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Health Outcome #2: Anthropometrics

Malnutrition remains a widespread problem in developing countries, in particular among the poorest and most vulnerable segments of the population. Typically, malnutrition is caused by a combination of inadequate food intake and infection that impairs the body's ability to absorb or assimilate food. It is an important cause of low birth weight, brain damage, and other birth defects and contributes to developmental (physical and cognitive) retardation, increased risk of infection and death, and other problems in infants and children.

One approach to studying nutrition is to assess nutritional status on the basis of anthropometric indicators. These are based on physical body measurements such as height or weight (related to the age and sex) and have the benefit of being both inexpensive and nonintrusive to collect. Nutritional status can be seen as the output of a health production function in which nutrient intake is one input, but in which other individual, household, and community variables also feature.

Anthropometric indicators are useful both at an individual and at a population level. At an individual level, anthropometric indicators can be used to assess compromised health or nutrition well-being. This information can be valuable for screening children for interventions and for assessing the response to interventions. At the population level, anthropometry can be used to assess the nutrition status within a country, region, community, or socioeconomic group and to study both the determinants and the consequences of malnutrition. This form of monitoring is valuable for both the design and the targeting of health and nutrition interventions.

This chapter discusses the construction, interpretation, and use of anthropometric indicators, with an emphasis on infants and children. The first section provides an overview of anthropometric indicators. The second discusses practical and conceptual issues in constructing anthropometric indicators from physical measurements and illustrates these issues with examples based on household data from Mozambique. Finally, the third section highlights some key issues and approaches to analyzing anthropometric data.

Overview of anthropometric indicators

Survey data often contain measures of weight and height, in particular for children. Weight and height do not indicate malnutrition directly. Besides age and sex, they are affected by many intervening factors other than nutrient intake, in particular

genetic variation. However, even in the presence of such natural variation, it is possible to use physical measurements to assess the adequacy of diet and growth, in particular in infants and children. This is done by comparing indicators with the distribution of the same indicator for a "healthy" reference group and identifying "extreme" or "abnormal" departures from this distribution. For example, three of the most commonly used anthropometric indicators for infants and children—weight-for-height, height-for-age, and weight-for-age—can be constructed by comparing indicators based on weight, height, age, and gender with reference data for "healthy" children (Alderman 2000; World Health Organization 1995).[1]

Weight-for-height

Weight-for-height (W/H) measures body weight relative to height and has the advantage of not requiring age data. Normally, W/H is used as an indicator of current nutritional status and can be useful for screening children at risk and for measuring short-term changes in nutritional status. At the other end of the spectrum, W/H can also be used to construct indicators of obesity. Low W/H relative to a child of the same sex and age in a reference population is referred to as "thinness." Extreme cases of low W/H are commonly referred to as "wasting." Wasting may be the consequence of starvation or severe disease (in particular, diarrhea). Low W/H can also be due to chronic conditions, although height-for-age is a better indicator for monitoring such problems. It is important to note that a lack of evidence of wasting in a population does not imply the absence of current nutritional problems such as low height-for-age.

Height-for-age

Height-for-age (H/A) reflects cumulative linear growth. H/A deficits indicate past or chronic inadequacies of nutrition and/or chronic or frequent illness, but cannot measure short-term changes in malnutrition. Low H/A relative to a child of the same sex and age in the reference population is referred to as "shortness." Extreme cases of low H/A, in which shortness is interpreted as pathological, are referred to as "stunting." H/A is used primarily as a population indicator rather than for individual growth monitoring.

Weight-for-age

Weight-for-age (W/A) reflects body mass relative to age. W/A is, in effect, a composite measure of height-for-age and weight-for-height, making interpretation difficult. Low W/A relative to a child of the same sex and age in the reference population is

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[1]In what follows, we do not distinguish between indexes and indicators. In principle, however, there are important conceptual differences. An index is simply a combination of different measurements. In contrast, an indicator relates to the use or application of an index to measure (or indicate) a specific phenomenon or outcome. For example, typically, anthropometric indexes are used as indicators for nutritional status. However, the extent to which the anthropometric index is an appropriate indicator depends on the nature of the relationship between nutrition and the index in question (formally, the sensitivity and specificity of the indicator). For a more detailed discussion, see WHO (1995).

referred to as "lightness," whereas the term "underweight" is commonly used to refer to severe or pathological deficits in W/A. W/A is commonly used for monitoring growth and to assess changes in the magnitude of malnutrition over time. However, W/A confounds the effects of short- and long-term health and nutrition problems.

Standardization on a reference population

As noted, the construction of anthropometric indicators is based on comparisons with a "healthy" reference population. For a long time, the international reference standard that was most commonly used (and recommended by the World Health Organization [WHO]) was based on data on weight and height from a statistically valid sample of infants and children in the United States.[2] The validity of this reference standard stems from the empirical observation that well-nourished and healthy children will have a distribution of height and weight very similar to the U.S. reference population, regardless of their ethnic background or where they live (Habicht et al. 1974). In other words, although there are some differences in growth patterns across ethnic groups, the largest part of worldwide variation in anthropometric indicators can be attributed to differences in socioeconomic factors.

Notwithstanding this empirical regularity, there is a long-standing debate about the appropriateness of the U.S. reference standard for children in developing countries, in particular concerning the extent to which growth paths will depend on feeding practices. Reflecting these concerns, in 1993 the WHO undertook a comprehensive review of the uses and interpretation of anthropometric references, concluding that the National Center for Health Statistics (NCHS)/WHO growth reference did not adequately represent early childhood growth. Since then, a multicenter growth reference study has been undertaken to develop new growth curves for assessing the growth and development of children, and in April 2006, the WHO issued new standards for children from birth to five years of age (WHO 2006).[3] These new standards capture the growth and development process of children from widely diverse ethnic backgrounds and cultural settings, with mothers engaged in fundamental health-promoting practices (breastfeeding and not smoking).[4] The new growth standards have been shown to have important implications for the monitoring and assessment of child growth and development (de Onis et al. 2006). Nonetheless, the new standards have not yet been routinely incorporated in standard statistical packages. For this reason, the empirical illustrations used in this chapter are not based on the new reference data.[5]

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[2]This is referred to as the U.S. National Center for Health Statistics (NCHS) reference group. Reference standards are available for children and adolescents up to 16 years of age, but are most accurate for children up to the age of 10.

[3]For a detailed discussion of the rationale, implementation, and findings from this work, see de Onis et al. (2004, 2006) and Garza and de Onis (2004).

[4]Some of the differences between the NCHS/WHO and the new WHO growth reference are also due to the methodologies applied to construct the two sets of growth curves, in particular in the treatment of skewed or kurtotic distributions.

[5]Currently, only the software package ANTRHO has incorporated the new standards. Further details on software packages for anthropometric analysis are provided later in this chapter.

Regardless of what particular reference data are used, anthropometric indices are constructed by comparing relevant measures with those of comparable individuals (in regard to age and sex) in the reference populations. There are three ways of expressing these comparisons:

a. *z-score (standard deviation score):* the difference between the value for an individual and the median value of the reference population for the same sex and age (or height), divided by the standard deviation of the reference population.
b. *Percent of median:* ratio of measured value for an individual to the median value of the reference data for the same sex and age (or height).
c. *Percentile:* rank position of an individual on a given reference distribution, stated in regard to what percentage of the group the individual equals or exceeds.

Box 4.1 *Example Computation of Anthropometric Indices*

For example, consider a 12-month-old girl who weighs 9.1 kg. On the basis of the reference standard weight-for-age for girls, it can be established that the median weight for healthy girls of this age is 9.5 and that the standard deviation in the reference population is 1.0. On this basis, the following calculation can be made:

$$\text{z-score}\,(\text{W/A}) = \frac{9.1 - 9.5}{1} = -0.4$$

$$\text{Percent of median }(\text{W/A}) = \left(\frac{9.1}{9.5}\right) = 95.8\%$$

On the basis of aggregated tables, we can establish only that 9.1 falls between the 30th and 40th percentile.

Source: Authors.

The preferred and most common way of expressing anthropometric indices is in the form of z-scores. That approach has a number of advantages. Most important, z-scores can be used to estimate summary statistics (e.g., mean and standard deviation) for the population or subpopulations. This cannot be meaningfully done with percentiles. Moreover, at the extreme of the distribution, large changes in height or weight are not necessarily reflected in changes in percentile values. The percent of median is deficient relative to the z-score in that it expresses deviation from the reference median without standardizing for the variability in the reference population.

What criterion do we use to determine whether an individual is malnourished or not? Using z-scores, the most commonly used cutoff to define abnormal anthropometry is a value of –2, that is, two standard deviations below the reference median, irrespective of the indicator used.[6] For example, a child whose height-for-age z-score is less than –2 is considered stunted. This provides the basis for estimating prevalence of malnutrition in populations or subpopulations (see table 4.1).[7] The WHO has also proposed a classification scheme for population-level malnutrition.

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[6]Using this criterion, approximately 2.3 percent of "healthy" children would be classified as having an abnormal deficit in any particular anthropometric indicator.
[7]WHO has also proposed a more general malnutrition classification that distinguishes between mild (z-score ≤1), moderate (z-score ≤2), and severe malnutrition (z-score ≤3).

Table 4.1 WHO Classification Scheme for Degree of Population Malnutrition

	Prevalence of malnutrition (% of children <60 months, below –2 z-scores)	
Degree of malnutrition	W/A and H/A	W/H
Low	<10	<5
Medium	10–19	5–9
High	20–29	10–14
Very high	≥30	≥15

Source: WHO 1995.

Other anthropometric indicators

Although weight-for-height, height-for-age, and weight-for-age are the most commonly used anthropometric indicators for infants and children, they are by no means the only ones that have been used.[8]

MID-UPPER ARM CIRCUMFERENCE   Mid-upper arm circumference (MUAC) is a measure of the diameter of the upper arm and gauges both fat reserves and muscle mass. It is used primarily for children, but can also be applied to pregnant women to assess nutritional status. Measurement is simple and requires minimal equipment. MUAC has therefore been proposed as an alternative index of nutritional status, in particular in situations in which data on height, weight, and age are difficult to collect. For children, a fixed (age-independent) cutoff point has sometimes been used to determine malnutrition. However, this risks overdiagnosing young children and underdiagnosing older children. Reference data based on U.S. children 6 to 60 months of age have been incorporated in recent versions of some anthropometric software packages.

BODY MASS INDEX   Body mass index (BMI) is a measure used to define overweight and thinness. BMI is defined as the weight in kilos divided by the square of height in meters. In developing countries, the BMI is used primarily with age-independent cutoffs to identify chronic energy deficiencies (or obesity) in adults (see table 4.2). Although there is some scope for using BMI for adolescents, the index

Table 4.2 BMI Cutoffs for Adults over 20 (proposed by WHO expert committee)

BMI range	Diagnosis
<16	Underweight (grade 3 thinness)
16–16.99	Underweight (grade 2 thinness)
17–18.49	Underweight (grade 1 thinness)
18.5–24.99	Normal range
25.0–29.99	Overweight (preobese)
>30	Obese

Source: Authors.

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[8]For further discussion of alternative anthropometric indicators, including indicators for adolescents and adults, see WHO (1995).

Figure 4.1 *BMI for Adults in Vietnam, 1998*
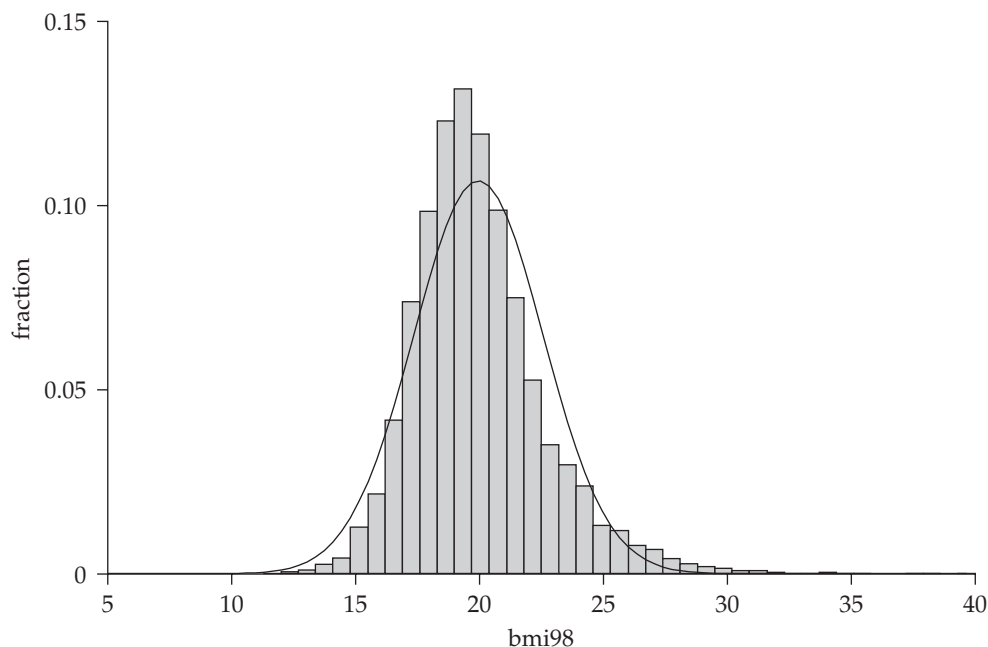
Source: Authors.

varies with age for children and teenagers and must therefore be interpreted in relation to BMI-for-age reference charts.

The incidence of overweight and obesity is a growing problem in many developing countries. In some regions of the world, in particular South and East Asia, prevalence remains relatively low. For example, in figure 4.1, a histogram of BMI for adults (over 20 years of age) in Vietnam illustrates that although nearly 45 percent of individuals are underweight, overweight and obesity are rare (less than 4 percent). However, in other regions of the world, the prevalence of overweight and obesity is high and rising.

Computation of anthropometric indicators

Anthropometric indicators can be computed either by using dedicated anthropometric software, which contains the relevant reference data and has easy procedures for constructing the indicators of interest, or by using a Stata add-in called zanthro.[9] This section provides a brief overview of the most popular anthropometric software packages and a step-by-step guide to either using one of them (EPI-INFO) or using Stata to compute indicators.

Software for anthropometric analysis

At the simplest level, anthropometric software uses raw measurement data in combination with reference data to calculate the corresponding anthropometric indicators. Many of the available software packages also have more advanced functions,

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[9]zanthro is an ado-file developed by Suzanna Vidmar and Tim Cole. It can be installed in Stata be typing webseek zanthro and following the instructions.

including statistical and graphical analysis. The two most popular software packages for anthropometric analysis are ANTHRO and EPI-INFO. Both can be downloaded without charge.

ANTHRO is a program that can be used to compare the growth of individual children with the growth patterns of the new 2006 WHO growth standards. It requires the sex, height, weight, and age of children to calculate normalized anthropometric z-values, percentiles, and percent-of-median. It can use dBase files for batch processing and has an anthropometric calculator. Recently, beta-versions of macros (`igrowup`) based on ANTHRO have been released for Stata and other statistical software.[10]

EPI INFO is a series of programs for Microsoft Windows. It contains a special-purpose module called NutStat, which can be used to compare data on height, weight, age, sex, and arm circumference with the international reference standards. The program calculates percentiles, z-scores and, depending on the reference data used, percent of median. EPI-INFO uses the Microsoft Access file format as a database standard, but many other file types can be analyzed, imported, or exported.[11]

From physical measurement to anthropometric indicators: a step-by-step guide using EPI INFO

One way to calculate z-scores for anthropometric analysis is to use dedicated software. Broadly speaking, this entails four steps: (i) setting up the data in a general statistical package, (ii) reading and processing the data in the anthropometrics package, (iii) reexporting the constructed variables to the general statistical package, and (iv) performing basic data cleaning. Each of these steps is described below for transitions between Stata and EPI-INFO, with an illustration based on data from a living standards survey from Mozambique.[12]

1. Preparing data for loading into EPI-INFO

The variables that must be loaded into EPI-INFO for the computation of anthropometric indicators depend on the indicators desired and also to some extent on the reference data that are used in the analysis (see table 4.3). The data do not need to contain all the listed fields.

There are a couple of important points to note in relation to the variables used in EPI-INFO. First, for many anthropometric indicators, age-specific reference data are used. When the data permit it, it is always preferable to calculate age as the difference between date of measurement and date of birth. This is almost always more

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[10]ANTHRO program files and supporting documentation can be downloaded from http://www.who.int/childgrowth/software/en/.

[11]EPI-INFO programs, documentation, and teaching materials can be downloaded from http://www.cdc.gov/epiinfo/index.htm. EPI-INFO is a CDC trademark, but may be freely copied, distributed, or translated.

[12]The 1996/97 Mozambique National Household Survey on Living Conditions (*Inquérito Nacional aos Agregados Familiares Sobre as Condições de Vida*) was designed and implemented by the National Statistics Institute in Mozambique and was conducted from February 1996 to April 1997. The sample covers approximately 43,000 individuals in 8,250 households. It was selected in three stages and is geographically stratified to ensure representativeness at the provincial level and for urban/rural areas.

Table 4.3 *Variables That Can Be Used in EPI-INFO*

Variable	Description and required format
Sex	1 or M for male, 2 or F for female
Age	Months or years
Birth date	Not necessary if age data are available
Date of measurement	Not necessary if age data are available
ID number	Unique individual identifier
First name	
Last name	
Height	In centimeters or inches
Recumbent	Boolean or 1/2; whether child is lying down
Weight	In kilos or pounds
Edema[13]	Boolean or 1/2; excessive amounts of fluid
Arm circumference	In centimeters or inches
Head circumference	In centimeters or inches
Notes	

Source: Authors.

accurate than age reported by survey respondents. The reference curves are based on "biologic" age rather than calendar age. Biologic age in months divides the year into 12 equal segments as opposed to calendar age in which months have from 28 to 31 days. Although this makes little difference in older children, it can have an effect on the anthropometric calculations for infants. Moreover, entering age by rounding to the nearest month and/or the most recently attained month can have a substantial effect on the anthropometric calculations, especially for infants. To calculate biologic age, anthropometric software calculates the number of days between the two dates. The age in days is divided by 365.25 and then multiplied by 12.

Second, for younger children, normally height is measured with the child in a recumbent position. This measurement is sometimes referred to as "length," which is contrasted with standing height measurements, referred to as "stature."[14] In some cases, this distinction is not important from the point of view of the analyst. For example, when the recommended 1978 CDC/WHO reference in EPI-INFO is used, recumbent length is assumed from birth to age 24 months, and standing height for 24 months and older. However, in EPI-INFO it is also possible to use a 2000 CDC reference standard. If this option is chosen, the user must indicate whether the measurements are recumbent length or standing height for children in the age group of

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[13]Edema refers to the presence of excessive amounts of fluid in the intracellular tissue. There is a strong association between edema and mortality. The presence of edema is therefore important for screening and surveillance purposes and can be used to flag children as severely malnourished, independently of their wasting, stunting, or underweight status. However, although edema is included as a variable in many anthropometric software programs for that reason, it is not generally used for evaluation purposes.

[14]For details on measurement, see WHO (1995) or http://www.cdc.gov/nccdphp/dnpa/bmi/meas-height.htm.

24 to 36 months (for younger and older children, recumbent and standing measurements are assumed, respectively).

Turning to the Mozambique illustration, the first step is to construct a data set with all the relevant variables in the appropriate format. In this case, we have data on the birth date, measurement date, sex, weight, and height of children under five years old. In the following code, the dates are used to construct the age in months and, before the relevant variables are saved in a new data file, weight is adjusted to account for the fact that a minority of children were weighed with their clothes on. At this stage it is also important to ensure that all variables are appropriately coded and in the correct units (see table 4.3).

```
generate birthdate = mdy(birth_mnth, birth_day, birth_yr)
generate measuredate = mdy(visit_mnth, visit_day, visit_year)
generate age_days = measuredate - birthdate
generate age_months = (age_days/365.25) * 12

replace weight_grams = weight_grams – weight_cloth if how_
weighed==1
generate weight_kilos = weight_grams / 1000
keep id sexo age_months weight_kilos height_cm
drop if sexo==. | age_months==. | weight_kilos==. | height_
cm==.
save filename, replace
```

2. Reading and processing the data in EPI-INFO

The NutStat module of EPI-INFO uses data in Access database format.[15] There are two ways of importing external data into NutStat. The Add Statistics feature simply processes the data from a Microsoft Access data file and adds the results of calculations to the file. In contrast, the Import Data feature can be used to import data from an existing table into a new table that has the data structure required by Nutstat. The table can be an EPI-INFO table or a table from Microsoft Access. Both the Add Statistics and Import Data features can be accessed from the File menu. Under either alternative, the user is first required to choose between the two alternative reference standards (1978 CDC/WHO or 2000 CDC). The user must thereafter link variables in the imported data file with fields that EPI-INFO requires to calculate the anthropometric indicators and, for some fields, select the unit of measurement. Finally, the user selects the statistics or indicators to calculate—for example, z-scores, percentiles, and percent of median for W/A, H/A, and W/H.[16] The selection of indicators to be calculated is restricted by the variables that were imported. When the data are then processed, the new variables are either added to the original file (Add Statistics option) or saved in a new data file (Import option) (see table 4.4).

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[15]Stata or SPSS data can be converted into Access format using conversion software such as DMBScopy or StatTransfer. Alternatively, data can be exported from Stata using the outsheet command, which can then be read into Access. It is also possible to copy data from the Stata browser and paste it in Access.
[16]Further anthropometric indicators can be calculated on the basis of specific WHO reference data (MUAC-for-age) or 2000 CDC reference (head circumference-for-age and BMI-for-age).

Table 4.4 *Key Variables Calculated by EPI-INFO*

Anthropometric indicator	Variable names 1978 CDC/WHO reference	Variable names 2000 CDC reference[a]
H/A z-score	fldWHOHAZ	fldCDCLAZ, fldCDCSAZ
H/A centile	fldWHOHAC	fldCDCLAC, fldCDCSAC
H/A percent of median	fldWHOHAPM	
W/A z-score	fldWHOWAZ	fldCDCWAZ
W/A centile	fldWHOWAC	fldCDCWAC
W/A percent of median	fldWHOWAPM	
W/H z-score	fldWHOWHZ	fldCDCLAZ, fldCDCSAZ
W/H centile	fldWHOWHC	fldCDCLAC, fldCDCSAC
W/H percent of median	fldWHOWHPM	
MUAC-for-age	MUACAZ[b]	MUACAZ

a. If stature and length are processed separately, two variables are created for each indicator.
b. Based on 2000 CDC reference.
Source: Authors.

3. Exporting the data for analysis

After the variables of interest have been constructed, the Microsoft Access database must be converted into a format that can be read by the general statistical package before the variables can be merged with the original data. In our example, z-scores, percentiles, and percent of median for W/A, H/A, and W/H were saved in a file named anthro_data.dta, which can now be merged with the main Statadata file.

```
use anthro_data.dta, clear
sort id
save, replace
use main_data.dta, clear
sort id
merge id using anthro_data.dta
```

4. Performing basic data cleaning

In the previous steps, we have added a set of anthropometric indicators to our original data. Before we proceed with the analysis of these indicators, there are a number of data-cleaning issues and potential sources of bias that analysts must be aware of.

The first issue to contend with concerns the problem of missing values. In most surveys, enumerators are not able to obtain all the relevant data for all sampled individuals. The most common problem concerns the age of the child, in cases in which the parent may not know the precise birth date and birth records are not available. Data may also be missing for weight or height, for example, because some parents do not agree to having their children weighed, or there may have been problems with the measuring equipment. A second problem concerns the calculated z-scores; errors in measurement, reporting of age, coding, or data entry sometimes result in biologically implausible values. The WHO (1995) recommends that, for the purpose of analysis, values outside a certain range should be treated as missing values (see table 4.5).

Table 4.5 *Exclusion Ranges for "Implausible" z-Scores*

Indicator	Exclusion range for z-scores
Height-for-age	<5.0 and >+3.0
Weight-for-height	<4.0 and >+5.0
Weight-for-age	<5.0 and >+5.0

Note: If observed mean z-score is below –1.5, the WHO recommends that a flexible exclusion range be used. For details, see WHO (1995).
Source: Authors.

These problems can be explored by looking at descriptive statistics, scatter plots, and histograms. In the Mozambique data, we construct indicator variables for missing and implausible values in the variables of interest.

```
generate missing = (age_months==. | haz==. | whz==. | waz==.)
generate outrange_haz = (haz < -5 | haz > 3)
replace outrange_haz = . if haz==.
... code for whz and waz
drop if missing==1 | outrange_haz==1 | outrange_whz==1 | out-
range_waz==1
```

In this example, nearly 20 percent of observations have missing values for age, weight, or height. In addition, approximately 3 percent of observations have values for one or more of the anthropometric indicators that are outside the plausible range. This is quite high and casts some doubt on the quality of the data. At this point, it is difficult to correct the problems that gave rise to missing and implausible values. However, before dropping these observations, it is important to assess whether doing so is likely to result in biases in subsequent estimates. This depends both on the proportion of the sample that is being dropped and on the extent to which the true values for the variables of interest are systematically different from the rest of the sample. Of course, with missing data values for the relevant variables, we cannot provide a precise answer to this question. That said, we can look at other characteristics of the observations that we are dropping and draw some conclusions on that basis. For example, in the Mozambique data, both average income and maternal education are significantly lower for the observations that will be dropped, and they are disproportionately from rural areas. Hence, we are dropping observations that most likely have a poorer nutritional status than the population average. Besides such problems of non-sampling bias, sampling bias, whereby the sample that we are analyzing is not representative of the target population, can sometimes be important for anthropometric data.[17] For example, data may be collected through schools or clinics that are not attended by all segments of the population.

Constructing anthropometric indicators using Stata

Some analysts prefer not going through dedicated software for anthropometric analysis. Provided relevant macros or add-ins (i.e., zanthro or igrowup) have been installed, anthropometric indicators can be constructed in Stata.

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[17]See chapter 2 on sampling and non-sampling bias.

For example, using the `zanthro`, the following command lines would generate indicator variables for low W/A, H/A, and W/H.

```
egen haz = zanthro(height_cm, ha, US), xvar(age_months)
gender(sexo) gencode(male=1, female=2) ageunit(month)

egen whz_stata = zanthro(weight_kilos, wh, US), xvar(height_
cm) gender(sexo) gencode(male=1, female=2)

egen waz_stata = zanthro(weight_kilos, wa, US), xvar(age_
months) gender(sexo) gencode(male=1, female=2) ageunit(month)
```

In this case, the variables are created using the 2000 CDC reference (`US` option in the `zanthro` command). If we had instead specified UK as an option, the 1990 British Growth Reference would have been used instead. The command automatically generates missing values if the absolute value of the z-score is greater than 5. By specifying the option `nocutoff`, calculation of all z-scores is forced.

Analyzing anthropometric data

At the most basic level, the analysis of anthropometric data concerns the identification of malnourishment in a population or subpopulation. However, in many cases analysts want to go beyond merely establishing prevalence to try to understand the causes of malnourishment and how can they be addressed.

A first step is to look at the distribution of the z-scores and the overall prevalence of malnourishment. When compared with the distribution of z-scores in the reference population, this provides a first impression of different dimensions of nutritional status in the population. In Stata, such descriptive analysis can be carried out as follows:

```
global zscores "haz waz whz"
foreach x of global zscores {
        graph twoway histogram `x' || function normden(x,0,1),
range(`x') title("`x'") xtitle("z-score") ytitle("Density")
legend(off)
        gen below2_`x' = (`x' < -2)
        gen below3_`x' = (`x' < -3)
}
tabstat $zscores below_* [aw=weight], stat(mean sd) col(stat)
```

where `below2_haz` is a dummy indicating a height-for-age z-score less than –2, and so forth. The results of this analysis of the Mozambique data are reported below. As can be seen from the graphs in figure 4.2 and from table 4.6, there are deficits in both H/A and W/A, but only limited evidence of wasting. More detailed histograms could be drawn by kernel density estimation (`kdensity`).

It is also useful to look graphically at the relationship between different anthropometric indicators. In general, weight-for-height and height-for-age are not correlated, whereas there tends to be a positive correlation between weight-for-height and weight-for-age and between weight-for-age and height-for-age (see figure 4.3). This pattern is confirmed in the Mozambique data.

```
twoway (scatter whz haz), ylabel(-6 0 5) xlabel(-6 0 5)
twoway (scatter whz waz), ylabel(-6 0 5) xlabel(-6 0 5)
twoway (scatter waz haz), ylabel(-6 0 5) xlabel(-6 0 5)
```

**Figure 4.2** *Distribution of z-Scores in Mozambique, 1996/97*

HAZ

WAZ

WHZ
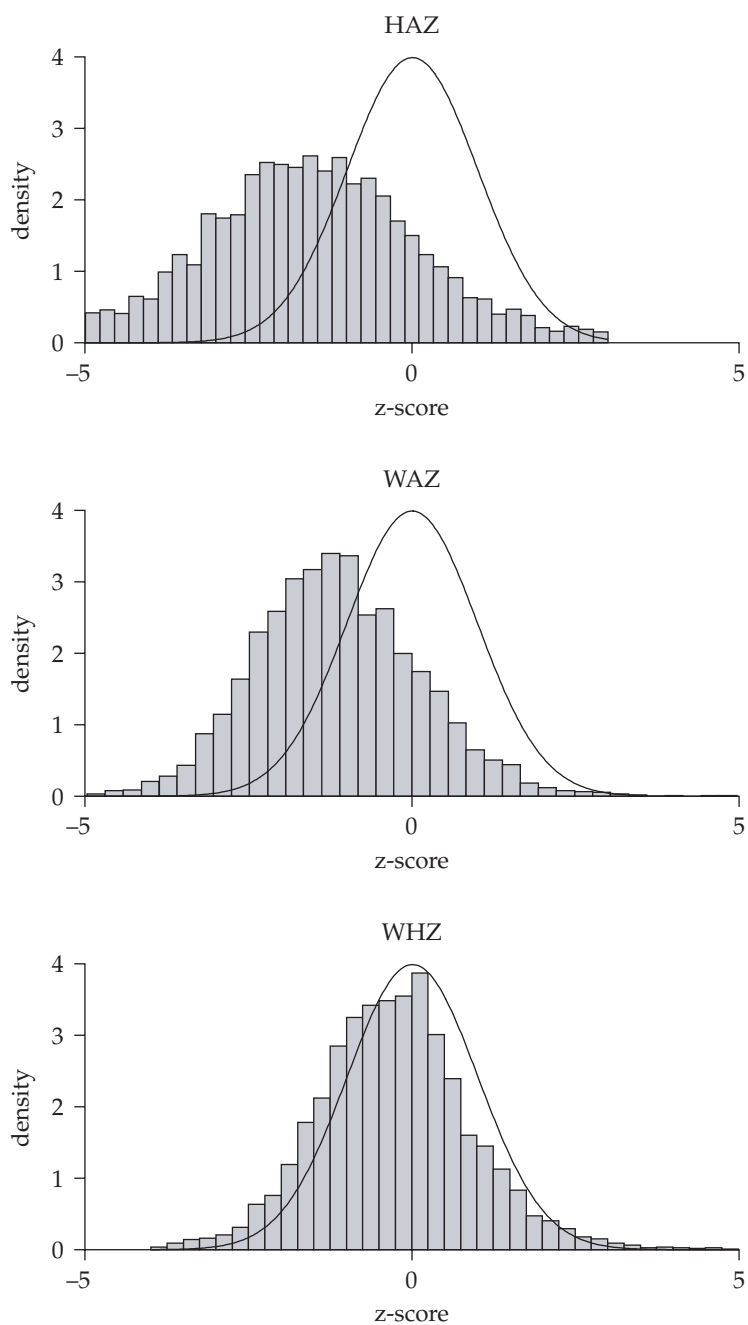
Source: Authors.

Table 4.6 *Descriptive Statistics for Child Anthropometric Indicators in Mozambique, 1996/97*

	HAZ	*WAZ*	*WHZ*	*n*
Mean	−1.88	−1.28	−0.15	4,514
S.D.	1.74	1.31	1.34	4,514
% below −2 S.D.	46.1	28.8	6.4	4,514
% below −3 S.D.	25.4	8.4	1.1	4,514

Source: Authors.

Figure 4.3 *Correlation between Different Anthropometric Indicators in Mozambique*
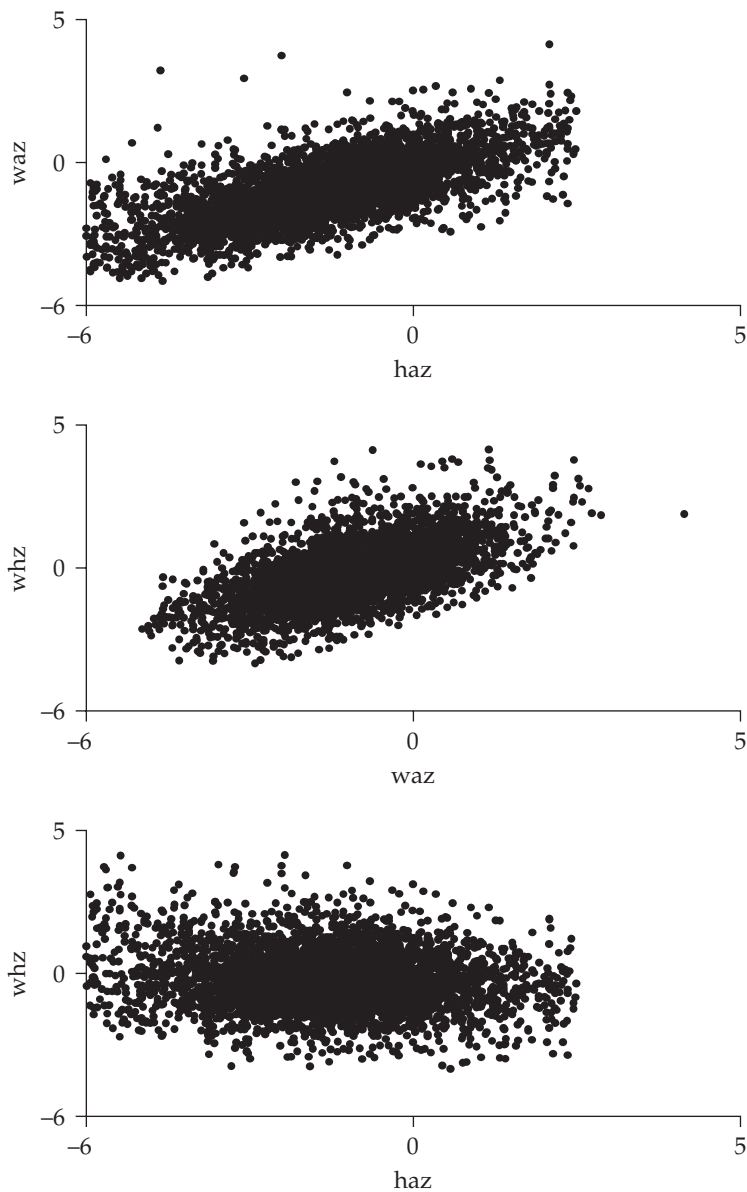
For many purposes, anthropometric data should be presented according to age and sex groups. The reason is that (i) patterns of growth failure vary with age, (ii) the identification of determinants of malnutrition is facilitated, and (iii) as a consequence of irregularities in the reference curves, wasting tends to be exaggerated for children in the 12- to 24-month age group. WHO (1995) recommends that at least two age disaggregations be used—under 24 months and 24 months and over—but for some purposes a more detailed disaggregation may be advisable.

```
tabstat below2* [aw=weight] if age_months < 24, stat(mean)
by(sex)
tabstat below2* [aw=weight] if age_months >= 24, stat(mean)
by(sex)
```

Table 4.7 *Stunting, Underweight, Wasting by Age and Gender in Mozambique*

| Age (months)	Group	HAZ<–2	WAZ<–2	WHZ<–2	n
0–23	Boys	44.6	35.8	11.2	1,025
	Girls	36.0	23.5	5.7	1,072
	Combined	40.0	29.2	8.3	2,097
24–60	Boys	53.6	28.0	5.0	1,207
	Girls	49.3	29.2	4.4	1,210
	Combined	51.5	28.6	4.7	2,417

Source: Authors.

Of course, a simple disaggregation of children under five into two age groups still hides a great deal of detail. To better understand the nature of malnutrition, it can be useful to look at the mean z-score for smaller age groups (e.g., by month). To do so, the age variable, which is often continuous, needs to be transformed into a categorical variable. The mean z-score for different anthropometric indicators can then be tabulated and graphed. For example, figure 4.4 illustrates how the z-score weight-for-age in children in Mozambique reaches very low levels already by the age of 10 months.

```
recode age_months (0/0.999=0) (1/1.999=1) (2/2.999=2) ///
  (3/3.999=3) (4/4.999=4) (5/5.999=5) ///
  (6/6.999=6) (7/7.999=7) (8/8.999=8) ///
  (9/9.999=9) (10/10.999=10) (11/11.999=11) ///
  (12/12.999=12) (13/13.999=13) (14/14.999=14) ///
  (15/15.999=15) (16/16.999=16) (17/17.999=17) ///
  (18/18.999=18) (19/19.999=19) (20/20.999=20) ///
  (21/21.999=21) (22/22.999=22) (23/23.999=23) ///
  (24/24.999=25), gen(age_months_cat2)
tabstat waz if age_months<=24, by(age_months_cat)
```

Figure 4.4 *Mean z-Score (weight-for-age) by Age in Months*
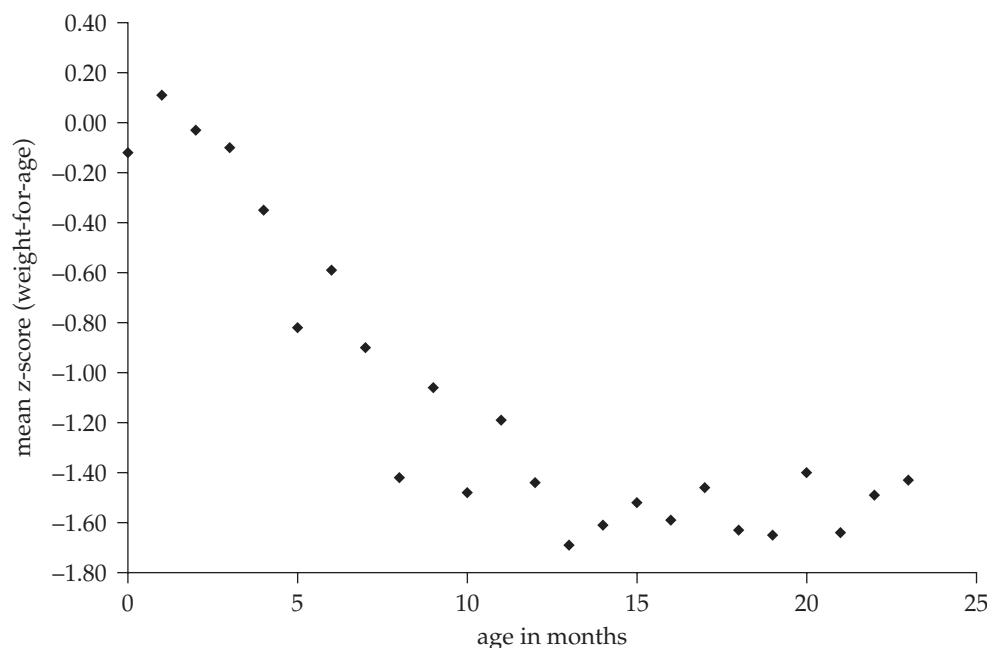
Source: Data from 1997 Mozambique Living Standards Survey.

It is also useful to explore how anthropometric indicators are related to different individual, household, and community characteristics. An important perspective in this regard is to assess socioeconomic inequalities in nutritional status. A simple way of looking at this issue is to examine the prevalence of malnutrition across income or wealth quintiles.

Prevalence rates of stunting, underweight, and wasting for different consumption quintiles in Mozambique are graphed in figure 4.5a, with a disaggregation by sex for stunting in figure 4.5b. The graphs show the expected tendency for malnutrition to be worse in poorer quintiles. But analysts should avoid drawing unwarranted conclusions about socioeconomic inequalities. In particular, it is important to look beyond the simple means by quintiles to assess whether the observed differences are significant. For example, in the case of stunting, a more detailed analysis of the Mozambique data reveals that the only statistically significant difference in prevalence between consumption quintiles is between the richest quintile and the rest. Moreover, although comparing means by quintiles is a useful place to start, it is quite a crude approach to assessing socioeconomic inequalities, and analysts should consider using concentration curves and indices discussed in chapters 7 and 8.

It is important that descriptive analysis of anthropometric data be accompanied by information to assist in the interpretation of findings. This includes information such as general characteristics of the population, sample design and size, method of determining age, and proportion of data missing or excluded. For some purposes it is also important to report standard errors or confidence intervals for estimates.

Analysts may wish to go beyond descriptive analysis and use anthropometric indicators to examine determinants of malnutrition. In that regard, it is customary to distinguish between distant and proximate determinants of malnutrition (Mosley and Chen 1984). Proximal factors are inadequate dietary intake and disease. Distant factors do not influence malnutrition directly, but rather through their impact on proximate determinants. They include, for example, poverty, education, cultural factors (e.g., duration of breast feeding, hygiene practices), and community and environmental characteristics (e.g., availability and quality of health services,

Figure 4.5 *Prevalence Rates of Stunting, Underweight, and Wasting for Different Consumption Quintiles in Mozambique and a Disaggregation by Sex for Stunting*

Figure 4.5a *By quintile*
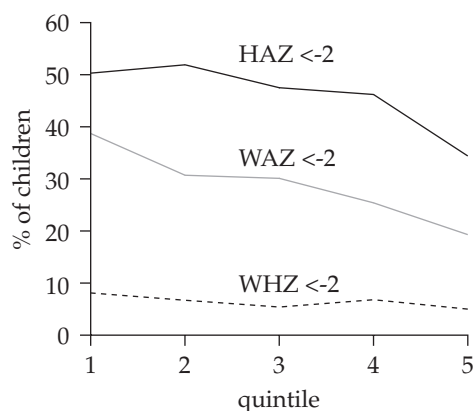
Figure 4.5b *By quintile, disaggregated by sex*
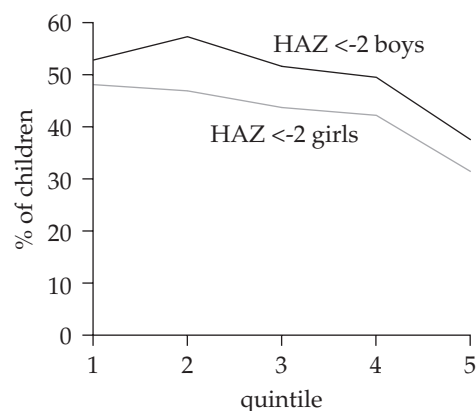
Source: Authors.

epidemiological profile).[18] The identification of socioeconomic inequalities should therefore be considered just the starting point for further analysis. A socioeconomic gradient most likely confounds the influence of many complex factors. To understand the contribution of different factors in determining nutritional status, a multivariate modeling framework is required. This type of analysis also has to contend with difficult conceptual and empirical issues, which are considered in chapter 10.[19]

Useful sources of further information

WHO global database on child growth and malnutrition: http://www.who.int/nutgrowthdb/.

Food Nutrition Technical Assistance Project: http://www.fantaproject.org/publications/anthropom.shtml.

Practical Analysis of Nutritional Data (PANDA): http://www.tulane.edu/~panda2/.

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[18]In some contexts, the distinction between *classifying* and *determining* variables is used; determining variables is used to refer to distal or proximate determinants that are amenable to being changed through interventions (e.g., feeding practices, sanitation, immunization, etc.). UNICEF has also proposed a conceptual framework on the causes of malnutrition, which distinguishes between immediate, underlying, and basic causes of malnutrition.

[19]For a detailed discussion, see Behrman and Deolalikar (1988) and Strauss and Thomas (1995).

WHO (World Health Organization). 1995. "Physical Status: The Use and Interpretation of Anthropometry. Report of a WHO Expert Committee." *World Health Organ Tech Rep Ser* 854: 1–452.

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