasting and 2-4 percentage points less underweight. The trends are comparable.

## 3 A new 'Antro Table' for Svedberg's classification of Anthropometric Failure

Svedberg's classification (see 1.7) is essentially an extension of Waterlow's classification, so we propose building a table in analogy with Table 1a but with the more refined classification in seven categories and using the display of WHZ by HAZ as in the 'Anthro Prevalence Graph' (Fig. 5). This disaggregation implies that the mean HAZ and WHZ are specific for each category. Therefore in Table 6 each category has its own row. The mean WAZ values are similar for some categories; in this case they are shown in the same column. Thus in Table 6 the result pertaining to each of the seven categories is given at the cross-section of its own row and its own or a shared column. For further explanation see the legend of Table 6

### *3.1 A new 'Antro Table' to visualize disaggregated prevalences of undernutrition*

The following analysis has again been done within the data set of the Demographic and Health Survey (DHS) for Kenya, 2003 (Measure DHS+, 2004). Table 6 tries to preserve more or less the relative position of each category as per the corresponding mean HAZ and WAZ values. In this way the layout of the 'Antro Table' mimicks the layout of the 'Anthro Prevalence Graph'. In order to make this possible, three columns had to be created for different degrees of underweight and non-underweight, respectively.

The following analysis has again been done with the data set from Kenya's 2003 Demographic and Health Survey (Measure DHS+, 2004). The total number of underweight children (see the figures in bold) was 985 (20.1%) and the total non-underweight was 3,900 (79.9%). Table 6 is the 'Antro Table' that represents the frequency distribution of the seven anthropometric categories in its two-way (bivariate) layout.
The columns are arranged from low to high mean WAZ values and the rows from high to low mean HAZ values, as in a two-way graph[27]. The mean WAZ values are shown at the top of the columns and the mean HAZ values at the left of the rows. The mean WHZ values of the seven categories can be seen to follow a diagonal gradient: lower for the categories on the left of or above the central diagonal (i.c. W, UW and SUW) and higher for the categories on the right of or below the central diagonal (i.c. N, S and SU), with the category on the central diagonal (i.c. U) taking an intermediate position in terms of mean WHZ. This elegant property of the Anthro Table is explained by the strong interrelationship between the three anthropometric indices discussed earlier. We propose calling a table with this special layout an 'Antro Table'. In such a table it is possible to indicate schematically where the dividing line between wasted and normal body proportions would run if it were a graph (i.e. at WHZ=-2.0). This line runs diagonally through the Antro Table from the lower left to the upper right. Looking at the prevalence percentages in Table 6, stunting can be seen to affect more children than wasting. This is expected, as stunting is a cumulative measure. The prevalences by category vary widely. There is a way to understand them. The prevalence in a category depends on which segment of the bivariate frequency distribution of the Kenyan underfives is captured by it. The bivariate frequency distribution of WAZ by HAZ is like a 'mountain' (or bellshape) laying on top of the Antro Graph or Antro Table. In the reference population, there is only 2.3% of the children who fall under the cut-off point of -2 standard deviations for each of the anthropometric indices.

[27] Admittedly, the distances between the mean Z-scores of the rows and columns are not constant. In this respect, the 'Anthro Prevalence Table' is a schematic visualization and not a precise graph.

**Table 6**. 'Antro Table' of number of children and prevalence% by seven categories of anthropometric category (Kenya, DHS 2003)

| | Anthropo-metric category | mean HAZ | mean WHZ | mean WAZ | Underweight -3.6 | Underweight -2.6 | Underweight -2.2 | Non underweight >-2 | Non underweight -1.2 | Non underweight -0.3 |
|---|---|---|---|---|---|---|---|---|---|---|
| non stunted | W | 1.4 | -2.4 | | | | | | **69 (1.41%)** | |
| non stunted | N | -0.5 | -0.0 | | | | | | | 3049 (62.41%) |
| non stunted | UW | -0.7 | -2.8 | | | **121 (2.48%))** | | | | |
| non stunted | U | -1.6 | -1.6 | | | | 142 (2.9%)) | | | |
| Stunted | -- | <-2 | <-2 | | | | | **---**[28] | | |
| Stunted | S | -2.6 | 0.5 | | | | | | 783 (16.03%) | |
| Stunted | SUW | -3.1 | -2.5 | | **88 (1.8%)** | | | | | |
| Stunted | SU | -3.2 | -0.8 | | | 634 (12.97%) | | | | |

Source of prevalence data: Kenya Demographic and Health Survey (2003) (Measure DHS+ 2004).
Legend: The anthropometric categories are defined by combinations of HAZ, WAZ and WHZ above or below Z=-2 (for the meaning of the abbreviations, see Table 3). Entries are arranged according to the category's mean HAZ by mean WAZ values as indicated in the margins. The position of a cell corresponds more or less to the midpoint of the anthropometric category in the 'Anthro Prevalence Graph'; the cell limits in Table 6 are not more than a grid to connect the results to their corresponding mean Z-scores; to see the whole area covered by any of the anthropometric categories, see the 'Anthrograph' (Figure 5). To obtain the numbers, cases were weighted using the sampling weights in the SPPS datafile, in order to correct for any differences in sampling probabilities. Numbers and prevalence percentages of children who are wasted (only or in any combination) are printed bold. Light shading is used for underweight or stunting, while dark shading is used for the combination of underweight and stunting. The totals wasted and stunted can be found in Table 1a. The total number of children underweight was 984 (20.1%); the total non-underweight was 3,901 (79.9%).
Results for wasting categories are printed in bold. One can imagine that the cut-off value for wasting (WHZ= -2) runs diagonally through the table from the lower left corner (between SUW and SU), through the center (between UW and U) up to the upper right corner (between W and N). The prevalence of wasting increases if one moves trhough the table from the lower right to the upper lefthand corner in a direction perpendicular to the diagonal for constant WHZ=-2 described above.

The child population in DHS Kenya 2003 was shifted downward (towards lower H/A) and leftward (towards lower W/A and lower W/H). The total CIAF prevalence is 100-62.4=37.6%, of which a large part (29.0%) is on account of children who are stunted but not wasted. Although the category U is relatively close to the center (thus the top) of the two-dimensional bellshape, its surface area is constrained: WAZ values of these children are just (and not much) below -2 and their WHZ and HAZ values are in the lower zones of the normal range. This explains the relatively low prevalence of the U category.

The 88 children in the SUW category (with the darkest shading) in Table 6 are the same as the 88 children labelled 'wasted + stunted' in Waterlow's classification (Table 1a). This is

[28] For reasons of consistency of pattern, a row has been included for the empty non-existant category of wasting, stunting and normal weight (cf note 20).

because any child who is both wasted and stunted is also necessarily underweight (see Footnote 21). However, the reverse is not true: a child who is neither wasted nor stunted does not necessarily have a normal WA. In fact, the cut-off line for wasting carves out of Waterlow's 'normal' children a small percentage of children (here 2.9%) who are underweight without being wasted or stunted: 'underweight only' (U). The average WAZ value of the U category is somewhat higher than the WAZ values of the UW and SU categories but lower than for N, which is consistent with its intermediate (central) position in the Antro Table.

In Table 6 it can be seen how the usual three (one-dimensional) indicators for undernutrition are related to Svedberg's CIAF (see above). Its prevalence in this example from Kenya is 100-62.4 = 37.6%. The indicator underweight (WAZ<-2.0; here: 20.2% of the children) unfortunately 'misses' the 16% of the children belonging to category S and the 1.4% belonging to category W, but has the merit of including 2.9% of the children (U) that are missed in Waterlow's classification. The stunting indicator (HAZ<-2.0; here: 30.8%) also misses the U category (2.9%) and is 'taunted' with the 1.8% of the children who are not only stunted but also wasted. The wasting indicator (WHZ<-2.0; here: 5.7%) misses the U category (2.9%) and includes the 1.8% of the children who are not only wasted but also stunted.

If the CIAF were considered the best indicator of the true prevalence of child undernutrition because it includes all forms of anthropometric failure (here 37.6%), Waterlow's classification would be a good second (here 34.7%), followed by stunting (here 30.8%), underweight (here 20.2%) and lastly wasting (here 5.7%). If the intention is to have the highest prevalence figure by not missing categories, their relative measure of success can indeed be judged from the above ranking order. However, this judgement in a way is not fair: wasting as an indicator of acute conditions is by its very nature usually a much more modest percentage than stunting. In this survey in Kenya, the prevalence of underweight is lower than the prevalence of stunting because the prevalence of wasting is relatively low.

A better criterion to judge the appropriateness of an indicator for monitoring purposes is how it reacts to change. One could say that using a composite index like the CIAF or the combination of wasting and stunting (or underweight for that matter) as an indicator would be more acceptable if wasting and stunting behave more similarly in terms of response to causal factors or in terms of association with outcomes concerning health and performance. On the other hand, the more wasting and stunting behave differently, the more reason there would be to promote either of them in their own right as an overall indicator. Since stunting as a measure of chronic conditions is considered to be a better indicator of poverty and of the effect of sustainable actions to alleviate poverty, current consensus goes in the direction of promoting stunting as the preferred indicator for monitoring the progress of MDG-1 (SCN 2008).

To address the above question, the differences in the seven anthropometric categories were investigated in terms of their score or performance on related factors, such as (i) possible causes or (ii) possible outcomes. A way of studying the association of child growth with another factor is to indicate the value of that factor for each of the seven anthropometric categories. Nandy et al. (2005) analyzed data from India and have provided graphs in which the X axis has the seven anthropometric categories arranged according to the number of anthro-pometric failures (N:none; S, U and W: one, SU and UW: two; SUW: three). The Y axis shows the average value of the factor investigated for the children in each category.

A similar analysis was done for this chapter using the DHS Kenya 2003 data set. In addition to a one-dimensional layout of the seven categories (as in the graphs by Nandy et al.), the

two-dimensional[29] character of the seven anthropometric categories is preserved by presenting the results of the association analysis in the form of an 'Antro Table'.
The related factor to be investigated in its relation to anthropometric performance then becomes a third dimension. It is possible to visualize this, but that would require a 3-dimensional graph[30]. For a correct interpretation of the 3-dimensional shape of such a graph, the reader may need several two-dimensional projections from different angles, as well as some dose of stereometric insight. A more straightforward and less demanding solution is to report the results of the factor to be investigated in the 2-dimensional 'Antro Table'[31]. This 2-dimensional table has the character of a grid on a map. The values of the factor to be investigated is mapped onto this grid according to the mean HAZ, WAZ and WHZ scores of the category in question. Not all cells need to be filled, but just those that correspond to the average location. Empty cells just represent 'surrounding area'.
The following sections give the results of two applications of the 'Antro Table' in investigating the association of anthropometric failure with other variables, i.e. diarrhoea (as an example of a possible consequence) and poverty (as an example of a possible cause).

### *3.2 Application of the 'Antro Table' to visualize the relationship between anthropometric failure and a major health condition – the case of diarrhoea*

The first application of the Anthro Table investigated in this study concerned the relationship between anthropometric status and recent episodes of diarrhoea (namely in the two weeks before the interview). Binary logistic regression analysis was used to generate a model of the occurrence of diarrhoea as a function of the child's anthropometric category[32]. As the child's age influences the result, this was included in the model as a continuous variable. The data were analyzed using SPSS software version 15.0. The output of the logistic regression is the set of odds ratios of having diarrhoea. The odds ratio is a measure of risk and expresses how many times the odds of having diarrhoea in one group is more than the odds of diarrhoea occurring in the referent group N. For instance, of the 3045 children in the referent group N, 448 had diarrhoea; the odds being 448/(3045-448)=0.17 or one child with diarrhoea for every six without diarrhoea. Of the 68 children who were wasted only, 19 had diarrhoea so the odds were 19/(68-19)=0.38 or one with diarrhoea for almost three without diarrhoea. The odds ratio[33] (not corrected for age) was 0.38/0.17=2.25 for the W category. After correction for age in the logistic model, the age-adjusted result was 1.80. In other words: wasted children were

[29] As explained above (1.5): strictly speaking the classification is 3-dimensional, but it boils down to two dimensions for practical purposes.
[30] While the third dimension in the case of prevalence percentages forms a bellshape (cf 3.1), the values of related factors form a plane in 3-dimensional space. It may be a flat plane, possibly tilted downwards to lower HAZ and/or WAZ values, or it may be curved (e.g. convex or concave) or ondulating. The 'Anthro Prevalence Table' basically portrays the values of that plane in seven selected areas of the HAZ by WAZ base plane. This is still a rather crude analysis, but it serves as a first stepping stone towards more refined 3-dimensional analysis (e.g. landscape analysis using 'multidimensional scaling' techniques).
[31] This arrangement corresponds to a view of the 3-dimensional graph from right above. As the magnitude of the factor to be investigated cannot be seen from above, it is reported as a number on the appropriate location (where its HAZ and WAZ meet).
[32] Because the dependent variable (diarrhoea) is a yes/no variable, binary logistic re-gression was used here. To represent the independent variable (anthropometric category), a yes/no variable was created for each of the six categories of anthropometric failure and for the N category (no failure). The latter was used as the referent group for the odds ratio, which in this analysis is a measure of the risk of diarrhoea.
[33] The odds ratio is the preferred measure of risk in case-control studies. The odds ratio is a ratio of odds. To put it in perspective, if one compares a group having a probability of two thirds with a group having a probability of one third, the first group has 2 times the chance, but 4 times the odds. if one compares a group having a probability of 75% with a group having a probability of 25%, the first group has 3 times the chance, but 9 times the odds.

almost twice as likely to have had diarrhoea as those without anthropometric failure. Table 7 presents the odds ratios of diarrhoea for the seven anthropometric categories.
The figures in bold (wasted children) run diagonalwise through the ‘Antro Table, just like the iso-WHZ lines run through the ‘Anthro Graph’ (Figure 5).

The inclusion of underweight in this classification is useful, as it serves to show the dynamics within three of the four categories of Waterlow’s classification: compare UW to W, U to N and SU to S. The OR’s for the latter two pairs show what would be expected: a gradual increase in the odds of diarrhoea going from upper right to lower left in Table 7, i.e. with increasing undernutrition. The most dramatic result is – as expected – for the triple anthropometric failure category of being wasted and stunted (and - by implication - underweight), which has a more than fourfold increase[34] in the odds of diarrhoea compared to the referent group ($OR_{SUW}$=4.38)[35]. The category SUW is at the lower end of the range for all anthropometric values: compared to the referent group, its mean WAZ, HAZ and WHZ are shifted by -3.3, -2,6 and -2.6 s.d. units, respectively (see Table 7 and Annex 2a). Double anthropometric failure (being underweight and wasted or stunted) gives an intermediate increase in the odds of diarrhoea ($OR_{UW}$=1.79 and $OR_{SU}$=1.97).

**Table 7**. ‘Antro Table’ of the relative odds of diarrhoea in the past two weeks by anthropometric status category (Kenya, DHS 2003)

| | | | | Underweight | | | | Non underweight | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Anthropo-metric category | mean HAZ | mean WHZ | mean WAZ | -3.6 | -2.6 | -2.2 | >-2 | -1.2 | -0.3 |
| non stunted | W | 1.4 | -2.4 | | | | | | 1.80 | |
| | N | -0.5 | -0.0 | | | | | | | 1.00 |
| | UW | -0.7 | -2.8 | | | 1.79 | | | | |
| | U | -1.6 | -1.6 | | | | 1.24 | | | |
| stunted | [SW][36] | <-2 | <-2 | | | | | -- | | |
| | S | -2.6 | 0.5 | | | | | | 1.38 | |
| | SUW | -3.1 | -2.5 | | 4.38 | | | | | |
| | SU | -3.2 | -0.8 | | | 1.97 | | | | |

Source: Kenya DHS (2003) (Measure DHS+ 2004)
Legend: The anthropometric categories are defined by combinations of HAZ, WAZ and WHZ above or below Z=-2 (for the meaning of the abbreviations, see Table 3). Entries are arranged according to the category’s mean HAZ by WAZ values as indicated in the margins. For the number of children in the survey and prevalence

[34] The terms ‘increase’ or ‘effect’ are used here to facilitate the interpretation of the size of the association between diarrhoea and growth outcomes. Strictly taken the quotients used in this analysis do not necessarily reflect actual cause-effect relationships. Undernutrition makes a child more vulnerable to diarrhoea, and diarrhoea in turn may aggravate undernutrition, especially of the acute type (i.c. wasting).
[35] The subscripts denote which odds is in the nominator and which odds is in the denominator of the quotient.
[36] See note 20. The theoretical combination SW is void.

percentages, see Table 6. The odds of diarrhoea in each anthropometric group are expressed as a ratio of the odds in group N (the referent group). These quotients are known as the odds ratio (OR). The ORs of wasted children (only or in any combination) are shown in bold. Light shading is used for underweight or stunting, while dark shading is used for the combination of underweight and stunting.

The categories UW and SU contrast less with N in terms of anthropometry than SUW does: their mean WAZ is shifted by -2.3. Their shifts in mean HAZ and WHZ are in line with their character: UW has – as expected - a downward shift of WHZ (2.8 units lower), but an almost equal HAZ (only .2 units lower), while for SU it is the reverse, a downward shift of HAZ (2.7 units lower) and WHZ only 0.9 units lower.
Being stunted without underweight raises the odds of diarrhoea 1.4 times. Category S is also closer to N in terms of anthropometry: its mean WAZ, HAZ and WHZ are shifted by -0.9, -2.1 and +0.4[37].
Being wasted without underweight raises the odds of diarrhoea 1.8 times. Category W is also closer to N in terms of anthropometry: its mean WAZ, HAZ and WHZ are shifted by -0.8, +1.9[38] and -2.5.
It is somewhat surprising to find that $OR_W$ (1.80) is as high as $OR_{UW}$, even if it is in a more favourable position in terms of anthropometry than the latter with an only modest shift of -0.8 in mean WAZ and a really high HAZ with a shift of. Apparently, being wasted alone suffices to have a relatively high OR of diarrhoea at more favourable WAZ and HAZ values. The lower WAZ and HAZ of category UW do not increase the OR further, as long as the child is not stunted. That $OR_W$ is as high as $OR_{UW}$ can be interpreted in two ways: the former being higher and/or the latter being lower than one would expect, given the more gradual increase in odds with increasing underweight among the non-wasted categories (compare $OR_U$ to $OR_N$ and $OR_{SU}$ to $OR_N$).
These results illustrate, how the seven anthropometric categories allow a more refined analysis than the Waterlow classification. Yet when one intends to give overall estimates[39], the grouping of categories according to the Waterlow classification allows to make fair comparisons in terms of the mean anthropometric values (see Annex 2a). The overall effect of being wasted on the odds of diarrhoea: ($OR_{(W+UW)/N}$=1.80) is about 10% higher than the effect of being stunted ($OR_{(S+SU)/N}$=1.64).
In both classification systems, $OR_{SUW/N}$=4.38 represents the effect of being both stunted and wasted on the odds of diarrhoea.
It can be concluded that the association with diarrhoea is stronger for moderate wasting than for moderate stunting (i.e. when comparing single failure categories) but that differential effect is not evident among the double failure categories. It is also evident that the odds of diarrhoea do not depend either on wasting or on stunting, but that both of them do contribute to the odds of diarrhoea. Witness to this is the largest odds ratio ($OR_{SUW/N}$=4.4) for the category which combines wasting and stunting (and by implication: underweight).
Within the U category the risk of diarrhoea is only slightly increased. Judging by the mean WAZ of SU and UW, there may be a threshold effect, such that a doubling of the OR may occur somewhere at a WAZ around -3.

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[37] That category S has a greater WHZ than category N can be expected: to be stunted but not underweight can only occur if WHZ is more favourable; otherwise the stunted child would be underweight as well and fall in an other category: SU.
[38] That category W has a greater HAZ than category N is also explained by the complementarity between stunting and wasting for given level of underweight (see previous note).
[39] These overall measures are also quite appropriate in terms of the mean anthropometric values of the categories compared. The combination of W+UW has the same mean HAZ as N, while it differs in mean WHZ (shift of -2.7); unavoidably, WAZ is also affected (shift of -2.1). The combination of S+SU has the same mean WHZ as N, while it differs in mean HAZ (shift of -2.9); unavoidably, WAZ is also affected (shift of -1.9).

Nandy et al (2005) did their analysis in data from the 1998-99 National Family Health Survey (NFHS-2) for India (children 0-36 months old). In addition to diarrhoea their database also had a variable about blood in the stools, which allowed them to categorize severe diarrhoea as well. In the Table 8 the results for India and Kenya are compared.

**Table 8**. Odds ratio of diarrhoea by anthropometric status category (India – 1998-99 NFHS-2 compared to Kenya - DHS 2003)

| Odds ratio of diarrhoea in the past two weeks | | Diarrhoea (0-5 years) Kenya, 2003 | Diarrhoea (0-3 years) Kenya, 2003 | Diarrhoea (0-3 years) India, 1998-99 | Severe diarrhoea (0-3 years) India, 1998-99 |
|---|---|---|---|---|---|
| Number of children | | 4,876 | 3,034 | 24,952 | 24,942 |
| A | **N: No failure**: Children whose height and weight are above the age-specific norm (i.e. above –2 z-scores) and do not suffer from any anthropometric failure. | 1.00 | 1.00 | 1.00 | 1.00 |
| F | **S: Stunting only**: Children with low height for age but who have acceptable weight, both for their age and for their short height. | 1.38 | 1.24 | 1.04 | 1.08 |
| Y | **U: Underweight only**: Children who are only underweight. | 1.24 | 1.14 | 1.19 | 1.64 |
| B | **W: Wasting only:** Children with acceptable weight and height for their age but who have subnormal weight for height. | **1.80** | **1.97** | **1.06** | **0.45** |
| C | **UW: Wasting and underweight**: Children with above-norm heights but whose weight for age and weight for height are too low. | **1.79** | **1.67** | **1.45** | **1.19** |
| E | **SU: Stunting and underweight**: Children with low weight for ageand low height for age but who have acceptable weight for their height. | 1.97 | 2.02 | 1.54 | 2.03 |
| D | **SUW: Wasting, stunting and underweight**: Children who suffer from anthropometric failure on all three measures. | **4.38** | **3.56** | **1.72** | **1.95** |

Anthropometric failure in Kenya increases the odds ratio of diarrhoea much more than in India. This even applies to the odds ratio of severe diarrhoea (except for children with underweight only). In the Indian results there is hardly an increase in the OR of diarrhoea when a child has a single anthropometric failure. In the Kenyan data, a single anthropometric failure already gives a clear increase in the OR of diarrhoea, in particular wasting. Among the double failure categories, the combination of stunting and underweight overtakes the combination of wasting and underweight in both datasets.

Interestingly, the odds of diarrhoea among the non-failure category are similar in both countries (0.22 for the Indian children below 3 years and 0.25 for the Kenyan children below 3 years). This means 1 case with diarrhoea over 4 cases without diarrhoea. The odds for the Kenyan children below 5 years are lower, namely 0.17 (1 over 6). That shows that the odds of diarrhoea are age dependent: the children of 3-5 years had less diarrhoea and thus diluted the odds; yet the relative occurrence of the seven anthropometric categories was almost the same . Because of this age dependence, the logistic regression applied included an adjustment for age, as stated above.

The effect of undernutrition should not be confused with the prevalence of undernutrition. In terms of prevalence of undernutrition, the Indian sample of 1998/99 has considerably more undernutrition than the Kenyan sample of 2003 and shows also a relative shift towards the wasting side of undernutrition. To give a few key figures for children 0-3 years of age: in Kenya twice as many had no anthropometric failure (62.1%, versus 32.5% in India) and the prevalence of wasting was one third (6.9%, versus 15.7 % years India).
Including the Kenyan children of 3-5 years hardly changed these prevalence rates (62.4% and 5.7%, respectively).

### *3.3 Application of the 'Antro Table' to visualize the relationship between anthropometric failure and wealth rating*

A similar analysis as in section 3.2 has been done for a factor that is one of the basic causes (or at least corrolaries) of undernutrition. The Kenya DHS 2003 dataset contains a wealth index factor z-score for each child based on a number of household goods and assets. The mean of the wealth index scores is close to zero since the index is standardized for households to produce z-scores (Rutstein and Johnson, 2004). The Kenya DHS 2003 dataset has a categorical variable derived from the wealth index, which divides the population approximately in quintiles (20% bands of the frequency distribution of ordered values). The quintiles are labelled from 'poorest' to 'richest' but these terms have to be understood in relative terms. The bar graph of Figure 12 gives the results of the prevalences of the seven anthropometric categories by wealth quintile[40]. The frequencies in which the different anthropometric categories occur differ according to wealth quintile. : there is more undernutrition with increasing poverty. While in the relatively wealthiest quintile, 24% of the underfives suffer from anthropometric failure of various kinds, it is doubled (48%) among the poorest).

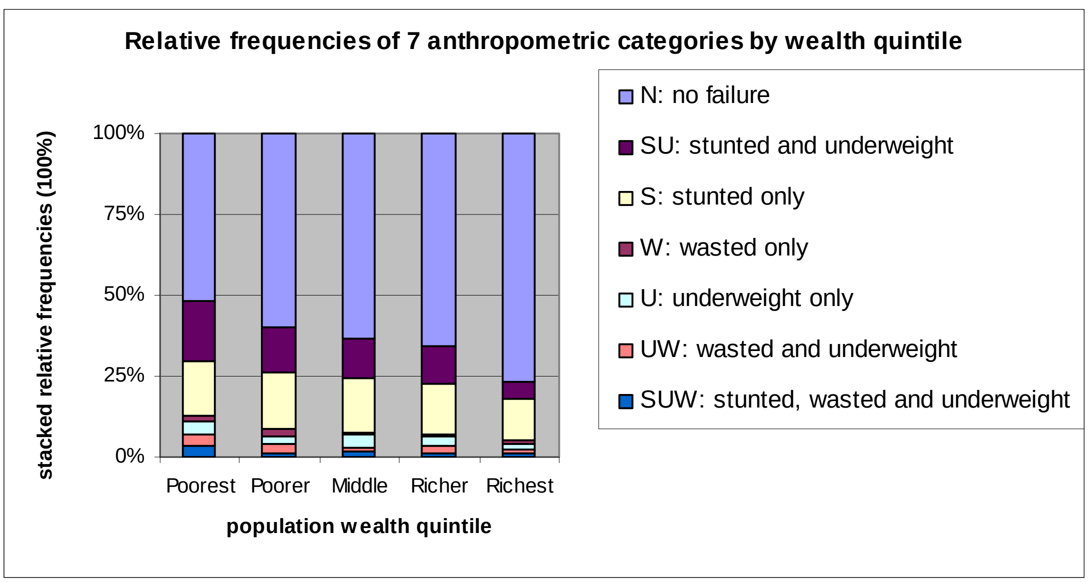


**Figure 12.** Relative frequencies of the seven anthropometric categories by population quintile based on the wealth index.
Source: Kenya DHS (2003) (Measure DHS+ 2004)

[40] The data were analyzed using SPSS software version 15.0.

To gain further insight into the pattern of frequencies in Figure 12, the results of the poorest quintile (first bar) were contrasted to those of the richest quintile, which served as a reference group (fifth bar). The results are shown in a one-dimensional arrangement (as Svedberg and Nandy did) in the upper part of Table 9. The prevalence percentages in the column of 'non-N' represent Svedberg's 'composite index of anthropometric failure' (CIAF): 24% among the richest group (indicated by Q5). Among the richest households, therefore, almost 1 in 4 under-fives are undernourished.

**Table 9.** Poverty and anthropometric categories

| | | Total[41] | SU | SUW | S | U | UW | W | non-N (CIAF) | N (no failure) |
|---|---|---|---|---|---|---|---|---|---|---|
| Number | Q1 | 1202 | 223 | 42 | 203 | 46 | 45 | 21 | 578 | 624 |
| | Q5 | 841 | 47 | 10 | 109 | 10 | 12 | 10 | 198 | 643 |
| Prevalence % | Q1 | 100% | 18.5% | 3.5% | 16.8% | 3.8% | 3.7% | 1.7% | 48.1% | 51.9% |
| | Q5 | 100% | 5.6% | 1.2% | 12.9% | 1.2% | 1.4% | 1.2% | 23.5% | 76.5% |
| Odds | Q1 | | 0.357 | 0.067 | 0.324 | 0.073 | 0.071 | 0.033 | 0.926 | 1.00 |
| | Q5 | | 0.073 | 0.016 | 0.169 | 0.015 | 0.018 | 0.016 | 0.307 | 1.00 |
| Odds Ratio | Q1:Q5 | | 4.90 | 4.29 | 1.92 | 4.78 | 3.87 | 2.05 | 3.01 | 1.00 |
| Odds Ratio (corrected for residency) | Q1:Q5 | | 5.77 | 3.60 | 2.53 | 6.49 | 5.74 | 2.74 | 3.8 | 1.00 |

Source: Kenya DHS (2003) (Measure DHS+ 2004).
Legend: W, UW, U, S, SUW, SU = anthropometric failure categories according to Svedberg and Nandy: combinations of wasting (W) and/or stunting (S) and/or underweight (U). N = category with no such anthropometric failure (see Table 3). Non-N = total of the six anthropometric failure categories; these constitute Svedberg's 'composite index of anthropometric failure'(CIAF).
Q1 = poorest household quintile; Q5 = richest household quintile.
Odds = prevalence of children in the anthropometric failure category divided by the prevalence of children in the no-failure category N.
Odds ratio (OR) = odds among children in Q1 divided by the odds among children in Q5. Here the Q5 serve as the referent group. Using the multinomial logistic regression module of SPSS, a corrected OR was estimated with type of residence as a covariate.

The prevalence of all individual anthropometric failure categories as well as the CIAF are higher among the poorest (indicated by Q1), at the expense of a lower prevalence in their N category. In a deeper analysis (see middle part of Table 9), for each of the two selected quintile classes the prevalence percentages are divided by the prevalence in the corresponding N category, which is used as the referent group. The ratio of two prevalences gives a measure

[41] That the numbers of children in these quintiles is larger than the expected 20% of the total sample of 3,681 underfives, may be due to two reasons: (i) the quintiles were derived from the frequency distribution of the wealth index factors scores in the adult population; (ii) due to ties (cases with the same values) it may not have been possible to find a cut-off score that would cut off exactly the lowest 20% of the child population.

known as ‘odds’[42]. The odds of composite anthropometric failure among the richest households are 0.307: for every one undernourished child, more than three are well nourished. In the poorest quintile, the CIAF prevalence is 48% (almost 1 in 2), which gives an odds of almost 1:1 (0.926).
The contrast in risk between the poorest and the richest is given by the Odds Ratio (OR) which is the ratio of the odds among the poorest and the odds among the richest (see lower part in Table 9). For the six failure categories combined (CIAF), the OR is 3.0 (almost 1:1 divided by almost 1:3). In other words, the odds of being undernourished among the poorest is three times the odds among the richest. The ORs for the individual failure categories range between 1.92 for S and 4.90 for SU.
SPSS has a module for multinomial logistic regression analysis[43], which allows an investigation of the influence of covariates. Children’s age had virtually no influence but their place of residence (urban/rural) did affect the odds of anthropometric failure. After correcting for type of residence (see the bottom row of Table 9), the influence of poverty on anthropometric outcomes became more pronounced, except for the SUW category. Among the poorest, the odds of the CIAF categories combined are almost fourfold compared to the richest quintile.
Table 9 shows that ORs are generally higher as one moves from single to double anthropometric failure, although the OR of SUW is not as high as its triple failure would lead one to expect compared to the double failure categories. The effect of poverty is surprisingly strong (OR=6.5) for children in the single failure category U, who are underweight and on their way to (or recovering from) being wasted or stunted. Note that these children are classified as ‘normal’ according to Waterlow. They do not have the levels of stunting and/or wasting of the SU and SUW categories but the effect of poverty is at least as strong.

While the prevalence percentages of the seven categories are shown in Figure 12 and in Table 9 in a one-dimensional layout, Table 10 shows the results of this risk analysis in the same two-dimensional layout as in Tables 6 and 7 according to Svedberg and Nandy’s classification, with shading according to Waterlow’s classification. This presentation by way of an ‘Anthro Table’ allows a differential inspection of wasting, stunting and underweight in terms of the strength of their association with poverty.
The various anthropometric values are again indicated in the margins (cf Tables 6 and 7). Starting from the referent category N, mean WHZ can be seen to follow a decreasing gradient from right to left, mean HAZ from top to bottom and mean WAZ from the upper right to the lower left- hand corner of the table. In the body of Table 9 the ORs of Q1 compared to Q5 are given. There are three trajectories for inspecting the OR tendencies while moving from the referent group N to the anthropometrically worse WSU group[44]: (i) through the upper part, i.e. passing through W and UW (the ‘wasting wing’); (ii) through the lower part, i.e. passing through S and SU (the ‘stunting wing’); and (iii) passing through the centre U (where both WHZ and HAZ are on the low side but are not yet below -2.0). Inspecting the results of Table 10 in this way shows that the ‘wasting’ and ‘stunting wings’ have similarly increasing OR gradients: from 1.0 for the referent group through 2.5-2.7 for the single failure categories to 5.7-5.8 for the double failure categories. This is surprising because higher odds ratios on the

[42] Odds are a ratio of probabilities: the odds in favour of an event are the quantity p/(1−p), where p is the probability of the event. In this analysis, partial odds are used: the prevalence p in any of the CIAF categories is divided by the prevalence in the non-CIAF category (i.e. N).
[43] The dependent variable in this analysis (anthropometric failure category) is a nominal variable with more than two categories. Logistic regression allows the contribution of a risk factor or of a set of risk factors in terms of the natural logarithms of the odds ratio to be estimated. Applying the natural exponential function to the regression estimates gives the odds ratio.
[44] The OR’s are again seen as a ‘sample’ of 7 outcomes from a plane in 3-dimensional space – see note 30.

**Table 10**. 'Antro Table' of the relative odds of belonging to a household in the poorest quintile of the population by anthropometric status category (Kenya, DHS 2003)

| | Anthropo-metric category | mean HAZ | mean WHZ | mean WAZ | Underweight -3.6 | Underweight -2.6 | Underweight -2.2 | Non underweight >-2 | Non underweight -1.2 | Non underweight -0.3 |
|---|---|---|---|---|---|---|---|---|---|---|
| non stunted | W | 1.4 | -2.4 | | | | | | **2.74** | |
| non stunted | N | -0.5 | -0.0 | | | | | | | 1.00 |
| non stunted | UW | -0.7 | -2.8 | | | **5.74** | | | | |
| non stunted | U | -1.6 | -1.6 | | | | 6.49 | | | |
| stunted | [SW][45] | <-2 | <-2 | | | | | **---** | | |
| stunted | S | -2.6 | 0.5 | | | | | | 2.53 | |
| stunted | SUW | -3.1 | -2.5 | | **3.60** | | | | | |
| stunted | SU | -3.2 | -0.8 | | | 5.77 | | | | |

Source of data: Subset of the Kenya Demographic and Health Survey 2003 (Measure DHS+ 2004), cases weighted: 1202 under-fives belonging to the lowest population quintile of the household wealth index (Q1 = the 'poorest') compared to 841 children in the highest quintile (Q5 = the 'richest').
Legend: The anthropometric categories are defined by combinations of HAZ, WAZ and WHZ above or below Z=-2 (for the meaning of the abbreviations, see Table 3). Entries are arranged according to the category's mean HAZ by WAZ values as indicated in the margins. For numbers of children in the survey and prevalence percentages see Table 6. The (partial) odds of belonging to the poorest quintile in each anthropometric group is expressed as a ratio of the odds in group N, which is taken as the referent group (odds ratio $OR_{N/N}$=1.00). The ORs of children who are wasted (only or in any combination) are printed bold. Light shading is used for underweight or stunting, while dark shading is used for the combination of underweight and stunting.

stunting side (lower part) might have been expected, in line with the accepted theory that stunting is more strongly associated with poverty than wasting. A second result (mentioned above) is that the U category (the combination of moderate thinness and moderate shortness) is more strongly affected by poverty (6.5) than the double failure categories UW and SU (5.7), even if U has slightly more favourable WAZ values (-2.3 compared to -2.5). The third curious result is that the OR of the anthropometrically most unfavourable SUW category is nowhere near the highest of all.

The multiplicity of failures (single, double or triple) is not necessarily a good guide and this investigation has tried to disentangle the effects of stunting, wasting and underweight. However, the SUW category is of no help in the differential analysis of these effects because it is a combination of all three anthropometric failures. The overall picture is that poverty tends to drive children out of the 'no anthropometric failure' category in the direction of underweight in general. Being underweight is then not only due to stunting (SU) but for some children it is rather due to wasting (UW) and, for other children, to moderate underweight (U). Thus the conclusion of the differential inspection of Table 10 is that the data do not support the view that stunting was a better indicator than underweight in Kenya in 2003. Finally it is appropriate to mention that the situation in the referent group was not ideal. Even

[45] See footnote 20. The theoretical combination SW is void.

in the relatively wealthiest quintile, a sizeable proportion of under-fives (24%) suffered from anthropo-metric failure of various kinds.

## 4 Conclusion

Anthropometry is the method of choice for monitoring the attainment of the hunger-related target of MDG1. In working out trend data it is imperative to make the data sets to be compared as comparable as possible, in any case in terms of age groups. Seasonality may also influence the results. There is evidence of some oscillation in trends; some of it may be biological in origin.

The indicator for MDG1 (underweight) is a combination of wasting and/or stunting (although some children are underweight without being wasted or stunted). It is important to look into the 'black box' of weight for age. The three anthropometric indices are closely intertwined. Yet a combined analysis is possible and useful. A graphical representation ('Anthro Graph') of H/A by W/A is proposed; W/H can be seen in the same graph. Prevalences can be presented in the form of an 'Anthro Prevalence Graph'. The decomposition of anthropometric failure can use the same principles; a schematic table ('Antro Table') is proposed that conserves essential information about the anthropometric values, and that allows the analysis of relationships with other variables, in particular a differential diagnosis of the corrolaries of being wasted versus being stunted. This 'Antro Table' was put to a test using health and wealth data from DHS Kenya. The results showed that the odds of a dependent variable did increase with increasing undernutrition, but not in a perfectly gradual way along the spectrum of underweight, and not in a perfect balance between the wasting and stunting sides of undernutrition. It is proposed that (re-)analysis of existing and forthcoming data-sets with these new tools is useful for the purpose of monitoring the attainment of MDG1, as it gives more insight in what actually happens with the growth of young children.

When monitoring MDG-1, the indicator of underweight prevalence needs to be classified according to three anthropometric indicators simultaneously to shed light on the issue of wasting versus stunting when analyzing long-term trends. The Anthro Table is a useful tool and adds value to a one-dimensional analysis. The analyses in this paper confirm the reliability of underweight as a sound overall value of growth performance in children. The measurement of height in addition to weight remains a useful recommendation but should not replace the prevalence of underweight by that of stunting in monitoring the attainment of the hunger-related target of MDG-1. It allows a better understanding of the reasons for a particular underweight prevalence or trend, and this, in turn, is important in evaluating and designing policies and programmes. Svedberg's (2000) classification, which was amended by Nandy et al. (2005), is a useful basis for a deeper analysis, which is further facilitated with the specially constructed Anthro Table presented in this paper.

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## Annex 1. Influence on prevalence percentages of the type of cut-off values used (percentage of the median versus median minus 2sd)

The lower limit of what is considered to be normal growth differs somewhat between the three prevalence percentages (of underweight, wasting and stunting, respectively). The cut-off values that Waterlow proposed are 80% of the median reference value in the case of W/A and W/H, and 90% in the case of H/A. The 'newer'[46] (recommended) system of expression uses the cut-off value of the median minus 2 standard deviations. In terms of percentages of the median (the old system of expression) these cut-off values are a few percentage points higher than 90% in the case of height-for-age and a few percentage points lower than 80% in the case of weight-for-age. In the case of weight-for-length or weight-for-height the results are mixed, namely a few percentage points lower than 80% for shorter children and a few percentage points higher than 80% for taller children.

Any difference between the two types of cut-off values implies that the two systems produce different estimates of a prevalence percentage for a group of children. And they do!

Using 90% of the median as a cut-off value for length-for-age or height-for-age produces a very sizeable underestimation of the prevalence of stunting: it tends to 'miss' more than half of the stunted children (according to HAZ<-2).

The differences in the prevalence of underweight are much more modest, although not insignificant: using 80% of the median as a cut-off value may lead to an overestimate of up to 5 percentage points.

The differences in the prevalence of wasting are sizeable. On the whole, they are somewhat less dramatic than for stunting, and for smaller body sizes, the 80% criterion leads to an overestimate of the prevalence of wasting and for larger body sizes to an underestimate. It has been argued, that in view of the fact that younger children are more vulnerable, the 80% criterion, which is easier to use in some practical settings, is on the safe side for them. It is clear that in any trend analysis prevalence data obtained with different cut-off values should not be compared directly and need to be corrected first, or recalculated from the original data.

In both the percentage of the median and the z-score systems, lower cut-off values may be used to characterize more severe degrees of undernutrition, e.g. W/A of 60%, or z-score of -3 or -4.

[46] Since the 1970s that is. See Waterlow (1973).

Annex 2a: Selected results of DHS Kenya 2003 by anthropometric category: the odds of diarrhoea (children 0-59 months old).

| | Weighted number of children with all three z-scores | mean HAZ | mean WHZ | mean WAZ | Weighted & rounded number of children with information on diarrhoea | Number with diarrhoea (age-adjusted) [recalculated from odds] | Odds of diarrhoea (age-adjusted) [recalculated from ORs] | 1/odds = number of children without diarrhoea to 1 child with it | 1/odds of referent group = number of children without anthropometric failure without diarrhoea to 1 with it | Odds ratio (age-adjusted) |
|---|---|---|---|---|---|---|---|---|---|---|
| N = no failure | **3048** | **-0.51** | **0.04** | **-0.32** | **3045** | 448.0 | 0.173 | 5.8 | 5.8 | **1.00** |
| W = wasting only | **69** | **1.36** | **-2.44** | **-1.16** | **68** | 16.1 | 0.311 | 3.2 | 5.8 | **1.80** |
| S = stunting only | **783** | **-2.61** | **0.46** | **-1.26** | **778** | 149.7 | 0.238 | 4.2 | 5.8 | **1.38** |
| U = underweight only | **142** | **-1.57** | **-1.56** | **-2.21** | **141** | 24.8 | 0.213 | 4.7 | 5.8 | **1.24** |
| SU = stunting and underweight | **634** | **-3.24** | **-0.85** | **-2.58** | **634** | 161.1 | 0.341 | 2.9 | 5.8 | **1.97** |
| UW = wasting and underweight | **121** | **-0.69** | **-2.77** | **-2.63** | **121** | 28.6 | 0.309 | 3.2 | 5.8 | **1.79** |
| SUW = wasting & stunting & underweight | **88** | **-3.08** | **-2.53** | **-3.64** | **87** | 37.5 | 0.756 | 1.3 | 5.8 | **4.38** |
| Total investigated | **4885** | **-1.26** | **-0.20** | **-0.95** | **4874** | 865.8 | 0.216 | 4.6 | 5.8 | 1.25 |
| | | | | | | | | | | |
| Waterlow's 'wasted + stunted' = SUW | 88 | -3.1 | -2.5 | -3.6 | 87.0 | 37.5 | 0.756 | 1.3 | 5.8 | 4.38 |
| Waterlow's 'wasted only': W+UW | 190 | 0.05 | -2.65 | -2.10 | 189 | 44.7 | 0.310 | 3.2 | 5.8 | 1.80 |
| Waterlow's 'stunted only': S+SU | 1417 | -2.90 | -0.13 | -1.85 | 1412 | 310.8 | 0.282 | 3.5 | 5.8 | 1.64 |
| Waterlow's 'normal': N+U | 3190 | -0.56 | -0.03 | -0.40 | 3186 | 472.8 | 0.174 | 5.7 | 5.8 | 1.01 |

Legend: WAZ = Weight-for-age Z-score; WHZ = Weight-for-height Z-score; HAZ = Height-for-age Z-score.
N=normal; S=stunted (HAZ<-2.0); U=underweight (WAZ<-2.0); W=wasted (WHZ<2.0); SU, UW, SUW are combinations of S, U and/or W.
Figures printed in bold are from the SPSS outputs. Other figures have been calculated from the SPSS results in Excel, weighted by the numbers.

Annex 2b: Selected results of DHS Kenya 2003 by anthropometric category: wealth index (children 0-59 months old).

| | Weighted number of children with all three z-scores | mean HAZ | mean WHZ | mean WAZ | Weighted & rounded number of children with information on wealth index | Mean wealth index factor z-score | Median wealth index factor z-score | Mean wealth index: deviation from group N | Median wealth index deviation from group N |
|---|---|---|---|---|---|---|---|---|---|
| N = no failure | 3049 | -0.51 | 0.04 | -0.32 | 3049 | -0.25 | -0.62 | 0.00 | 0.00 |
| W = wasting only | 69 | 1.36 | -2.44 | -1.16 | 69 | -0.41 | -0.78 | -0.17 | -0.16 |
| S = stunting only | 783 | -2.61 | 0.46 | -1.26 | 783 | -0.46 | -0.73 | -0.21 | -0.11 |
| U = underweight only | 121 | -0.69 | -2.77 | -2.63 | 121 | -0.53 | -0.80 | -0.29 | -0.18 |
| SU = stunting and underweight | 142 | -1.57 | -1.56 | -2.21 | 142 | -0.56 | -0.76 | -0.31 | -0.14 |
| UW = wasting and underweight | 634 | -3.24 | -0.85 | -2.58 | 634 | -0.60 | -0.78 | -0.35 | -0.16 |
| SUW = wasting & stunting & underweight | 88 | -3.08 | -2.53 | -3.64 | 88 | -0.64 | -0.85 | -0.40 | -0.23 |
| Total investigated | 4885 | -1.26 | -0.20 | -0.95 | 4885 | -0.35 | | -0.11 | |
| | | | | | | | | | |
| Waterlow's 'wasted + stunted' = SUW | 88 | -3.1 | -2.5 | -3.6 | 88 | -0.64 | | -0.40 | |
| Waterlow's 'wasted only': W+UW | 190 | 0.05 | -2.65 | -2.10 | 190 | -0.49 | | -0.24 | |
| Waterlow's 'stunted only': S+SU | 1417 | -2.90 | -0.13 | -1.85 | 1417 | -0.52 | | -0.27 | |
| Waterlow's 'normal': N+U | 3190 | -0.56 | -0.03 | -0.40 | 3190 | -0.26 | | -0.01 | |

Legend: WAZ = Weight-for-age Z-score; WHZ = Weight-for-height Z-score; HAZ = Height-for-age Z-score.
N=normal; S=stunted (HAZ<-2.0); U=underweight (WAZ<-2.0); W=wasted (WHZ<2.0); SU, UW, SUW are combinations of S, U and/or W.
Figures printed in bold are from the SPSS outputs. Other figures have been calculated from the SPSS results in Excel, weighted by the numbers.