Assessing the Quality of Anthropometric Data

Background and Illustrated Guidelines for Survey Managers

Kees Kostermans
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(List continues on the inside back cover)
Assessing the Quality of Anthropometric Data

Background and Illustrated Guidelines for Survey Managers
The Living Standards Measurement Study (LSMS) was established by the World Bank in 1980 to explore ways of improving the type and quality of household data collected by statistical offices in developing countries. Its goal is to foster increased use of household data as a basis for policy decisionmaking. Specifically, the LSMS is working to develop new methods to monitor progress in raising levels of living, to identify the consequences for households of past and proposed government policies, and to improve communications between survey statisticians, analysts, and policymakers.

The LSMS Working Paper series was started to disseminate intermediate products from the LSMS. Publications in the series include critical surveys covering different aspects of the LSMS data collection program and reports on improved methodologies for using Living Standards Survey (LSS) data. More recent publications recommend specific survey, questionnaire, and data processing designs and demonstrate the breadth of policy analysis that can be carried out using LSS data.
Assessing the Quality of Anthropometric Data

Background and Illustrated Guidelines for Survey Managers

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Abstract

As systematic and random errors in anthropometry can have a great impact on the prevalence estimates of malnutrition, strict quality control of the fieldwork of anthropometry in household surveys is very important.

This paper defines and provides background information on sensitivity, specificity and positive predictive value of indicators in general. The most frequently used anthropometric nutritional indicators -- weight-for-age, height-for-age, weight-for-height and body mass index - are discussed in detail.

With many examples, using a data set from the Pakistan Integrated Household Survey 1991, the impact of errors in weight-, height-, or age measurement on the prevalence estimates of malnutrition among children under five years old are shown. Relatively small systematic errors in weight or age measurement can cause significant changes in the calculated rates of malnutrition. The presence of random errors are shown to increase the prevalence estimates in a less dramatic way.

The classic quality control methods are summarized and new methods, made possible with the use of personal computers during the fieldwork of household surveys, are offered. These methods allow for an assessment of the quality of the gathered anthropometric data in general or for an assessment of the performance of a particular surveyor or survey team. With a personal computer one can readily detect end-digit preference, clumping in age or a high proportion of unlikely Z-scores in the results of a particular surveyor or survey team and one can take measures to correct the situation while the survey is still going on.

Computer based quality control tools alone can not guarantee data of good quality. One needs also a well motivated survey team. But the quality control of anthropometry in an LSMS household survey deserves special attention because anthropometric measurements are among the very few observational data in a survey full of interview data and because the rate of malnutrition in a developing country may be considered as a comprehensive indicator for its standards of living.
Acknowledgements

I would like to thank Laura Caulfield of the Johns Hopkins School of Hygiene and Public Health, who taught me the principles of nutritional epidemiology; Kalpana Mehra, World Bank, who relentlessly prepared data sets for me during this study; Peter Lanjouw, World Bank, for his cooperation.
Foreword

The prevalence of malnutrition may be considered as a comprehensive indicator for the standards of living in a developing country. For this reason anthropometry forms an essential part of a Living Standards Measurements Study Household Survey.

Anthropometry, the measurement of a persons weight and height, may not seem to be a difficult task. However, mistakes are easily made especially when the survey sample is large like in an LSMS survey. This paper shows how relatively small errors especially in the determination of weight or age of children have a significant impact on the prevalence estimates of malnutrition.

The importance of this mainly methodological paper is that it offers tools for survey managers to assess the quality of the gathered anthropometric data while the survey is still in the field. The personal computer can be used during data entry for range checks and consistency checks, but as well for some further preliminary analysis as this paper proposes. The methods offered in this paper complement the classic quality control methods for anthropometry and should be incorporated in the LSMS survey design.

The author worked as a consultant in the Poverty and Human Resources Division of the Policy Research Department (PRDPH) and helped analyzing the anthropometric data of the Pakistan Integrated Household Survey, 1991. At the moment he works in the Population and Human Resources Division of the Southern Africa Department.

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I. Introduction

Living Standard Measurement Study (LSMS) household surveys are designed to permit extensive analysis of welfare in a particular country or region. For this purpose they typically collect a whole host of socio-economic variables at the community, the household and the individual level, often including weight and height variables for at least a subset of the surveyed population. This paper will highlight some of the implications on the prevalence estimates of malnutrition stemming from common errors made when such anthropometric outcomes for children are measured in household surveys such as the LSMS survey. Issues concerning the practical aspects of measuring weight and height are described elsewhere (United Nations, 1986), and this paper does not replace nor repeat, but only partly summarizes this necessary information for survey managers. This paper shows some methods of quality assessment of the anthropometric data, which, drawing on simple user friendly software packages, can be applied while the survey is still being conducted, and which can supplement existing quality control measures as proposed in the UN guide.

The reasons for including anthropometry in an LSMS are multiple. Malnutrition is often closely linked to poverty, especially in developing countries. Anthropometry allows one to estimate the prevalence of malnutrition. One can then proceed to assess correlations between the anthropometric variables and indicators of food intake, food prices, socio-economic status and access to services at the household and community level. This analysis may help to assess which type of interventions may most effectively alleviate malnutrition and poverty in a surveyed population. In a survey full of interview data like the LSMS household survey, anthropometric data are among the very few observational data with a potential laboratory precision and high validity. As such the anthropometric data, if of good quality, can help to validate the results of the interview data.

Sample data from the Pakistan Integrated Household Survey 1991 (PIHS), and particularly the anthropometric data of children under 5 years, will be used in the paper to illustrate the implications of errors in anthropometry. The data are used to make the examples with simulated errors as realistic as possible. One must, however, remember that the size of the impact of errors will depend on the actual rates and severity of malnutrition in a country, and these will differ with different settings.

The fieldwork of the PIHS was carried out between January and December 1991. In the survey weight and height of all children under the age of 5 years and of their mothers were measured. A more ample description of the nutritional status of the people of Pakistan can be found, for example, in the report of the Pakistan Demographic and Health Survey 1990/1991 (National Institute of Population Studies, 1992). The distinct differences in rates of malnutrition

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1 Only children under 5 years old and their mothers were weighed and measured in the Pakistan Integrated Household Survey 1991.
among children between the PIHS and the latest Pakistan Demographic and Household Survey 1990/1991 provided the motive for undertaking this study.

In Section 2 conceptual issues concerning anthropometric indicators of malnutrition, such as their sensitivity, specificity and positive predictive value in context of a determined situation will be discussed. The most commonly used indicators for children and for adults are briefly described. In the short Section 3 the necessary equipment for anthropometry and the calculation of the values of the indicators is discussed. Section 4 turns to common errors in anthropometry and illustrates the impact of those errors on prevalence estimates of malnutrition in the data set of the PIHS. The section starts with a more theoretical discussion on the influence of systematic and random errors. Section 5 describes classic quality control methods and proposes several new complementary computer-based methods for use in the field. Section 6 concludes the paper.

The aim of this paper is to give LSMS and other survey managers some theoretical background knowledge about anthropometry and to provide them with some practical guidelines for the assessment of the quality of the gathered data on basis of which action can be undertaken while the survey is still being conducted.

I will use the term malnutrition as it is commonly used, i.e. as a synonym for under-nutrition, and not as a term to indicate both under- and over-nutrition.
II. Anthropometric Nutritional Indicators

Introduction, Advantages and Limitations of Anthropometry

The nutritional status of an individual can be assessed in many different ways. One can, for example, conduct a biochemical analysis of blood or body tissues to determine a person's serum-cholesterol or hemoglobin. A clinical examination can detect a.o. vitamin A deficiency, protein deficiency, etc. One can also compare a person's food intake with the amount of energy expended. Anthropometry, the measurement of the human body, represents yet another method. Anthropometric indicators of a person's nutritional status include weight, height, mid upper arm circumference (MUAC), and skinfold thickness.

In household surveys the most commonly used approach is the measurement of a person's weight and height. Reasons for choosing this method are inter alia:

a) The comprehensiveness of the indicators;
b) The relative ease of the method while retaining a high degree of validity and precision.

Measurement of the subscapular skinfold requires for example more extensive training and it is difficult to obtain reliable results in inexperienced hands. The same is true for MUAC (Gibson, 1990);
c) The method is safe and non-invasive;
d) The necessary equipment is inexpensive, portable and can often be purchased locally;
e) Computations with the two indicators of weight and height allow for the possibility of detecting both chronic and acute malnutrition;
f) Weight and height are sufficiently responsive to interventions in the nutritional status of a population (WHO, 1976; Habicht, 1980, 1982). In a more statistical presentation: Responsiveness = Response / Standard Deviation of the response; and
g) The dependability of weight and height as indicators of nutritional status has been far more extensively studied than that of many other indicators.

Anthropometry has also its limitations. First, the measurement of a child's weight and height does not tell us much about its body composition. Second, the dependability of anthropometric indicators may have been studied carefully, but for height the dependability is low. Disturbances in nutritional status over a short period of time can not be detected by changes in height. And finally, anthropometric nutritional indicators do not guide us directly towards the reasons for malnutrition in a population.

---

2 Validity, also called accuracy, measures how close the measured value is to the real value, and precision is the degree to which repeated measures yield the same value.

3 An indicator of nutritional status is dependable when a change in the indicator can be depended on to reflect a change in nutritional status. The more non-nutritional factors affect the indicator, the less dependable the indicator is.
Anthropometry of Children

*Height-for-age, weight-for-age, weight-for-height*

Given a child's weight, height, sex and age, its nutritional status can be expressed in three different ways: gender specific height-for-age (H/A), weight-for-height (W/H) and weight-for-age W/A). Instead of height-for-age, the term stature-for-age is used in order to indicate clearly that the child is measured in a standing position. The term length-for-age is used for children under two years old who should be measured while laying down horizontally.

Figure II-1: A typical pattern of prevalence rates of wasted and stunted children in a developing country

Note: The figure was created on basis of a review of Demographic Health Survey data of many different countries.
The relation between growth and nutrition is firmly established. In fact, growth status during childhood is accepted almost universally as the best indicator, in field studies, of nutritional status at the individuals and community levels (Gomez et al., 1956; Lancet, 1970; Jelliffe, 1966; Tanner, 1976; Nowak and Munro, 1977; Waterlow et al., 1977; Jelliffe and Jelliffe, 1979).

The three different indicators H/A, W/H and W/A each evaluate a different aspect of a child’s nutritional status. Height-for-age reflects a child’s past or chronic nutritional status, as it is influenced by long-term food shortages, and chronic or frequently returning diseases. Children who are too short for their age are called stunted. Stunting is a slowing of skeletal growth and stature, defined by Waterlow as "the end-result of a reduced rate of linear growth". Periods of malnutrition in a child’s life cause periods of stunting, which are often not followed by a complete catch-up growth. By consequence, the result of periods of stunting accumulates. Because of its chronic character and cumulative effect, the prevalence of stunted children normally increases with age. The major increase in the prevalence of stunting occurs, however, in the first two years of life. After that period the curve flattens. Weight-for-height reflects more a child’s current nutritional status, because weight can fluctuate due to acute diseases, while height can not. For example, a child with diarrhea can easily loose a kilogram of weight, but will not become shorter. Children whose weight is too low for their height are too thin and are called wasted. The highest prevalence of wasting generally occurs during the post-weaning period (WHO, 1986), when periods of infectious diseases are most frequent. Figure 11-1 presents a typical pattern of the prevalence of wasted and stunted children of different age groups in a developing country.

A child’s weight should be more or less the same for a given height irrespective of its age. Its relative independence of age enhances the usefulness of the weight-for-height index in areas where the ages of the children are uncertain (Gibson, 1990). One can use it, for example, as a quick screening tool in refugee camps. The third indicator W/A combines information of the former two indicators as weight is influenced by thinness and by height. As a composite indicator it has its own value, combining acute and chronic influences. By consequence being wasted is a better indicator for the determination of short term survival, while the sensitivity and specificity for survival in a one to two year period is highest for weight-for-age (Gomez et al., 1956, Habicht et al, also Vella et al, 1992).

The reference population and the meaning of Z-scores

Given a child’s gender and age one can compare its weight and height with the weight and height of a reference population. The National Center for Health Statistics (NCHS) Growth Data were chosen as such a reference by the World Health Organization (1983). The reference data are derived from several sources. The values for weight, length, and weight for length from birth to thirty-six months are taken from longitudinal data collected by the FELS Research Institute, Ohio, between 1960 and 1975. This group of children consisted of white, mainly middle-class and bottle-fed, infants and children. The data from two to eighteen years of age
were compiled from three sources: the Health Examination Survey, Cycle 1 and 2 (HES 1 and HES 2) and the first National Health and Nutrition Examination Survey (NHANES 1) from the USA. The data include measurements on all socio-economic, ethnic and geographic groups in the USA. The NCHS data were selected as a reference because they met most of the criteria suggested by the International Union of Nutritional Sciences for ideal reference data (IUNS, 1972), i.e. the sample was cross sectional, data collection procedures were well-standardized and fully documented, raw data are available to any investigator, and the population examined appears to have attained its full growth potential. The sample was large and had at least 200 well-nourished children in each age and sex subgroup. A combined working group of the NCHS and Centers for Disease Control and Prevention (CDC) constructed a set of smoothed percentile distributions for attained weight and height (Dibley et al, 1987).

The use of one NCHS/WHO standard as the international standard is appealing and it is justified for various reasons (Graitcer, 1981). The first reason is the principle one. Genetic differences in growth potential among children under 7 are small: more than 90 percent of the variation in growth are due to environmental factors (Lancet, 1984; Agarwal, 1991). Other reasons are more practical. It would be very costly if every country in the world had to develop its own standard growth charts, with large enough subgroups of children in every age category to arrive at valid standards. Often, one standard per country wouldn't even be enough to account for racial and tribal differences within the country. The use of one standard makes data from different countries easily comparable. In surveillance studies, reference data allow for trends over time, and the effectiveness of interventions, to be evaluated (Gibson, 1990). However, the discussion about the use of one international standard is not closed, as there is evidence that genetic factors play some role in the growth of a child. Although size at birth seems to have very little correlation with hereditary factors, monozygotic twins show a steadily increasing concordance of size relative to dizygotic twins until the age of 8 years (Wilson, 1976, 1979). The question of how far genetic factors are a determinant for a child's size is complicated by the fact that heritability is far from a fixed notion, but is sample specific, and varies significantly with the nature of the environment (for an overview, see Johnston, 1986).

The nutritional status of a child is normally expressed in the Z-score of the concerned indicator. Weight and height of children of a certain age group follow more or less a normal distribution. The height-for-age Z-score (HAZ) compares the height of a child of a certain age with the median height of the reference population of that age group; the weight-for-age Z-score (WAZ) does the same for weight; and the weight-for-height Z-score (WHZ) compares the weight of a child of a certain height with the reference median weight for a child with the same height. The value of the Z-score can be conceived as the number of standard deviations that the child is away from the median of the concerned indicator of the children of that age/sex group from the standard population. In mathematical terms:

\[
Z\text{-score} = \frac{\text{Individuals anthropometric value} - \text{Median of reference population}}{\text{S.D. of reference population}}
\]
A Z-score for height-for-age of -1.5 (HAZ=-1.5) means that a child's height is 1.5 standard deviations below the median height of that age and sex group in the reference population. The Z-score indicates the size of the probability that a child will have a score that low or lower if it is part of the reference population. By comparing the proportion of children with such a low score in a surveyed population with the probability in the reference population, one can assess the nutritional status of the surveyed population. The NCHS developed tables of weight-for-age, height-for-age and weight-for-height, which are now used as the international standard for the calculation of the prevalence of malnutrition. The tables and the argumentation for their use were published by the World Health Organization in 1983 (WHO, 1983; also: Waterlow et al, 1977; Dibley, 1987). In those tables, the distributions of weight and height, as they were found in the cross sectional data sets, were normalized, i.e. fitted into a normal distribution. This means that the standard deviation above and below the mean are not always equal in size. A Z-score of -2 is normally used as the cut-off point to discriminate between well-fed and malnourished children. A Z-score of -3 is used as the cut-off for the definition of severe malnutrition. The prevalence rates of malnutrition among children under 5 years in the PIHS sample are presented in Table II-1 as an illustration.

---

4 The introduction of the Z-scores has made the use of percent of the median weight or height obsolete as an indicator. The advantage of the Z-score is the fact that it takes the variance in the population into account. A child which has a height that is 90 percent of the median can be below the 5th percentile or can be well within the normal range, depending on its age.

5 For example: for the weight of a boy of 36 months the standard deviation below the median is 1.6 kg and 1.8 kg above the median. The actual distribution of the weight of boys of 36 months is skewed. This distribution is normalized by applying two different standard deviations above and below the median. The situation is similar for girls. The difference between the two standard deviations increases with increasing age. For boys the difference increases from 0.1 kg at age 0 month to 0.3 kg at 5 years; for girls the difference increases from -0.1 to 0.9 kg. By applying different standard deviation below and above the median the skewed distribution of weights is fitted into the pattern of a normal distribution. The distribution of height has the same standard deviation above and below the median for most age groups.
Table II-1: Prevalence of malnutrition among children under 5 by age category

<table>
<thead>
<tr>
<th>Age in Months</th>
<th>Height for Age</th>
<th>Weight for Height</th>
<th>Weight for Age</th>
<th>Number of Children</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Below - 3 SD</td>
<td>% Below - 2 SD</td>
<td>% Below - 3 SD</td>
<td>% Below - 2 SD</td>
</tr>
<tr>
<td>&lt;6 M</td>
<td>7.7</td>
<td>15.9</td>
<td>5.3</td>
<td>15.9</td>
</tr>
<tr>
<td>6-11</td>
<td>15.7</td>
<td>33.6</td>
<td>7.3</td>
<td>21.1</td>
</tr>
<tr>
<td>12-23</td>
<td>25.5</td>
<td>50.1</td>
<td>11.0</td>
<td>31.5</td>
</tr>
<tr>
<td>24-35</td>
<td>25.6</td>
<td>49.5</td>
<td>8.0</td>
<td>24.1</td>
</tr>
<tr>
<td>36-47</td>
<td>25.3</td>
<td>47.8</td>
<td>7.0</td>
<td>24.4</td>
</tr>
<tr>
<td>48-59</td>
<td>20.4</td>
<td>48.2</td>
<td>5.7</td>
<td>21.2</td>
</tr>
<tr>
<td>Total</td>
<td>21.8</td>
<td>44.3</td>
<td>7.5</td>
<td>23.8</td>
</tr>
</tbody>
</table>

1. Z-scores $<-6$ or $> +6$ for height and weight for age are excluded.
2. Children with a Z-score $<-3$ are included in this group as well.

Above the age of 7 years the tables of weight-for-age, height-for-age and weight-for-height of the NCHS reference populations lose their importance as an international standard because from then on genetic factors start playing a greater role in the determination of a child's height and weight. WHO has presented extensive percentile tables for males and females from 2 until 18 years old at one month intervals also based on data from the USA. The tables contain the 3rd, 5th, 10th, 20th, 30th, 40th, 50th, 60th, 70th, 80th, 90th, 95th and 97th percentiles for height-for-age, weight-for-height and weight-for-age, as well as the Z-scores of +1, -1, +2, -2 and +3, -3 for the three indicators. WHO does, however, advise not to use the tables for the comparison of the nutritional status of groups of children older than ten years of age, because of the marked differences in the age of onset of puberty among populations (WHO, 1983). The cross-sectional character of the data makes them also unfit for the monitoring of individual growth, which is by definition a longitudinal phenomenon.
Anthropometry of Adults

In the anthropometry of adults age does not play as prominent a role as it does in the anthropometry of children. An adult’s age only slightly influences his weight or height. Another major difference between adult and child anthropometry is that an adult’s height, and thus his weight, are largely determined by the genotype. The standard manner in which the nutritional status of adults is assessed is by using the Quetelet Index or Body Mass Index (BMI), in which the relation between the weight and height of a person is assessed. The BMI is computed by dividing weight by height squared. Weight is expressed in kilograms and height in meters.

\[
\text{BMI} = \frac{\text{Weight}_\text{kg}}{\text{Height}_\text{m}^2}
\]

The advantage of the BMI is that it is an indicator of relative weight, more or less independent of height. No internationally accepted standard cut-off points have been set for the BMI to discriminate between well-fed and malnourished adults. However, a BMI below 16 can be considered as severe malnutrition. Women often lose their reproductive capacity below this BMI-value. A BMI above 18.5 can be considered as normal. A BMI-value of 27 is sometimes used as a cut-off point above which people are called obese (James 1988)\(^6\). The Royal College of Physicians in London has proposed as BMI cut-off points for males and females, which are presented in Table II-2.

<table>
<thead>
<tr>
<th>BMI Value for Males</th>
<th>Description of Category</th>
<th>BMI Value for Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI ≤ 18.4</td>
<td>Health risk</td>
<td>BMI ≤ 17.5</td>
</tr>
<tr>
<td>18.4 &lt; BMI ≤ 19.9</td>
<td>Under weight</td>
<td>17.5 &lt; BMI ≤ 18.6</td>
</tr>
<tr>
<td>19.9 &lt; BMI ≤ 25.0</td>
<td>Acceptable</td>
<td>18.6 &lt; BMI ≤ 23.8</td>
</tr>
<tr>
<td>25.0 &lt; BMI ≤ 29.9</td>
<td>Over weight</td>
<td>23.8 &lt; BMI ≤ 28.5</td>
</tr>
<tr>
<td>BMI &gt; 29.9</td>
<td>Obese</td>
<td>BMI &gt; 28.5</td>
</tr>
</tbody>
</table>

Source: Royal College of Physicians (1983)

\(^6\)James et al. identify in the article three cut-off points for BMI: 18.5, 17.0 and 16.0. A BMI above 18.5 is classified as normal and a BMI below 16.0 as severe chronic energy deficiency.
Many other reference data, especially from the United Kingdom and the USA, are available. A comprehensive overview of reference data sets is presented by Gibson (1990).

The prevalence rates of malnutrition among the mothers of children under five in the PIHS sample are presented in Table II-3.

| Table II-3: Nutritional status of women with children less than 5 years old by urban/ rural areas |
|-----------------|-----------------|-------|-------|
| BMI             | Description     | Urban | Rural |
| BMI ≤ 17.5      | Health Risk     | 10.2% | 16.4% |
| 17.5 < BMI ≤ 18.6 | Under weight   | 8.7%  | 13.7% |
| 18.6 < BMI ≤ 23.8 | Acceptable     | 41.9% | 53.6% |
| 23.8 < BMI ≤ 28.5 | Overweight     | 24.9% | 11.7% |
| BMI > 28.5      | Obese           | 14.3% | 4.5%  |
Sensitivity, Specificity and Positive Predictive Value

Each of the above mentioned nutritional indicators detect a different aspect of a persons' nutritional status and all have their own sensitivity and specificity. The sensitivity of a nutritional indicator is its capacity to detect accurately those persons who are truly malnourished. Its specificity is the capacity of the indicator to detect correctly those who are not malnourished. The sensitivity and specificity of each indicator will depend on the degree of malnutrition which one wants to detect in the population or the place of the cut-off point. They depend as well on the underlying reasons for malnutrition in a certain population. Sensitivity and specificity are inversely related.

<table>
<thead>
<tr>
<th>Diagnosis of Malnutrition</th>
<th>Truly Malnourished</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>TP</td>
<td>FP</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>FN</td>
<td>TN</td>
</tr>
</tbody>
</table>

TP = True positive diagnosis  
FP = false positive  
FN = false negative  
TN = true negative

Sensitivity = TP/ (TP+FN);  
Specificity = TN/ (FP+TN);  
Positive Predictive Value = TP / (TP+FP);  
Real prevalence of malnutrition = (TP + FN)/ All;  
Measured Prevalence = (TP + FP)/ All.

The best diagnostic test or indicator would be the one with the highest proportion of correct diagnoses, i.e. the least false-positive and false-negative results (Habicht,1982). This positive predictive value (PPV) depends on the actual prevalence of malnutrition in a population, and it increases if the characteristic of concern becomes more prevalent in the population. Tables II-5 and 6 give an example of this phenomenon: if we keep the sensitivity and specificity of an indicator constant (80 percent and 90 percent respectively) the positive predictive value decreases from 84 percent to 67 percent when the prevalence rate of malnutrition decreases from 40 percent to 20 percent.

---

7 The concepts of sensitivity and specificity are similar to type I, or $\alpha$, error and type II, or $\beta$, error. A small type I error means a high specificity and a small type II error means a high sensitivity.
Table II-5: The positive predictive value of an nutritional indicator (prevalence rate of malnutrition is 40 percent)

<table>
<thead>
<tr>
<th>Diagnosis of Malnutrition</th>
<th>Truly Malnourished</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>32</td>
<td>6</td>
</tr>
<tr>
<td>No</td>
<td>8</td>
<td>54</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>60</td>
</tr>
</tbody>
</table>

Note: The positive predictive value of the indicator is: $32/38 = 84$ percent (sensitivity = 80 percent and specificity = 90 percent).

Table II-6: The positive predictive value of an nutritional indicator (prevalence rate of malnutrition is 20 percent)

<table>
<thead>
<tr>
<th>Diagnosis of Malnutrition</th>
<th>Truly Malnourished</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>No</td>
<td>4</td>
<td>72</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>80</td>
</tr>
</tbody>
</table>

Note: The positive predictive value of the indicator is: $16/24 = 67$ percent (sensitivity = 80 percent and specificity = 90 percent).

Measurement errors will influence the sensitivity and specificity and by consequence the positive predictive value of the indicator. If, for example, the sensitivity and specificity of a nutritional indicator decrease to 65 percent and 80 percent respectively because of errors, while the true rate of malnutrition stays 20 percent, the positive predictive value will decrease to only 45 percent (see Table II-7). This means that less than half of the children indicated as malnourished are truly so. The PPV appears to be very sensitive to changes in sensitivity and specificity of the indicator.
Table II-7: The positive predictive value of a nutritional indicator (prevalence rate of malnutrition is 20 percent, sensitivity and specificity decreased)

<table>
<thead>
<tr>
<th>Diagnosis of Malnutrition</th>
<th>Truly Malnourished</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>13</td>
<td>16</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>7</td>
<td>64</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>80</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Note: The positive predictive value of the indicator is:

\[ \frac{13}{29} = 45 \text{ percent} \] (sensitivity = 65 percent and specificity = 80 percent).

Table II-8: The positive predictive value of a nutritional indicator (prevalence rate of malnutrition is 40 percent, sensitivity and specificity decreased)

<table>
<thead>
<tr>
<th>Diagnosis of Malnutrition</th>
<th>Truly Malnourished</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>26</td>
<td>12</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>14</td>
<td>48</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>60</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Note: The positive predictive value of the indicator is:

\[ \frac{26}{38} = 68 \text{ percent} \] (sensitivity = 65 percent and specificity = 80 percent).
By comparing Table II-7 and 8 we see that the impact of a change in the sensitivity and specificity of an indicator on the PPV becomes bigger when the true prevalence rate of malnutrition decreases. Keeping the true prevalence rate of malnutrition at 40 percent the decrease in sensitivity from 80 to 65 percent and in specificity from 90 to 80 percent leads to a decrease in the PPV by 16 percent points (84-68). At a true prevalence rate of 20 percent it leads to a decrease in the PPV by 22 percent points (67-45). The same issues are illustrated in a summarizing way in Figure II-2 which shows how the PPV declines when the true prevalence rate of malnutrition decreases for two levels of sensitivity and specificity of the nutritional indicator. The distance between the two curves changes with a changing prevalence rate.

The choice of the indicator depends on the underlying reality of concern (functional outcome) (Habicht, 1982). If one measures mortality as a functional outcome of malnutrition the sensitivity and specificity of the indicators will depend, among others, on the time interval between the measurement of malnutrition and the measurement of mortality. Some indicators predict better short term survival, while other predict better long term survival. A nutritional indicator might be quite sensitive if mortality, but not if school performance is considered as a functional outcome. If different outcomes are under consideration this may also request the determination of different cut-off points of a certain nutritional indicator in order to maintain its discriminatory function.

Figure II-2: The dependency of the PPV of a nutritional indicator on the prevalence rate of malnutrition

Note:

PPV1:  
Sensitivity = 80%  
Specificity = 90%

PPV2:  
Sensitivity = 65%  
Specificity = 80%
III. Equipment

Measuring Board and Weighing Scale

Weight and height can be measured with great accuracy and validity without using very sophisticated measuring equipment. Special boards have been developed to measure length or height. These or similar boards can often easily be produced at low cost in a developing country where a survey is performed. Drawings are available from the C.D.C., Division of Nutrition, in Atlanta or from UNICEF. It is important that the board is made as light and as easy to carry as possible. However, one must make sure that it has a stable support to put the feet on, or against when laying, and a stable movable device which indicates the exact height or length of the person. One should make sure that both the support and the movable device always make an angle of 90 degrees with the board. Children below 2 years (or below 80 cm if age is unknown) have to be measured in a laying position and older or bigger children are measured in a standing position. That is why one speaks about a child’s length or stature respectively.

For the weighing of small children a hanging spring scale is often used. This scale, which is easily transportable, measures children when they are hanging from the scale in a bag or by just clinging to the hook. Older children and adults can be measured with a standing model weighing scale. The mechanical parts of weighing scales often deteriorate from transport over bumpy roads. The Demographic and Health Surveys (DHS) today use mostly weighing scales with digital readings. It may also be generally advisable to use such scales for reasons mentioned in Chapter V of this paper.

Standardized techniques for measuring length or stature and weight should always be used to ensure accurate and precise measurements, and to make the results comparable with the results of other surveys.

Personal Computer

Personal computers have become more and more a part of the field equipment in household surveys. They allow for quick data processing and cleaning while the survey is still going on (Ainsworth, 1986). Data cleaning normally consists of range- and consistency checks. Personal computers, however, also allow for an assessment in the field of the quality of the data and the performance of the surveyors. The introduction of computers in the field work of a survey is not just a technological addition but has large implications for the design and implementation of the survey (Ainsworth, 1986).

* The United Nation Guide "How to Weigh and Measure Children", written by Irwin Shorr, provides excellent drawings for the construction of a measuring board.
Calculation of Z-scores is easily done with software for personal computers. The Centers for Disease Control and Prevention (CDC) and the World Health Organization have been active in developing software for computing anthropometric Z-scores, especially the height-for-age, weight-for-age and weight-for-height indices based on the CDC/WHO reference population. The primary software packages are Epi Info, Anthro, CASP, ISSA and IQ (Sullivan, 1990). Anthro is available as a separate package or as part of the broader epidemiologic package Epi Info. The software is able to use dBase files. Both Anthro- and Epi Info packages are available at low cost from the CDC or WHO, and one is encouraged to give copies of the software to friends and colleagues. An IBM-mainframe version of the Fortran code is also available from the CDC.

* for further information, contact:
Division of Nutrition, CDC, 1600 Clifton Road, MS A08, ATLANTA, GA 30333, USA.
or: Nutrition Unit, WHO, 1211 GENEVA 27, SWITZERLAND.
## IV. Measurement Errors and their Effects

### Sources of Error

Possible sources of error in anthropometry are multiple. Summarized in the following table, adapted from Zerfas (1979) and Gibson (1990), are some common errors and their possible solutions.

<table>
<thead>
<tr>
<th>Measurement and Common Error</th>
<th>Proposed Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All Measurements</strong></td>
<td></td>
</tr>
<tr>
<td>Inadequate instrument</td>
<td>Select method appropriate to resources.</td>
</tr>
<tr>
<td>Restless child</td>
<td>Postpone measurement until child is quiet; involve a person who is familiar with the child.</td>
</tr>
<tr>
<td>Reading</td>
<td>Training, refresher training, quality control.</td>
</tr>
<tr>
<td>Recording</td>
<td>Record results immediately after measurement is taken; have results checked.</td>
</tr>
<tr>
<td><strong>Length</strong></td>
<td></td>
</tr>
<tr>
<td>Incorrect method for age</td>
<td>Use only when child less than 2 years old.</td>
</tr>
<tr>
<td>Footwear or headwear not removed</td>
<td>Remove as local culture permits (or make allowances).</td>
</tr>
<tr>
<td>Head not in correct plane</td>
<td>Correct the position of the head.</td>
</tr>
<tr>
<td>Child not straight along the board and/or feet not parallel with movable board</td>
<td>Have assistant and a family member of the child present; do not measure as long as the child is struggling.</td>
</tr>
<tr>
<td>Board not firmly against heels</td>
<td>Practice correct pressure.</td>
</tr>
<tr>
<td>Length read in inches instead of centimeters</td>
<td>Use a board with only centimeters indications.</td>
</tr>
</tbody>
</table>

(continued on next page)
(Table IV-1 continued)

<table>
<thead>
<tr>
<th>Height</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorrect method for age</td>
<td>Scale not well calibrated to zero</td>
</tr>
<tr>
<td>Footwear or headwear not removed</td>
<td>Room too cold, no privacy</td>
</tr>
<tr>
<td>Head not in correct plane, subject not straight, knees bent, or feet not flat on floor</td>
<td>Subject wearing heavy clothing</td>
</tr>
<tr>
<td>Board not firmly against head</td>
<td>Subject moving or anxious</td>
</tr>
<tr>
<td>Height read in inches instead of centimeters</td>
<td>Scale read in pounds instead of kilograms</td>
</tr>
</tbody>
</table>

| Use only when child more than 2 years old.                           | Re-calibrate after every subject.                                       |
| Remove as local culture permits (or make allowances).               | Use appropriate facilities.                                             |
| Correct technique with practice and regular retraining; provide adequate assistance; calm non-cooperative children. | Remove as much as possible all clothing, or make allowances, if necessary. |
| Move head board to compress hair.                                    | Wait until subject is calm; use digital scale.                         |
| Use board with only centimeters indications.                         | Use scale with only kg indications.                                     |

It may seem that most of the solutions proposed are given by using common sense and can be easily fulfilled. Problems however may easily arise, as for example in cultures where children wear clothes with heavy jewelry, which can not be taken off and its weight may be difficult to guess. The custom to subtract for the clothes of every child the same amount does not take the variations in clothing into account. Repeating each measurement is a good way to increase accuracy, but time constraints make two measurements, at enough distance apart to be independent, often difficult. Although age itself is not in Zerfas’ table, an accurate age measurement is very important as it affects both height- and weight-for-age. If no reliable date of birth can be obtained from any certificate, a calendar on which local events are superimposed over a local calendar may be very useful. An example of such a calendar is given in Annex 1.
The Influence of Systematic and Random Errors in General

Measurement errors can be divided into two groups: systematic errors and random errors. A systematic error, or bias, will change the mean of the normal distribution of height or weight. Random errors will not influence the mean or median, but will increase the variance. Both types of error influence the estimates of the prevalence of malnutrition. The prevalence of malnutrition will be under- or over estimated depending on the direction of the bias of the systematic error. In the case of a random error, the prevalence will always be overestimated because the tails of the distribution become fatter due to the increased variance (Bairagi, 1986). Figure IV-1 illustrate this phenomenon. The random error is very important because malnutrition is a phenomenon of one tail of the distribution: the lower one. A regression analysis misses this point because it utilizes the means of the distribution of the variables. The mean is not affected by random error. The random error in the dependent nutritional variable will affect the proportion of unexplained variation, i.e. lower the $R^2$, and decrease the power to detect statistically significant associations with explanatory variables. The random error is further important because it seldom comes alone.

Figure IV-1: The impact of a random error on the prevalence of malnutrition

---

10 In the very exceptional case that the mean of the Z-scores of a population is below the cut-off point the prevalence estimate of malnutrition will decrease because of the increased variance caused by the random error.
The following paragraphs will look at the effect of systematic errors in the measurement of weight, height and age on the prevalence estimate of malnutrition.

The Effect of a Systematic Error in Weight Measurement

A child's weight is commonly overestimated when it is measured without taking off the child's clothes. This might seem easily to prevent, but one has to consider that in most cases the measurements are taken in public places during the survey. Other sources of systematic error are (as presented in the beginning of the chapter): the scale is not well adjusted to 0; the child's weight is consistently rounded upward or consistently downward; or the scale is read in pounds instead of kilograms

A positive bias in the measurement of children's weight will lead to an underestimation of the prevalence of malnutrition. The impact on the prevalence estimate will depend firstly on the size of the bias. The bigger the bias, the bigger the influence. Secondly the impact will depend on the value which is chosen as cut-off point for the definition of malnutrition. The further away this cut-off point is from the median, the lower the influence on the prevalence of malnutrition will be in absolute numbers. Or in other words: the impact of the bias will be smaller in percent points if the real prevalence of malnutrition becomes lower in the population. And thirdly, the influence will be larger at a lower age, because younger children weigh less, and the bias forms by consequence a bigger proportion of the child's weight, assuming that the bias has a constant value. The maximum influence of the bias occurs when the average of the medians of the reference population and the measured population is chosen as cut-off points. These issues are illustrated in Figures IV-2 and 3.

---

11 Even if the weight is randomly read from the scale in pounds or in kilograms, one can still consider it as a systematic error because of the systematic difference between pounds and kilograms. The same can be said for height, when it is read randomly in inches or centimeters.
Figure IV-2: The impact of a negative systematic error on the prevalence estimate of malnutrition

Figure IV-3: Maximum effect of the bias
To illustrate the influence of a systematic error we added 0.5 kg to the weight of every child of the PIHS sample. The results are presented in Table IV-2, and one can compare the figures of this table with the original figures of Table II-1 which is, for convenience, also printed on the last page of this paper. The estimates of malnutrition measured by H/A of course do not change by this intervention. The malnutrition rate measured by W/A decreases by the intervention with 10.4 percent points, from 45.8 percent to 35.6 percent, if a Z-score of -2 is used as cut-off point. If WAZ=-3 is used as cut-off, the prevalence of malnutrition decreases only 6.2 percent points (=18.8-12.6 percent). If we look at weight-for-height, the differences caused by the intervention are respectively 10.4 and 3.0 percent points for the two cut-off points. There is a slight trend in this data set, which shows that the influence of adding 0.5 kg to the weight of every child is less with increasing age.

Table IV-2: Prevalence of malnutrition if added 0.5 kg to the weight of every child

<table>
<thead>
<tr>
<th>Age in Months</th>
<th>Height for Age</th>
<th>Weight for Height</th>
<th>Weight for Age</th>
<th>Number of Children</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Below - 3 SD</td>
<td>% Below - 2 SD²</td>
<td>% Below - 3 SD</td>
<td>% Below - 2 SD²</td>
</tr>
<tr>
<td>&lt;6 M</td>
<td>7.7</td>
<td>16.0</td>
<td>2.4&lt;</td>
<td>6.9&lt;</td>
</tr>
<tr>
<td>6-11</td>
<td>15.7</td>
<td>33.6</td>
<td>4.7&lt;</td>
<td>9.9&lt;</td>
</tr>
<tr>
<td>12-23</td>
<td>25.7</td>
<td>50.3</td>
<td>6.7&lt;</td>
<td>18.1&lt;</td>
</tr>
<tr>
<td>24-35</td>
<td>25.6</td>
<td>49.5</td>
<td>5.6&lt;</td>
<td>14.3&lt;</td>
</tr>
<tr>
<td>36-47</td>
<td>25.3</td>
<td>47.8</td>
<td>4.7&lt;</td>
<td>13.5&lt;</td>
</tr>
<tr>
<td>48-59</td>
<td>20.4</td>
<td>48.3</td>
<td>2.5&lt;</td>
<td>13.2&lt;</td>
</tr>
<tr>
<td>Total</td>
<td>21.9</td>
<td>44.3</td>
<td>4.5&lt;</td>
<td>13.4&lt;</td>
</tr>
</tbody>
</table>

1. Z-scores for height for age and weight for age outside of the -6 < Z < +6 range were discarded.
2. Z-scores < -3 are included in this group.
3. A "<" or ">" behind the prevalence estimate indicates if the given estimate is significantly different from the estimate shown in the original Table II-1. The direction of the sign indicates if the estimate in this table is bigger or smaller than the original estimate. The number of signs, i.e. * < * or * < < *, indicates the level of significance: p = .05 or p = .01 resp.
Effect of a Systematic Error in Height Measurement

The most frequently made systematic error when measuring height is probably an underestimation of height, caused by the fact that the child is not properly stretched. Another source of error is the fact that children do not always take off their shoes during the measurement (see the beginning of this chapter for an overview). If surveyors note down the height in inches instead of in centimeters, or randomly in one way or the other, the prevalence estimates of malnutrition will be drastically influenced.

The influence of a systematic error in the height measurement is usually not very large, because the size of the error is small compared to the actual size of the height and to the size of the standard deviation. For example, for girls at birth the size of the median length is 49.9 cm and the size of the SD is 2.2 cm. By consequence an error of 0.5 cm will not influence the prevalence estimate of malnutrition very much. At 12 months, the size of the median length for girls is 74.3 and the size of the lower standard deviation is 2.8 cm. The SD increases with age which makes the influence of an error, which is usually not bigger than 1 cm, even smaller. A systematic overestimation of height or length will lead to an underestimation of the prevalence of stunted (H/A) children and an overestimation of wasted (W/H) children.

The Effect of a Systematic Error in Age Measurement

In contrast with errors in the weight- and height measurement, errors in the age estimation can be made by the interviewee or by the survey team member. Errors in this third component of the anthropometric evaluation (age) are common (see for example in Section V under "Clumping of age"). Especially in developing countries, where the exact birth date of many children is unknown, the influence of the error can be great. In such a case the age of allegedly stunted children might be overestimated, while the age of the children who are large for their age is underestimated. Logically, the prevalence of malnutrition is overestimated when the age of children is overestimated. Assuming that the size of the bias is constant the impact of the bias is biggest for the youngest age groups, because growth velocity is highest for them. If the birth date is not known for many children it is often very useful in the estimation of ages to make a calendar of the last five years with all the important local events on it. All those events can be put in a roster of months and years. In Pakistan people might, for example, remember that their son was born during Ramadan just after General Zia Ul-Hak had died in a plane crash. This information would then provide an almost exact estimation of the age of a child. In order to arrive at an age estimation which is as correct as possible, one should ask the interviewee in different ways and at different moments of the survey about the age of each child. Annex I gives an example of a calendar with local events superimposed over a normal calendar.

To show the influence of error in the age measurement 2 months were added to the age of each child in the PIHS data set. The new prevalence estimates of malnutrition are presented
in Table IV-3. (Again: compare these figures with the original data of Table II-5 on the last page.) Malnutrition as measured by weight-for-age increases overall by 10.3 percent points (from 45.8 to 56.1 percent) if the Z-score of -2 is used as a cut-off point. If weight-for-age Z-score = -3 is used as a cut-off, the difference is 6.2 percent points. For height-for-age the results are similar. Note that the absolute difference is bigger for the younger age-groups. And that weight-for-height does not change if 2 months are added to the age of each child. The small differences in the prevalence estimates measured by weight for height are caused by the fact that a certain percentage of the children moved to the next age category by the intervention. The intervention caused differences which were highly statistically significant for all age groups.

| Table IV-3: Prevalence of malnutrition among children under 5 if 2 months were added to the age of every child |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Age in Months   | Height for Age  | Weight for Height | Weight for Age  | Number of Kids |
|                 | % Below - 3 SD  | % Below - 2 SD  | % Below - 3 SD  | % Below - 2 SD  |                  |
| < 6 M           | 25.1 >         | 51.9 >         | 4.3             | 14.9 >         | 41.3 >         | 235              |
| 6-11            | 30.2 >         | 55.8 >         | 6.8             | 26.5 >         | 58.7 >         | 453              |
| 12-23           | 38.2 >         | 63.0 >         | 10.1            | 34.1 >         | 62.5 >         | 733              |
| 24-35           | 30.1 >         | 57.6 >         | 8.3             | 28.4 >         | 61.7 >         | 845              |
| 36-47           | 31.7 >         | 55.9 >         | 6.9             | 22.8 >         | 56.0 >         | 939              |
| 48-59           | 25.4 >         | 56.1 >         | 5.8             | 19.0 >         | 48.0 >         | 867              |
| Total           | 30.6 >         | 57.2 >         | 7.3             | 25.0 >         | 56.1 >         | 4072             |

1. A "<" or ">" behind the prevalence estimate indicates if the given estimate is significantly different from the estimate shown in the original Table II-1. The direction of the sign indicates if the estimate in this table is bigger or smaller than the original estimate. The number of signs, i.e. " > " or "> > ", indicates the level of significance: p = .05 or p = .01 resp.
The influence of the age measurement on the prevalence of malnutrition is shown in another way by comparing the malnutrition rates in children with and without a birth certificate in Table IV-4. The lower prevalence of malnutrition among children with a birth certificate may mean that in general age is over-estimated in children without a birth certificate. The fact, however, that wasting, i.e. too low weight-for-height, is also more prevalent among children without a certificate contradicts this assumption. Children without a certificate belong to another socio-economic class among which malnutrition is more prevalent. The certificate is probably a confounder, as it is related to cause and effect. Poor children are more than twice as likely to have no birth certificate than children from households living above the poverty line (author, own calculation). The clear relation between poverty and malnutrition will be presented in another paper.

Table IV-4: Nutritional status of children with and without birth certificates by age category

<table>
<thead>
<tr>
<th>Age in Months</th>
<th>% HAZ &lt; -2&lt;sup&gt;1&lt;/sup&gt;</th>
<th>% WHZ &lt; -2&lt;sup&gt;1&lt;/sup&gt;</th>
<th>% WAZ &lt; -2&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Number of Children</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>with</td>
<td>without</td>
<td>with</td>
<td>without</td>
</tr>
<tr>
<td>&lt; 6 M</td>
<td>14.5</td>
<td>17.3</td>
<td>9.9</td>
<td>20.0</td>
</tr>
<tr>
<td>6-11</td>
<td>30.2</td>
<td>36.0</td>
<td>15.7</td>
<td>24.9</td>
</tr>
<tr>
<td>12-23</td>
<td>42.2</td>
<td>55.2</td>
<td>26.9</td>
<td>34.3</td>
</tr>
<tr>
<td>24-35</td>
<td>44.1</td>
<td>51.5</td>
<td>21.3</td>
<td>25.0</td>
</tr>
<tr>
<td>36-47</td>
<td>42.4</td>
<td>50.1</td>
<td>17.8</td>
<td>26.4</td>
</tr>
<tr>
<td>48-59</td>
<td>41.8</td>
<td>49.9</td>
<td>15.3</td>
<td>22.8</td>
</tr>
<tr>
<td>Total</td>
<td>37.2</td>
<td>47.4</td>
<td>18.8</td>
<td>25.8</td>
</tr>
</tbody>
</table>

1. HAZ, WHZ, WAZ = Height for Age, Weight for Height and Weight for Age Z-score.
The Influence of the Random Error

So far we have looked in the examples for the influence of systematic errors in anthropometry. But besides these errors there will always be a random error. The most frequent cause for random errors is lack of accuracy among the survey team. The error expresses itself in reading mistakes, wrongly rounding, etc.

By definition the size of random errors in the present data set is not measurable. In order to assess the influence of a random error on the prevalence estimates of malnutrition in the PIHS data set a realistic random value was added or subtracted to the age, weight, and height of every child of the sample in the following way. By the SAS program three random numbers were generated with a normal distribution, a mean of 0, and a standard deviation of 1. The new age, weight and height for every child was calculated as follows:

Random-age = Age + (Age/12 x R1-number/2)

Random-weight = Weight + (Age/12 x R2-number/5)

Random-height = Height + R3-number

where R1, R2 and R3 are the values of the three series of random numbers created by SAS for each particular observation. By introducing the value "Age/12" we accounted for the fact that the size of the random error in age and weight estimation is probably greater at older ages. For height this is not the case, as correct stretching of the child is especially difficult for younger age groups. The random number was divided by 2 for age and by 5 for weight to give the error a reasonable size. In this way, at an age of 59 months, 96 percent of the errors will be in the range -2.5 to +2.5 months for age, -1 to +1 kg for weight and -1 to +1 cm for height. The reduction of the sample size is caused by the intervention, as children with a random-age below 0 or above 59 months were excluded from the analysis. In reality, the random error would never cause a negative age, but would cause the inclusion of some children in the sample, whose real age was older than 59 months. This last phenomenon did not happen either by our intervention, as we used the original sample.
Table IV-5: Prevalence of malnutrition among children under 5 by age category if a random value is added to the weight, height and age of every child\(^{1,2}\)

<table>
<thead>
<tr>
<th>Age in Months</th>
<th>Height for Age</th>
<th>Weight for Height</th>
<th>Weight for Age</th>
<th>Number of Children</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Below - 3 SD</td>
<td>% Below - 2 SD(^2)</td>
<td>% Below - 3 SD</td>
<td>% Below - 2 SD(^2)</td>
</tr>
<tr>
<td>&lt;6 M</td>
<td>8.5</td>
<td>16.4</td>
<td>6.1</td>
<td>16.4</td>
</tr>
<tr>
<td>6-11</td>
<td>18.6</td>
<td>36.0</td>
<td>10.0&gt;</td>
<td>23.7</td>
</tr>
<tr>
<td>12-23</td>
<td>27.0</td>
<td>49.3</td>
<td>12.6</td>
<td>30.2</td>
</tr>
<tr>
<td>24-35</td>
<td>25.6</td>
<td>51.0</td>
<td>9.4</td>
<td>27.5&gt;</td>
</tr>
<tr>
<td>36-47</td>
<td>23.1</td>
<td>44.1&lt;</td>
<td>9.7&gt; &gt;</td>
<td>24.4</td>
</tr>
<tr>
<td>48-59</td>
<td>22.2</td>
<td>50.4</td>
<td>6.6</td>
<td>22.4</td>
</tr>
<tr>
<td>Total</td>
<td>22.2</td>
<td>43.8</td>
<td>9.3&gt; &gt;</td>
<td>24.9</td>
</tr>
</tbody>
</table>

1. Z-scores <-6 or >+6 for height and weight for age are excluded.
2. Children with a Z-score <-3 are included in this group as well.
3. A *" or "+* behind the prevalence estimate indicates if the given estimate is significantly different from the estimate shown in the original Table II-1. The direction of the sign indicates if the estimate in this table is bigger or smaller than the original estimate. The number of signs, i.e. *" or "+*>, indicates the level of significance: p=.05 or p=.01 resp.

The influence of our random error is not as spectacular as in former interventions with systematic errors. As expected the prevalence of malnutrition as measured by the indicators increases in general, although there is a decrease for certain subgroups, comparing these results with the originals of Table II-6 (see Annex II on last page of this paper).
V. Quality Control

The United Nations Guide (1986) provides some guidelines for quality control, standardization of the equipment and anthropometric data collection. One cannot emphasize enough the importance of these types of quality control throughout the survey. I will present some additional quality control methods, which have become available with the development of personal computers. The methods can be performed by a survey team supervisor or quality control officer during the survey on a set of data (rounding, end-digit preference and clumping of age) or on individual data (unlikely Z-scores). They allow for assessment of the quality of the data in general, but also for monitoring the performance of surveyors or survey teams.

Classic Quality Control Methods

The United Nations' Guide (1986) on "How to Weigh and Measure Children" has a separate chapter on quality control of the reading of measurements and recording of measurements, the reading and the recording system, and the checking of the measurement technique. The chapter offers a fine tuning of technical issues on how to read the measuring tape and the weighing scale correctly. It explains how to write the measuring results clearly and correctly in the questionnaire forms. If the person who notes the measurements down on the form is different from the person who reads them, the recorder should repeat out loud the figure (s)he heard the measurer saying, and wait for confirmation before filling out the form, says the Guide. After that, the measurer should visually confirm what the recorder has written down. The chapter concludes with a summary of the correct techniques of measuring length, height, weight, arm circumference, and advises to check if the numbers are filled out in the right boxes of the questionnaire. All these techniques of quality control have to be carried out by the survey team member her/himself, and not by a supervisor who gives a "second opinion" on the quality of the work of the survey team members. As the techniques for quality control, or repeated measurements performed by the survey team member her/himself, are not at all independent or neutral, a further check of the quality of the data is required.

Only in Annex H does the Guide deal with the precision and accuracy of the measurements. The Guide provides an elaborate system of checking these issues for each enumerator, and gives rough but practical guidelines for what level of imprecision and inaccuracy is acceptable. The techniques are based on standardization exercises presented by Martorell (1975). The suggested techniques of quality checks (the Guide calls it "procedures for standardizing the collection of anthropometric data in the field") are very helpful during the training of enumerators, but the open character of the quality control during the field work has its disadvantages. If an enumerator knows that her/his measurements will be checked by the supervisor (s)he is probably more likely to measure more precisely and accurately than normally. A high quality of data collected by the enumerator on the day that the data are checked, does not at all guarantee a high quality of data collection on other days. Another disadvantage of the quality control by a supervisor is that the control necessarily includes only a sub-sample of the measured children. However, these disadvantages do not make the quality control, as suggested in Annex H of the Guide, redundant. The described methods are very useful, but it seems
preferable not to announce in advance who, or when and where the measurements will be checked.

For the PIHS, the UN Guide provided the methods of quality control. The enumerators were trained in all measuring procedures as described in the Guide. During the field work, supervisors were supposed to remeasure regularly sub-samples of the children. However, as the supervisors in the PIHS were all male, it was culturally not appropriate for them to remeasure any women. As children were almost always accompanied by women, they couldn't be remeasured either. When the data were entered in the computer, no range-checks were made (such range-checks were beyond the scope of the Guide).

An elaboration on some further quality control methods for anthropometry, which check the quality of the gathered data and which could be performed during the field work of a survey using a personal computer, follows.

**Rounding or End-Digit Preference**

When measuring weight or height with one decimal, the size of this decimal should be in 10 percent of the cases ".1", in 10 percent of the cases ".2", etc. The surveyors might, however, have an end-digit preference, especially for ".0" or ".5". The presence of this preference can easily be studied by presenting the data as in Table V-1. In the PIHS' anthropometric data exists a huge end-digit preference: more than 70 percent of the children have a weight ending in .0 or .5. For height this end-digit preference is 45.5 percent. Because this end-digit preference will have a bigger influence on the prevalence estimate of malnutrition in the lower age groups, a break down was made of the end-digit preference by age group in Table V-2. The table shows that for weight the preference does increase with age but that this is not the case for height.

The influence of end-digit preference, if it is just a matter of rounding, is bigger where weight is concerned than where height is concerned, because of the relation between the size of the rounding to the absolute value of the measurement. For example, a normal value for weight and height of a girl of 6 months old is 7.2 kg and 65.9 cm, while the maximum value of rounding constitutes for the measurements 0.5 kg or 0.5 cm. This equals 6.9 percent of the actual weight, while only 0.7 percent of the actual height.

---

12 One must remember that anthropometry constituted for only a very small part of the PIHS, which was an economical survey.
Table V-1: End-digit preference (percent) in weight and height measurements

<table>
<thead>
<tr>
<th>End-digit</th>
<th>Weight</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>.0</td>
<td>59.7</td>
<td>29.0</td>
</tr>
<tr>
<td>.1</td>
<td>2.4</td>
<td>6.0</td>
</tr>
<tr>
<td>.2</td>
<td>4.3</td>
<td>11.0</td>
</tr>
<tr>
<td>.3</td>
<td>2.5</td>
<td>9.7</td>
</tr>
<tr>
<td>.4</td>
<td>2.5</td>
<td>7.8</td>
</tr>
<tr>
<td>.5</td>
<td>22.8</td>
<td>16.5</td>
</tr>
<tr>
<td>.6</td>
<td>1.9</td>
<td>6.3</td>
</tr>
<tr>
<td>.7</td>
<td>1.4</td>
<td>5.9</td>
</tr>
<tr>
<td>.8</td>
<td>1.1</td>
<td>4.2</td>
</tr>
<tr>
<td>.9</td>
<td>1.4</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Table V-2: End-digit preference in weight and height measurements of children under 5 by age category

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Weight End-digit = .0 or .5</th>
<th>Height End-digit = .0 or .5</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 6 Months</td>
<td>69.5</td>
<td>44.8</td>
</tr>
<tr>
<td>6-11 Months</td>
<td>76.1</td>
<td>49.8</td>
</tr>
<tr>
<td>12-23 Months</td>
<td>79.3</td>
<td>47.6</td>
</tr>
<tr>
<td>24-35 Months</td>
<td>85.2</td>
<td>49.2</td>
</tr>
<tr>
<td>36-47 Months</td>
<td>86.3</td>
<td>41.7</td>
</tr>
<tr>
<td>48-59 Months</td>
<td>86.9</td>
<td>42.4</td>
</tr>
<tr>
<td>Total</td>
<td>82.4</td>
<td>45.5</td>
</tr>
</tbody>
</table>

The influence of end-digit preference might be identical to the influence of rounding, which has the effect of a random error, as one child is rounded upwards and the other downwards. End-digit preference might, however, also be a sign of carelessness. Tables V-3A and V-3B show the difference in the prevalence of malnutrition by age group comparing the children with an end-digit "0" or "5" for their weight or height, with children who's weight
or height ended with another digit. Measured by height-for-age and weight-for-age (Table V-3A) the prevalence of malnutrition in most cases increases when the measurement ends in ".0" or ".5". This may be partly due to the increased variance caused by rounding. The fact that the significant differences occur mainly in the older age groups, while the influence of rounding should be greatest in the younger age groups, indicates, however, that carelessness is probably the major cause for end-digit preference. In the category of children with a weight-for-age Z-score of less than minus two (WAZ < -2) the prevalence of malnutrition is significantly less in the group with end-digit preference of ".0" or ".5", than in the group with an end-digit ".1", ".2", ".3" etc. The differences in prevalence of malnutrition between the two WAZ < -2 groups in Table V-3A cannot be explained by rounding. The same picture is shown in Table V-3B where there is significantly less wasting in the higher age groups which have an end-digit preference in the weight measurement. For those older age groups the weights have probably not only been rounded, but overestimated as well when they were "rounded" to ".0" or ".5". This suggests that the prevalence estimate for wasting in Pakistan would have been even higher if all children were measured with the same validity as the children whose weight measurement did not end in ".5" or ".0".

Probably the best way of preventing end-digit preference is the use of digital measurement devices. A weighing scale with a digital reading only indicates a weight if the child has been quiet on the scale for a certain time.

As a guideline to determine what end-digit prevalence for a certain end-digit is acceptable, one may possibly best use the 95 percent confidence interval of a single sample proportion of a binary variable, using the formula:

\[ d^2 = \frac{(Z^2)(p)(q)}{n} \]

where \( d \) = the size of half the 95 percent confidence interval, \( Z = 1.96 \) (corresponding to \( \alpha = .05 \)), \( p \) = the probability that a certain end-digit will occur (= 0.1), \( q = 1 - p \), and \( n \) = the sample size. The occurrence of a certain end-digit is random and is not affected by cluster or other design effects. If 200 children have been measured this leads to \( d^2 = \frac{(1.96^2)(0.1)(0.9)}{200} \) resulting in \( d = 0.042 \). This means that any value between 5.8 and 14.2 percent occurrence of a certain end-digit would be acceptable. If 100 children have been measured \( d = 0.059 \) (range of 4.1-15.9 percent for the occurrence of an end-digit is acceptable). If only 50 children have been measured any value between 1.7 and 18.3 percent would be acceptable for a certain end-digit. Logically the interval becomes more narrow if a bigger number of children have been measured.
<table>
<thead>
<tr>
<th>Age Group</th>
<th>% HAZ &lt;-3</th>
<th>% HAZ &lt;-2</th>
<th>% WAZ &lt;-3</th>
<th>% WAZ &lt;-2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>End-digit 0 or 5</td>
<td>Other End-digits</td>
<td>End-digit 0 or 5</td>
<td>Other End-digits</td>
</tr>
<tr>
<td>&lt;6 M</td>
<td>7.1</td>
<td>8.2</td>
<td>14.8</td>
<td>16.8</td>
</tr>
<tr>
<td></td>
<td>18.9</td>
<td>12.6</td>
<td>37.3</td>
<td>29.9</td>
</tr>
<tr>
<td>6-11</td>
<td>24.6</td>
<td>26.2</td>
<td>47.4</td>
<td>52.5</td>
</tr>
<tr>
<td></td>
<td>27.4</td>
<td>24.0</td>
<td>52.2</td>
<td>47.0</td>
</tr>
<tr>
<td>36-47</td>
<td>27.7</td>
<td>23.6</td>
<td>53.4*</td>
<td>43.8*</td>
</tr>
<tr>
<td>48-59</td>
<td>25.3*</td>
<td>16.8*</td>
<td>51.1</td>
<td>46.1</td>
</tr>
<tr>
<td>Total</td>
<td>23.8</td>
<td>20.2</td>
<td>46.4</td>
<td>42.5</td>
</tr>
</tbody>
</table>

1. Z-scores < -6 or > +6 for height and weight for age are excluded.
2. HAZ = Height for Age Z-score, WAZ = Weight for Age Z-score.
   *: Differences are statistically significant at p < .05.
Table V-3B: Influence of the end-digit preference on the prevalence estimates of wasting

<table>
<thead>
<tr>
<th>Age in Months</th>
<th>Height End-digit 0 or 5 (n=1883)</th>
<th>Weight End-digit 0 or 5 (n=3412)</th>
<th>Weight and Height End-digit 0 or 5 (n=1645)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% WHZ &lt;-3</td>
<td>% WHZ &lt;-2</td>
<td>% WHZ &lt;-3</td>
</tr>
<tr>
<td>&lt; 6 M</td>
<td>5.3</td>
<td>14.8</td>
<td>7.6</td>
</tr>
<tr>
<td>6-11 M</td>
<td>7.6</td>
<td>17.4</td>
<td>6.5</td>
</tr>
<tr>
<td>12-23 M</td>
<td>12.9</td>
<td>33.3</td>
<td>9.6 &lt;</td>
</tr>
<tr>
<td>24-35 M</td>
<td>7.7</td>
<td>24.8</td>
<td>7.2 &lt;</td>
</tr>
<tr>
<td>36-47 M</td>
<td>9.4 &gt;</td>
<td>26.7</td>
<td>6.1 &lt;</td>
</tr>
<tr>
<td>48-59 M</td>
<td>8.1 &gt;</td>
<td>21.7</td>
<td>4.8 &lt;</td>
</tr>
<tr>
<td>Total</td>
<td>8.8 &gt;</td>
<td>24.4</td>
<td>6.8 &lt;</td>
</tr>
</tbody>
</table>

Note: a "<" or ">") sign behind the prevalence estimate indicates if the given estimate is significantly different from the estimate produced by the other end-digits. The direction of the sign indicates if the estimate in this table is bigger or smaller than the estimate of the other end-digits. The number of signs, i.e. < or <<, indicates the level of significance: P=.05 or P=.01 resp.

Clumping in Age

Just as every end-digit should occur in more or less equal proportions, so should the number of months which represents the age of the child. It is frequently observed that ages are rounded to a whole or half number of years, which make 6, 12, 18, 24 etc. months more prevalent in the sample than is possible by chance alone. This phenomenon is called clumping and its cause and effect can be compared with rounding or end-digit preference.

A listing of the PIHS data set of children showed that the age notation had several flaws. The age of every child should have been written down in number of months only, but:

1) often age was missing,
2) very often age was written down in the wrong way, i.e.
   a) the age was written down in years, and on top of that calculated in months,
   b) the age was written down in years+months,
   c) age was only notated in years.

Part of these points are illustrated in Figure V-1, in which a bar histogram shows the frequency of the occurrence of every age in months for children under 5 years. The higher frequencies in
the first year are explained because of notation as explained above under 2-b. The original software program considered only the "age in months" variable to calculate the age, and by consequence, an age of 4 years, 3 months was read as an age of 3 months.

Figure V-1: Age distribution of the age of children in the PIHS data set

The distribution of ages shows enormous clumping around the whole years and some clumping around half years. The pattern of the distribution suggests also that for more children the age was rounded upwards than downwards. In fact, the interviewees have done something similar to what was suggested earlier when 2 months were added to the age of every child in the PIHS sample (see Table IV-3). Here the age was recalculated for many children by using the date of birth from the birth certificate (28 percent), as told by the parents (52 percent), or by correcting apparently wrong age notations as explained above under 2-a, -b and -c. Figure V-2 shows these results. There is still an over-representation of the youngest age group in the resulting data set. The clumping around the whole years is explained by all those children whose age was only given in years in the questionnaire. The prevalence rate of malnutrition was also calculated while excluding the age groups of 1, 12, 24, 36 and 48 months. The results differed
Figure V-2: Age distribution of children in the PIHS data set after recalculating the age of every child

only slightly from the original estimates as presented in Table II-1 and are therefore not presented here.

To indicate again the influence of rounding-up of the ages of children by the interviewees, we subtracted two months from the age of every child. The results are presented in Table V-4. Those results may better reflect the prevalence of children who are too short or too light for their age than the original Table II-1 (Annex II). Note again that the prevalence of wasting is not really affected by the last intervention.
Table V-4: Prevalence of malnutrition among children under 5 if 2 months are subtracted from the age of every child

<table>
<thead>
<tr>
<th>Age in Months</th>
<th>Height for Age</th>
<th>Weight for Height</th>
<th>Weight for Age</th>
<th>Number of Children</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Below - 3 SD</td>
<td>% Below - 2 SD¹</td>
<td>% Below - 3 SD</td>
<td>% Below - 2 SD¹</td>
</tr>
<tr>
<td>&lt;6 M</td>
<td>2.5 &lt; &lt;</td>
<td>5.7 &lt; &lt;</td>
<td>5.5</td>
<td>17.9</td>
</tr>
<tr>
<td>6-11</td>
<td>8.0 &lt;</td>
<td>19.6 &lt; &lt;</td>
<td>10.5</td>
<td>25.2</td>
</tr>
<tr>
<td>12-23</td>
<td>20.5 &lt; &lt;</td>
<td>42.1 &lt; &lt;</td>
<td>11.1</td>
<td>31.4</td>
</tr>
<tr>
<td>24-35</td>
<td>19.0 &lt; &lt;</td>
<td>40.3 &lt; &lt;</td>
<td>8.5</td>
<td>25.8</td>
</tr>
<tr>
<td>36-47</td>
<td>17.4 &lt; &lt;</td>
<td>38.2 &lt; &lt;</td>
<td>6.4</td>
<td>22.4</td>
</tr>
<tr>
<td>48-59</td>
<td>17.0 &lt; &lt;</td>
<td>39.2 &lt; &lt;</td>
<td>4.1</td>
<td>19.4</td>
</tr>
<tr>
<td>Total</td>
<td>15.2 &lt; &lt;</td>
<td>33.0 &lt; &lt;</td>
<td>7.7</td>
<td>23.9</td>
</tr>
</tbody>
</table>

1. A "<" or ">" behind the prevalence estimate indicates if the given estimate is significantly different from the estimate shown in the original Table II-1. The direction of the sign indicates if the estimate in this table is bigger or smaller than the original estimate. The number of signs, i.e." >" or " > >", indicates the level of significance: p<.05 or p<.01 resp.

As a guideline to determine what size of clumping is still acceptable one can repeat the same kind of calculations as performed under the previous paragraphs which dealt with end-digit preference. One can calculate the age for each child in whole years and number of months. Each number of months has then a probability of 1/12 (= 8.3 percent) to occur. If 200 children have been measured, any value between 4.5 percent and 12.2 percent for the occurrence of any number of a months would be acceptable. If 100 children have been measured, the interval is 2.9 - 13.7 percent. However, if one detects clumping in age, one must always look for factors which might explain a peak in the number of births in a certain period, as these peaks are not uncommon in many societies.
Prevalence of Unlikely Z-Scores

A third easily performed quality control technique is checking the proportion of unlikely Z-scores for every surveyor or survey team. As the Z-scores are derived from a normalized distribution of weight and height in a population, the probability of having a Z-score of +6 is more or less equal to the probability related to 6 standard deviations away from the mean. In a country with a lot of malnutrition, many children will have negative Z-scores, but Z-scores outside of the -6 < Z < +6 range are always very unlikely. With the personal computer, one can easily calculate the proportion of unlikely Z-scores per interviewer or team, and this may help one take adequate measures to improve the situation.

Table V-5 shows the occurrence of unlikely Z-scores by province in Pakistan during the PIHS. For all provinces, the proportion of unlikely Z-scores is unacceptably high in the PIHS data set. In the PIHS data set of children under five 4.4 percent of the children were eliminated with a HAZ < -6, and 1.9 percent with a HAZ > +6; 1.0 percent of the children had a WAZ < -6 and 1.7 percent a WAZ > +6. In total, 338 (8.2 percent) children were eliminated because of an unlikely Z-score.

One might consider restricting the range of possible Z-scores more narrowly than the -6 < Z < +6 range. In fact, a Z-score of more than 2 for height-for-age (HAZ > 2) is already almost too unlikely to exist in a developing country. As an example the range of likely Z-scores was narrowed to -4 < Z < +4 and the prevalence of malnutrition was computed again among the children. The results are presented in Table V-6. Logically the prevalence of malnutrition decreases if one compares the rates with the rates of Table II-1. In fact the prevalence of malnutrition decreases much more than what would have to be expected on the basis of a likelihood of having a Z-score outside the -4 < Z < +4 range but within the -6 < Z < +6 range, which was the allowed range for Table II-1 (see Annex II). In the great majority of the cases only a very small percentage of the population has a Z-score value between -4 and -6 or between +4 and +6.

In the first part of this Chapter it was suggested that one could introduce range-checks when entering the data in the computer. By doing that, one looses partially this last possibility of quality control. However, within the allowed range one can still calculate the number of children with a Z-score in one part of the tail of the distribution, and compare this number with the number that could have been expected on basis of a normal distribution. Assessing the presence of unlikely Z-scores outside of an allowed preset range is useful at more than one level. Firstly, in the data entry program these individuals can be flagged for reweighing. Secondly, over a body of observations they may inform about a surveyors' reliability.
Table V-5: Absolute and proportional provincial prevalence of unlikely Z-scores for height- and weight-for-age

<table>
<thead>
<tr>
<th>Province</th>
<th>Unlikely Height for Age Z-score&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Unlikely Weight for Age Z-score&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Total Number of Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punjab</td>
<td>78 (3.6%)</td>
<td>29 (1.3%)</td>
<td>2169</td>
</tr>
<tr>
<td>Sindh</td>
<td>133 (11.8%)</td>
<td>62 (5.5%)</td>
<td>1126</td>
</tr>
<tr>
<td>N.W.F.P.</td>
<td>37 (4.4%)</td>
<td>12 (1.4%)</td>
<td>841</td>
</tr>
<tr>
<td>Balochistan</td>
<td>37 (11.2%)</td>
<td>18 (5.4%)</td>
<td>330</td>
</tr>
<tr>
<td>Total</td>
<td>285 (6.4%)</td>
<td>121 (2.7%)</td>
<td>4466</td>
</tr>
</tbody>
</table>

1. A Z-score is considered unlikely if the score is outside the -6 < Z < +6 range.

Table V-6: Nutritional status of children under 5 by age category with HAZ or WAZ in -4 < Z > +4 range<sup>1</sup>

<table>
<thead>
<tr>
<th>Age in Months</th>
<th>Height for Age</th>
<th>Weight for Height</th>
<th>Weight for Age</th>
<th>Number of Children</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Below - 3 SD</td>
<td>% Below - 2 SD&lt;sup&gt;2&lt;/sup&gt;</td>
<td>% Below - 3 SD</td>
<td>% Below - 2 SD&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>&lt; 6 M</td>
<td>6.1</td>
<td>14.7</td>
<td>4.2</td>
<td>14.7</td>
</tr>
<tr>
<td>6-11</td>
<td>9.2</td>
<td>29.0</td>
<td>5.3</td>
<td>18.4</td>
</tr>
<tr>
<td>12-23</td>
<td>14.2</td>
<td>42.1</td>
<td>6.7</td>
<td>27.2</td>
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<td>24-35</td>
<td>13.0</td>
<td>40.4</td>
<td>3.6</td>
<td>19.8</td>
</tr>
<tr>
<td>36-47</td>
<td>15.5</td>
<td>40.8</td>
<td>3.3</td>
<td>21.9</td>
</tr>
<tr>
<td>48-59</td>
<td>13.5</td>
<td>43.6</td>
<td>4.7</td>
<td>20.1</td>
</tr>
<tr>
<td>Total</td>
<td>12.8</td>
<td>37.7</td>
<td>4.5</td>
<td>20.8</td>
</tr>
</tbody>
</table>

1. HAZ = height for age Z-score, WAZ = weight for age Z-score; only -4 < Z < +4 included.
2. Children with a Z-score < -3 included in this group.
While no correlation was found in the PIHS data at any level between end-digit preference and unlikely Z-scores for height-for-age or weight-for-age, there was a high correlation found between unlikely height- and unlikely weight Z-scores: Odds Ratio=24.5 (C.I. 16.4, 36.6)\(^{13}\). This correlation existed at the interviewer level (O.R. =8.25 C.I. 0.9, 86.6), the supervisor level (O.R. =52 C.I. 1.8, 8616.7) and the operator level (O.R. =36 C.I. 1.2, 6345.3). This can mean that a surveyor who measures the child’s height with a low validity also measures its weight with a low validity. It may also mean, however, that the calculation of age is the problem, because this would affect both the weight-for-age and height-for-age Z-score.

\(^{13}\) The Odds Ratio (O.R.) compares the likelihood of the presence of a characteristic if a second characteristic is present with the likelihood of the presence of the first characteristic if the second characteristic is absent. The two characteristics under consideration here are an unlikely Z-score for height-for-age and an unlikely Z-score for weight-for-age. Presented here is the O.R. with its 95 percent confidence interval.
VI. Conclusions and Recommendations

While quality control is of crucial importance in a survey, it seldom receives proper attention. In large surveys, like the LSMS Household Surveys, the installation of at least one national quality control officer for anthropometry is not a luxury but a requirement. One must make sure that such an officer is not restricted by cultural barriers to follow the survey teams and observe or repeat all their activities. As far as anthropometry is concerned, this officer can supervise the field work of the interviewers, as well as perform calculations like the ones presented in this paper. With the development of personal computers, it has become easier to conduct quality control when the survey is still in progress. The development of user friendly epidemiologic software, like Epi-Info or Anthro, which are available at negligible cost from WHO and the CDC, makes the use of personal computers in the field even more appealing. Analyses like those presented in this paper, performed on a portable computer in the field, allow for an early detection of mistakes at a time when one can still go back to the household to correct probable mistakes. With such analyses, one can check the performance of a specific survey team or surveyor. One can detect their end-digit preference in the measurements or clumping in the ages of the children. Also, the proportion of unlikely Z-scores can be easily calculated for each surveyor or survey team. The advantage of these computer methods of quality control over a method in which a survey supervisor duplicates the measurements of the surveyors, is that the computer can take all measurements into account and not just a sub-sample, as in the traditional methods of quality control. Another advantage is that one overcomes the issue that a survey team might perform better than average on a day that the supervisor or quality control officer duplicates the measurements.

It is desirable that every survey team has a personal computer at its disposal. However, if a computer does not belong to the possibilities in the field a simple one page chart, with the likely Z-score ranges of the nutritional indicators for every age or height, belongs to the standard tools of the survey team supervisor and quality control officer. With this pocket card the supervisor can directly check the measurements of weight and height, or the age determination.

Good quality of the data is not guaranteed by the above described quality control measures. The most important ingredient for the quality of the data is probably the motivation and spirit of the survey team. This means that the team must be convinced of the importance of the survey. The training of a survey team should include lectures on how the data will be used, with examples from former surveys. To keep the spirit high during the field work one must listen to the concerns of team members and address them.

Reliability and validity of anthropometry increases considerably with repeated measurements. For this reason, it might be a good idea to measure every person twice during a survey. Ainsworth (1986) recommends for LSMS surveys to remeasure only a sub-sample: those who have been flagged at data entry as outliers and in addition a randomly selected 20 percent of all individuals. This is feasible in LSMS surveys where households are normally visited twice by the interviewers. However, the size of an LSMS survey is already enormous, and one must keep in mind that an increase of the activities of a survey does not promote the quality of the data.
This paper dealt mainly with systematic errors. Random errors are important as well and they will always be there. Random errors derive their importance in anthropometry from several factors. The random error increases the variance, i.e. it makes the tails of the distribution 'fatter'. Malnutrition is a phenomenon of one tail, the lower one, and not from the center of the normal distribution. Furthermore a random error seldom comes alone. Although the single effect of a random error in weight measurement alone might be small, the effect of multiple random errors in weight, height and age can lead to a considerable increase in the prevalence estimate of malnutrition. In a multi-variate analysis, random errors will cause the weakening of possible correlations between malnutrition and other variables.

Measurement errors will decrease the sensitivity and specificity of the nutritional indicators and by consequence lead to a big decrease in the PPV of the indicator. Trends in increase or decrease of malnutrition may not be detected because of this loss in PPV. If sensitivity and specificity do not add up to more than 100 percent, the trends observed will be a reverse to the real trends. The PIHS,1991 Data Set has been used in this paper as an example. The analysis of the data made it clear that systematic errors in weight measurement and age calculation especially have severe implications for the prevalence estimate of malnutrition in an area. The size of the implications of errors in anthropology or age estimation will vary for every country depending on the actual prevalence of malnutrition. The PPV of a nutritional indicator decreases when the true prevalence of malnutrition decreases in a country. Errors, which decrease the sensitivity and specificity of an indicator, have a bigger or smaller influence on the PPV depending on the actual prevalence rate of malnutrition in the population.

Anthropometry is not difficult. But it is not as easy as it may at first appear, to keep the quality of the measurements high from the beginning to the end of the survey. Anthropometry is of great importance in an LSMS survey, as the prevalence of malnutrition is a comprehensive indicator of the standards of living in a developing country. The fact that the measurements of weight and height are among the very few hard observational data in a survey full of interview data makes them of special interest.
Bibliography


ANNEX 1: Table A-1: A calendar with local events and festivals to facilitate the determination of the date of birth and death

<table>
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<tr>
<th></th>
<th></th>
<th></th>
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<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>January</td>
<td>01</td>
<td>Rice /</td>
<td>6-Daume Khor</td>
<td>24-Deyune Khor</td>
<td>13-Deyune Khor</td>
<td>3-Deyune Khor</td>
<td>1-Daume Khor</td>
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<td>28-Daume Khor</td>
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<td></td>
<td>02</td>
<td>Cotton</td>
<td>22-Harvest</td>
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<td>06</td>
<td>22-Juneh</td>
<td>1-Rosh</td>
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<td>1-Rosh</td>
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<td>22-Harvest</td>
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<tr>
<td>September</td>
<td>09</td>
<td>22-Harvest</td>
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<td>22-Harvest</td>
<td>22-Harvest</td>
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<td>December</td>
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<td>22-Harvest</td>
<td>22-Harvest</td>
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<td>22-Harvest</td>
<td>22-Harvest</td>
<td>22-Harvest</td>
<td>22-Harvest</td>
<td>22-Harvest</td>
</tr>
</tbody>
</table>
ANNEX II

The original prevalence estimates for malnutrition of the sample of children from the PIHS 1991 are presented below, to facilitate comparison with the estimates in other tables.

Table II-1: Prevalence of malnutrition among children under 5 by age category.

<table>
<thead>
<tr>
<th>AGE in months</th>
<th>% below -3 SD</th>
<th>% below -2 SD²</th>
<th>% below -3 SD</th>
<th>% below -2 SD²</th>
<th>% below -3 SD</th>
<th>% below -2 SD²</th>
<th>Number of children</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;6 M</td>
<td>7.7</td>
<td>15.9</td>
<td>5.3</td>
<td>15.9</td>
<td>3.7</td>
<td>11.9</td>
<td>377</td>
</tr>
<tr>
<td>6-11</td>
<td>15.7</td>
<td>33.6</td>
<td>7.3</td>
<td>21.1</td>
<td>17.6</td>
<td>39.0</td>
<td>426</td>
</tr>
<tr>
<td>12-23</td>
<td>25.5</td>
<td>50.1</td>
<td>11.0</td>
<td>31.5</td>
<td>27.6</td>
<td>53.0</td>
<td>699</td>
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<tr>
<td>24-35</td>
<td>25.6</td>
<td>49.5</td>
<td>8.0</td>
<td>24.1</td>
<td>22.5</td>
<td>53.4</td>
<td>846</td>
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<tr>
<td>36-47</td>
<td>25.3</td>
<td>47.8</td>
<td>7.0</td>
<td>24.4</td>
<td>17.6</td>
<td>51.5</td>
<td>943</td>
</tr>
<tr>
<td>48-59</td>
<td>20.4</td>
<td>48.2</td>
<td>5.7</td>
<td>21.2</td>
<td>16.6</td>
<td>44.5</td>
<td>848</td>
</tr>
<tr>
<td>Total</td>
<td>21.8</td>
<td>44.3</td>
<td>7.5</td>
<td>23.8</td>
<td>18.8</td>
<td>45.8</td>
<td>4139</td>
</tr>
</tbody>
</table>

1. Z-scores < -6 or > +6 for height and weight for age are excluded.
2. Children with a Z-score < -3 are included in this group as well.
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