DHS WORKING PAPERS

Where the Standard Makes the Difference in the Real World of Malnutrition: Analysis of 10 Countries with DHS Data

Monica T. Kothari

Shea O. Rutstein

Jasbir K. Sangha

2009 No. 66

DEMOGRAPHIC AND HEALTH RESEARCH

September 2009

This document was produced for review by the United States Agency for International Development.

The *DHS Working Papers* series is an unreviewed and unedited prepublication series of papers reporting on research in progress based on Demographic and Health Surveys (DHS) data. This research was carried out with support provided by the United States Agency for International Development (USAID) through the MEASURE DHS project (#GPO-C-00-03-00002-00). The views expressed are those of the authors and do not necessarily reflect the views of USAID, the United States Government, or the organizations to which the authors belong.

MEASURE DHS assists countries worldwide in the collection and use of data to monitor and evaluate population, health, and nutrition programs. Additional information about the MEASURE DHS project can be obtained by contacting ICF Macro, Demographic and Health Research Division, 11785 Beltsville Drive, Suite 300, Calverton, MD 20705 (telephone: 301-572-0200; fax: 301-572-0999; e-mail: reports@macrointernational.com; internet: www.measuredhs.com).

Where the Standard Makes the Difference in the Real World of Malnutrition:

Analysis of 10 Countries with DHS Data

Monica T. Kothari[1]

Shea O. Rutstein[2]

Jasbir K. Sangha[2]

September 2009

Corresponding authors: Monica T. Kothari, PATH/DHS and Shea O. Rutstein ICF Macro/DHS, Demographic and Health Research Division, ICF Macro, 11785 Beltsville Drive, Calverton, Maryland 20705, USA; Phone 301-572-0540; Fax 301-572-0999; Email: monica.t.kothari@macrointernational.com; shea.o.rutstein@macrointernational.com.

[1] PATH/DHS
[2] ICF Macro/DHS

ACKNOWLEDGEMENTS

The authors thank Fred Arnold and Avril Armstrong for reviewing the study and for their valuable comments. Also, thanks to Yuan Gu for formatting and Bryant Robey for editing the paper. Special thanks to Vinod Mishra for guidance at various stages during the course of the study and also for facilitating the publication of the working paper.

Suggested citation:

Kothari, Monica T., Shea O. Rutstein, and Jasbir K. Sangha. 2009. *Where the Standard Makes the Difference in the Real World of Malnutrition: Analysis of 10 Countries with DHS Data*. DHS Working Papers No. 66. Calverton, Maryland, USA: ICF Macro.

ABSTRACT

The 1977 International Growth Reference, formulated by the National Center for Health Statistics (NCHS) and endorsed by World Health Organization (WHO), has long been used to assess the nutritional status of children. In 2006, however, WHO introduced new Child Growth Standards to replace the 1977 NCHS Reference. The study reported here presents findings from 10 DHS surveys, representing countries in South Asia, Central Asia, sub-Saharan Africa, and South America to compare the prevalence of stunting, wasting, underweight, and overweight in children under age 5 years by these two international standards.

Using the 2006 WHO Standards increases the prevalence of stunting, wasting, and overweight among children, while the prevalence of underweight children is lower compared with using the 1977 NCHS Reference. After controlling for various background characteristics of children, the study finds that place of residence (rural versus urban) and birth order are the only two characteristics that seem not to be important predictors of differences in stunting and wasting, respectively, between the 1977 NCHS Reference and the 2006 WHO Standards. Most findings of our study agree with findings from other studies reported in the literature.

These findings have implications for evaluating children's nutritional status and for analyzing trends. Our major conclusion is that malnutrition tabulations should be made using both the 1977 NCHS Reference and the 2006 WHO Standards during the transition between the former reference and the new standards.

INTRODUCTION

Using data from 10 recent Demographic and Health Surveys (DHS), this study compares the nutritional status of children according to two different international anthropometric measurement standards—the 1977 International Growth Reference, developed by the National Center for Health Statistics (NCHS) and endorsed by the World Health Organization (WHO)[1], and the more recent WHO Child Growth Standards, introduced in 2006[2].

Anthropometric measurements (height and weight) are the core DHS components to assess the nutritional status of children under age 5. Anthropometric indices (height-for-age, weight-for height, and weight-for-age also are used for nutrition surveillance, clinical studies, program evaluation, and trend analysis. Anthropometric indices typically are compared against local and/or international references or standards.

For many years, the 1977 NCHS Reference has been the most widely used standard and has been used in DHS surveys to assess prevalence of childhood malnutrition. Recently, however, the DHS program has started using the 2006 WHO Standards and has produced some of the first nationally representative statistics on children's nutritional status using this new international standard. Unlike the 1977 NCHS Reference, the 2006 WHO Standards describe how children "should grow" by using standards based on breastfeeding children who grow under optimal conditions in their early years of life. Thus the introduction of the new standards represents a shift from a "descriptive" approach to a "prescriptive" point of view in assessing childhood nutritional status.

By the 2006 WHO Standards, a number of surveyed countries have been surprised to find worse childhood malnutrition rates than previously believed, especially the prevalence of

[1] Hereafter referred to in this paper as the "1977 NCHS Reference"
[2] Hereafter referred to in this paper as the "2006 WHO Standards"

stunting. As yet, however, DHS data have not been analyzed to explore the differences in the prevalence of malnutrition across countries when comparing the 1977 NCHS Reference with the 2006 WHO Standards. In addition, the role of background variables in the differences observed in malnutrition when nutritional status is assessed by the 1977 NCHS Reference versus the 2006 WHO Standards has not yet been investigated.

The study reported here is the first to make these comparisons with regard to DHS survey data and to explore how the two international standards differ in their impact on prevalence of childhood malnutrition in the surveyed countries. In addition, the study tests a proposed algorithm by Hong and de Onis (2008) to estimate equivalent values of malnutrition from the 1977 NCHS Reference for the 2006 WHO Standards for the purpose of assessing trends. Our study joins other studies that have compared the effect of using these two standards on the estimation of malnutrition in overall populations (see Review of Literature). Such studies by level of malnutrition and by background characteristics are sparse, and thus our study makes an important contribution to knowledge.

A chief criticism of the use of the 1977 NCHS Reference has been that, because the reference is based on children from a developed country who were mostly bottle-fed, this single standard should not be applied for all children around the world. An earlier DHS study has disproved this hypothesis, however, by showing that "elite" children (that is, children of more advantaged socioeconomic status and thus assumed to be well-fed) from a number of surveyed countries have the same distribution of nutritional indicators as that of the 1977 NCHS Reference. When the 2006 WHO Standards were developed, the study sample comprised children from different parts of the globe, using criteria that would help children to achieve their optimal growth and to attain their genetic potential. Hence, we expect that the nutritional status of the elite children from our study sample of the DHS population would be similar to that of the children on which the 2006 WHO Standards are based. To investigate this hypothesis, our paper compares the nutritional status of the elite children according to the 1977 NCHS Reference with their status according to the 2006 WHO Standards. Our assumption is that the distribution of nutritional status of elite children should be normally distributed by either standard.

Background

In 1977 the NCHS released the first internationally recognized reference for assessing nutritional status of children, derived from the Fels Research Institute Longitudinal Study (1929-1975) for children age 0-23 months. For older children (age 2-18 years) the data came from three surveys in the US carried out between 1960 and 1975. In 1978 the US Centers for Disease Control (CDC) normalized the 1977 NCHS percentiles and adopted them to assess the health status of children for their study purposes. Subsequently, WHO also adopted the NCHS Reference. For a long time, these NCHS normalized curves were the only internationally recognized reference for the assessment of nutritional status of children, which became known as NCHS/CDC/WHO International Growth Reference (Ogden et al., 2002; WHO, 1995) (as mentioned, in this paper termed the 1977 NCHS Reference).

As mentioned above, however, the 1977 NCHS Reference has received various criticisms, chiefly that the original NCHS reference was based on formula-fed white middle-class infants in southwestern Ohio, US, raising questions about its validity when used for children that are mainly breastfed and genetically, geographically, and socioeconomically different. Further, there were notable differences between the recumbent length in the Fels data set and standing stature in the national data set used for the older child growth charts, leading to a disjuncture between the infant and older child growth curves between 24 and 36 months. Additionally, another major concern about this old reference was related to differences in the percentile values of the original NCHS and the normalized CDC version of the growth curves. This criticism along with others motivated the development of a new international reference or set of standards for childhood nutritional status (de Onis et al., 1997).

In 2000, CDC Growth Charts were released to replace the 1977 NCHS Reference. In the new charts the lengths of the babies at birth were taken from vital registrations of the states of Wisconsin and Missouri. The weight-for-age curve data came from US vital statistics (birth certificates). However, because these references are based on the US data, these charts were recommended for the use in the US only and were not adopted for international use (de Onis, 2007).

Around the same time, WHO took the lead in developing new growth standards that would be representative of the international population and that would take into account the shortfalls of the 1977 NCHS Reference. The new standards were developed with the philosophy that children around the world of various ethnicities, given an optimal environment, have the same capacity to reach their genetic potential, especially during the early years of their development. Prior to their release, field-testing was conducted at four sites (Argentina, Italy, Pakistan, and Maldives) to ascertain the clinical validity of the new standards, which were subsequently approved for use in clinical settings as well as in the field because of their reliability. In 2006 WHO unveiled the new Child Growth Standards (as mentioned, referred to in this paper as the 2006 WHO Standards) to replace the 1977 NCHS Reference (WHO, 2006).

The 2006 WHO Standards stem from a Multiple Growth Reference Study (MGRS) that is based on a final sample of 7,551 children from the cities of Davis, California (USA); Muscat

(Oman); and Oslo (Norway); and selected neighborhoods of Pelotas (Brazil), Accra (Ghana), and South Delhi (India). These locales were chosen from various world regions that were well-off economically and where nearby institutions were interested in and capable of doing the investigation. Beyond including children from various ethnic groups, the MGRS ensured selection of children who lived in socioeconomic conditions favorable for childhood growth. At least 20 percent of the mothers of the children included in the MGRS followed health-promoting practices, such as adherence to WHO specific feeding recommendations on breastfeeding and complementary feeding[3], and the mothers did not smoke. Children included in the MGRS were without apparent diseases or significant morbidity, were singleton full-term births, and had no known health or environmental constraints to growth (de Onis et al., 2006a).

The MRGS included both a longitudinal component and a cross-sectional component. In the longitudinal component 882 compliant children were followed from birth to 24 months with 21 home visits. The cross-sectional component studied 6,669 children age 18-71 months, who were breastfed until at least age 3 months (de Onis et al., 2006; de Onis et al., 2007). The hallmark of the study was to identify breastfeeding as the "biological norm" and to accept a breastfed child is the "normative model for growth and development" (de Onis et al., 2006a). Given the rigorous methods adopted to develop the 2006 WHO Standards, they are assumed to be more robust in assessing the nutritional status of the children, especially infants, than was the case for the 1977 NCHS Reference.

[3] Exclusive or predominant breastfeeding for at least 4 months, introduction of complementary foods by the age of 6 months, and continued partial breastfeeding up to at least 12 months.

REVIEW OF LITERATURE

A number of studies based on various populations have assessed differences in nutritional status based on the 2006 WHO Standards versus the 1977 NCHS Reference. In 2006 a study found that the prevalence of stunting is higher throughout childhood using the 2006 WHO Standards than the 1977 NCHS Reference. The prevalence of underweight among breastfed children is higher during early infancy and lower afterward. For wasting, the main difference occurs during infancy, when the prevalence of wasting is higher using the 2006 WHO Standards. The prevalence of overweight is also higher when the 2006 WHO Standards are used (de Onis et al., 2006a). Report published by de Onis and colleagues substantiate similar differences between nutritional status based on the 2006 WHO Standards and the 1977 NCHS Reference (de Onis et al., 2007).

A study in Sind Province, Pakistan, to compare estimates of under-nutrition among pre-school children also reported higher prevalence of stunting and wasting by the 2006 WHO Standards compared with the 1977 NCHS Reference. The differences between the two standards were noticeable for severely wasted and stunted infants (Nuruddin et al., 2008). A study in rural Malawi comparing the nutritional status of children using the 2006 WHO Standards and the 1977 NCHS Reference reported differences in the prevalence of stunting, wasting, and underweight similar to those reported in other studies. This study also reported that underweight prevalence during early infancy that was 3.5 times higher using the 2006 WHO Standards than the 1977 NCHS Reference (Prost et al., 2008).

A study by Schwarz et al. (2008) of nutritional status of children in Gabon showed considerable differences in patterns of growth faltering depending on which standard was used to assess the prevalence of stunting and underweight. The proportion stunted and underweight was highest when children were assessed using the 2006 WHO Standards compared with either the

1977 NCHS Reference or the 2000 CDC Growth Charts.

A study by Fenn and Penny (2008) in Peru, Vietnam, and the Indian state of Andhra Pradesh of children age 6 to 18 months found higher mean weight-for-length/height and weight-for-age using the 1977 NCHS Reference than the 2006 WHO Standards. In each of the three countries, however, the mean length/height for-age was similar between the two international standards. Like other studies, Fenn and Penny also reported a higher prevalence of stunting and a lower prevalence of underweight for the 2006 WHO Standards compared with the 1977 NCHS Reference.

The literature highlights clear differences in tracking nutritional status of children between the two standards. When children's nutritional status is tracked on the 2006 WHO Standards, the children do very well for weight-for-age; however when tracked on the 1977 NCHS Reference, they register growth faltering beginning at age 2 months (de Onis, 2007).

The literature cites various advantages of using the 2006 WHO Standards. One advantage is the extension of the WHO weight-for-length/height curves to 110 cm, making it possible for a tall 2-year-old to be measured lying down, if they cannot stand due to malnutrition or for other reasons. This extension was not possible with either the 1977 NCHS Reference or the 2000 CDC Growth Charts (de Onis et al., 2007).

In summary, based on the limited number of published studies, it appears that the 2006 WHO Standards reflect the rapid growth of early infancy better than the 1977 NCHS Reference (de Onis, 2007). However, in emergency situations such as those in a refugee camp, the 2006 WHO Standards have been found to significantly increase the number of children who would be admitted to the feeding programs, because acute malnutrition (weight-for-height) is higher when compared with the 1977 NCHS Reference (Seal and Kerac, 2007, Prinja et al., 2009).

DATA AND METHODS

Data

We used the data from 10 recent DHS surveys (see table below) to compare the nutritional status of children using the 1977 NCHS Reference with their status using the 2006 WHO Standards. Information was collected on the height, weight, and age of each child and on whether the child was measured lying down or standing up. Only children whose mothers were interviewed in the surveys were included in the study sample for further analyses.

Country (Year)	Number of children under age 5 year who stayed in the household the night before the survey	Number of children included in this analysis
Azerbaijan 2007	1,979	1,919
Dominican Republic 2006	10,522	8,675
Ethiopia 2005	4,586	4,255
India 2005-06	46,655	44,546
Liberia 2007	5,166	4,102
Mali 2006	11,877	10,614
Nepal 2006	5,262	4,998
Peru Continuous 2005-2007	4,334	3,565
Swaziland 2006	2,940	2,044
Uganda 2006	2,687	2,367

Methods

1. Weight and height measurement

In the surveys included in this analysis, weight was measured using the digital UNISCALE procured from UNICEF, and height/length was measured using Shorr wooden height boards. For details on the method of weight and height measurements, refer to the Anthropometry, Anemia and HIV Testing Field Manual (Macro International, 2008).

It is important to highlight that interviewers were instructed to measure infants and young children less than age 2 years in lying down position and children age 2 years and older in a standing position.

2. Anthropometric indices

To assess the nutritional status of children under age 5 years, the following standard indices were derived using each of the two international standards—the 1977 NCHS Reference and the 2006 WHO Standards.

- *Height-for-age*: The height-for-age index is an indicator of linear growth retardation among children. Children who are more than two standard deviations below the median of the reference population in terms of their height-for-age z-score (for discussion of z-score, see paragraph following the bullets) are considered short for their age ("stunted") or chronically malnourished.
- *Weight-for-height*: The weight-for-height index looks at body mass in relation to body length. Children who are more than two standard deviations below the median of the reference population in terms of their weight-for-height z-score are considered too thin ("wasted"), i.e., they are acutely malnourished. Children more than two standard deviations above the median weight-for-height z-score are considered overweight.
- *Weight-for-age*: Weight-for-age, also referred to as “underweight,” takes into account both chronic and acute malnutrition and is often used to monitor nutritional status on a longitudinal basis.

Z-score is an indicator used in data analysis which measures how far a given data point is from the mean of the data. A z-score is derived by subtracting the population mean from an individual raw score and then dividing the difference by the population standard deviation. This conversion process is called standardizing or normalizing. We use z-scores because they allow us to identify a fixed point in the distributions of different indices across different ages and sex for conducting useful further analysis. The z-scores in this study are calculated as the difference between the height (length)/weight value for an individual child and the mean/median height (length)/weight value of the reference/standard population for the same age and sex, divided by the standard deviation of the reference/standard population.

The nutritional status of children from 10 DHS surveys was compared using the using both the 1977 NCHS Reference the 2006 WHO Standards. The algorithms suggested by Hong and de Onis (2008) were applied to convert the 1977 NCHS Reference point estimates into their equivalent 2006 WHO Standards values, to calculate the prevalence of malnutrition in children.

In order to see the differences in mean z-scores, values were derived by subtracting the mean z-scores based on the 2006 WHO Standards from those of the 1977 NCHS Reference. The differences in the mean z-scores were calculated for the total sample and for each of the selected background characteristics that could influence the measurement and nutritional status of children. The standard deviations of the mean z-scores based on each standard were also computed.

3. Background characteristics included in the analysis

- Child's age was determined by subtracting the date of the birth of the child from the date of measurement of the child. Then age was categorized into eight subgroups for analytical purposes. For the calculation of the z-scores, both the child's full date of birth (year, month, and day) and the full date of interview were used.

- Child's sex.
- Child's birth order (1, 2-4, 5+).
- Socioeconomic characteristics: Type of area of residence (urban, rural), household wealth index quintile (poorest to richest), and mother's education (none, primary, secondary or higher).
- Age and method of measurement: Two of the anthropometric indices (height-for-age and weight-for-age) are influenced by the accuracy of the reporting of the child's age. In the DHS, as recommended, the child's height is measured either lying down (length) and or standing (height), based on the child's age. A variable was created to indicate whether the child was appropriately measured for his or her age and was used as a background variable for the bivariate and multivariate analyses.
- Exclusive breastfeeding: One of the criteria in the development of the 2006 WHO Standards was that children of only those mothers who were willing to follow the MGRS feeding recommendations (see footnote 3) were selected. Hence, exclusive breastfeeding was included as a background variable in multivariate analysis to explore whether this characteristic influences results by the 2006 WHO Standards.

4. Methods of analysis (univariate, bivariate and multivariate)

- Simple univariate tables were created to assess the nutrition status of the children from the 10 DHS countries using the 1977 NCHS Reference and the 2006 WHO Standards. The mean z-scores and differences between the mean z-scores were calculated for each of the three anthropometric indices, height-for-age, weight-for-height, and weight-for-age.

- Bivariate tables were constructed for each of the countries to show the difference by background characteristics in the mean z-scores of each of the three indices.
- Multivariate models were run to explore the influence of the background characteristics on the mean differences in height-for-age, weight-for-height, and weight-for-age z-scores. The data file included all 10 countries pooled together to run the analysis of variance (ANOVA) and multiple classification analysis (MCA) regression models. The data file was also split into three categories by age—children under age 24 months, age 24 months, and age 25 months and over—and analysis of variance and multiple classification analysis were performed for each age split to see if there are interactive effects.

Natural variations in height and weight of well-fed children follow a normal distribution. Therefore we prepared curves of the distribution of the children's z-scores from the two standards and compared them with the cumulative normal distribution curve for the three anthropometric indices for each country.

5. Elite children

To simulate the population selected for the creation of the 2006 WHO Standards, we also selected elite children from our data sets. Elite children were defined as children whose mothers had secondary or higher education; father or mother's current partner had secondary or higher education; the child's household had electricity, a refrigerator, a TV, an automobile or truck; and were children who neither suffered from diarrhea nor had a cough or fever in two weeks preceding the survey. Children under age 5 months were also excluded from the elite group if they were not exclusively breastfed, as well as children age 5 months or older if they did not receive complementary foods with breastfeeding. Also excluded were children for whom the type of measurement conducted was not as recommended. We then prepared curves of the cumulative distributions of these elite children's z-scores based on the two standards and compared them with the cumulative normal distribution.

RESULTS

Prevalence of Stunting, Wasting, Overweight, and Underweight

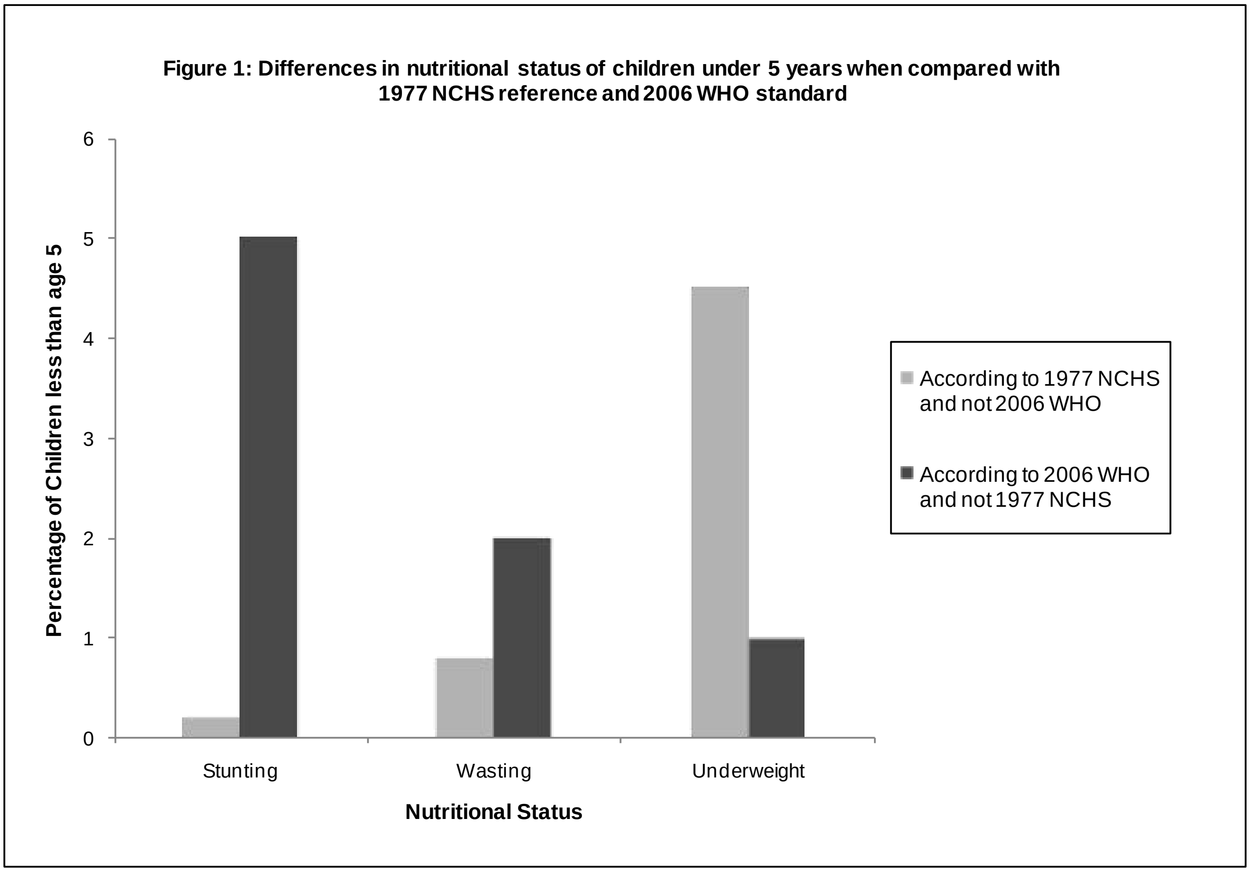
The prevalence of stunting, wasting, and overweight in children under age 5 years is higher in the surveyed countries using the 2006 WHO Standards than using the 1977 NCHS Reference, except for wasting in Peru, where it has the same very low value (Table 1). However, the prevalence of underweight is higher in all countries using the 1977 NCHS Reference compared with the 2006 WHO Standards. On average, when the indices are based on the 2006 WHO Standards, the prevalence of stunting is 4 percentage points higher and underweight is 4 percentage points lower than when based on the 1977 NCHS Reference. Differences in the prevalence of wasting and overweight are only 1 and 2 percentage points, comparing the two international standards.

Table 1: Percentage of children under five years living with their mothers classified as malnourished according to three anthropometric indices of nutritional status: height-for-age (stunting), weight-for-height (wasting and overweight), and weight-for-age (underweight).

Country, Year	Percentage stunted (below -2SD)		Percentage wasted (below -2SD)		Percentage underweight (below -2SD)		Percentage overweight (above +2SD)		Number of children
	1977 NCHS	2006 WHO	1977 NCHS	2006 WHO	1977 NCHS	2006 WHO	1977 NCHS	2006 WHO	
Azerbaijan 2006	20.8	23.1	5.5	6.9	9.5	7.8	7.2	10.5	1,919
Dominican Republic 2007	7.1	9.5	1.9	2.2	4.2	3.0	6.3	8.1	8,675
Ethiopia 2005	46.1	50.8	10.3	11.8	38.0	33.3	2.6	3.6	4,255
India 2005-06	42.4	47.9	16.9	19.7	47.7	42.6	1.0	1.2	44,546
Liberia 2007	33.3	37.5	6.2	7.5	22.3	18.1	2.0	3.5	4,102
Mali 2006	33.6	37.5	13.5	15.3	31.7	26.9	2.8	3.6	10,614
Nepal 2006	42.6	49.3	11.7	12.7	44.8	38.5	0.5	0.6	4,998
Peru 2007	23.7	29.6	1.0	1.0	7.5	5.3	6.3	8.9	3,565
Swaziland 2006	22.1	26.9	2.2	2.5	6.4	5.0	7.5	10.0	2,044
Uganda 2006	31.3	37.1	5.4	6.4	20.0	15.8	3.1	4.3	2,367
Average percentage	**30.3**	**34.4**	**7.5**	**8.6**	**23.2**	**19.6**	**3.9**	**5.4**	**87,085**

Differing Classifications of Children as Stunted, Wasted, and Underweight according to Standard

A child may be classified as malnourished (stunted, wasted, or underweight) by one standard but not the other. Table 2 and Figure 1 present the different classifications of stunting, wasting, and underweight in children under age 5 years by the two standards.



Taking an average of the 10 surveys included in the analysis, Table 2 indicates that both the 1977 NCHS Reference and the 2006 WHO Standards classified 65 percent of children as not stunted, and both classified 30 percent of children as stunted. The remaining 5 percent are children who were classified as stunted on the 2006 WHO Standards but not on the 1977 NCHS Reference (and virtually no children were classified as stunted on the 1977 NCHS Reference but not on the 2006 WHO Standards.) For wasting, the respective values are 91 percent, 7 percent, and 2 percent, and almost 1 percent classified as wasted on the 1977 NCHS Reference but not on the 2006 WHO Standards. For underweight, the respective averages are 76 percent, 19 percent, and 1 percent, with 4.5 percent classified as underweight on the 1977 NCHS Reference but not on the 2006 WHO Standards. Figure 1 shows these results graphically for the averages over the countries.

Table 2: Differences in stunting, wasting, and underweight in children under 5 years by 1977 NCHS Reference and 2006 WHO Standards.

	Percentage of children not stunted by 1977 NCHS and 2006 WHO	Percentage of children stunted by both 1977 NCHS and 2006 WHO	Percentage of children stunted by 1977 NCHS and not by 2006 WHO	Percentage of children stunted by 2006 WHO and not by 1977 NCHS
Azerbaijan 2007	77.3	19.2	0.0	3.5
Dominican Republic 2007	90.5	7.1	0.0	2.4
Ethiopia 2005	49.1	45.6	0.2	5.1
India 2005-06	51.9	42.1	0.2	5.8
Liberia 2007	62.3	32.8	0.3	4.6
Mali 2006	62.2	33.0	0.4	4.4
Nepal 2006	50.8	42.6	0.0	6.6
Peru 2007	70.4	23.7	0.0	5.9
Swaziland 2006	72.9	21.6	0.3	5.2
Uganda 2006	62.9	30.9	0.1	6.1
Average	**65.0**	**29.9**	**0.2**	**5.0**

To be continued..

Table 2 --- Continued

	Percentage of children not wasted by 1977 NCHS and 2006 WHO	Percentage of children wasted by both 1977 NCHS and 2006 WHO	Percentage of children wasted by 1977 NCHS and not by 2006 WHO	Percentage of children wasted by 2006 WHO and not by 1977 NCHS
Azerbaijan 2007	92.3	4.7	0.8	2.2
Dominican Republic 2007	97.5	1.5	0.4	0.7
Ethiopia 2005	87.1	9.2	1.0	2.6
India 2005-06	78.8	15.4	1.5	4.3
Liberia 2007	92.0	5.7	0.5	1.8
Mali 2006	83.5	12.4	1.1	3.0
Nepal 2006	85.6	10.1	1.7	2.6
Peru 2007	98.8	0.8	0.1	0.2
Swaziland 2006	97.4	2.0	0.2	0.4
Uganda 2006	92.8	4.6	0.7	1.8
Average	**90.6**	**6.6**	**0.8**	**2.0**

	Percentage of children not underweight by 1977 NCHS and 2006 WHO	Percentage of children underweight by both 1977 NCHS and 2006 WHO	Percentage of children underweight by 1977 NCHS and not by 2006 WHO	Percentage of children underweight by 2006 WHO and not by 1977 NCHS
Azerbaijan 2007	89.8	7.1	2.4	0.7
Dominican Republic 2007	95.5	2.7	1.5	0.3
Ethiopia 2005	61.2	32.5	5.5	0.9
India 2005-06	50.4	40.6	7.1	2.0
Liberia 2007	76.6	17.1	5.3	1.0
Mali 2006	67.2	25.8	5.9	1.1
Nepal 2006	53.8	37.1	7.7	1.4
Peru 2007	92.2	5.1	2.5	0.3
Swaziland 2006	92.8	4.2	2.2	0.8
Uganda 2006	79.0	14.8	5.2	1.0
Average	**75.9**	**18.7**	**4.5**	**1.0**

Mean and Standard Deviations of the Z-Scores by Standard

Table 3 presents the average value of each country's z-scores using the 1977 NCHS Reference, the 2006 WHO Standards, and the differences between them. For height-for-age, the mean z-scores are consistently lower across all the countries using the 2006 WHO Standards, with an average difference of 0.16. The situation is reversed for weight-for-age, as mean weight-for-age z-scores are consistently higher using the 2006 WHO Standards. The weight-for-height mean z-scores are also consistently higher for the 2006 WHO Standards than for the 1977 NCHS Reference.

Table 3: Mean Z-scores and difference in mean z-scores (1977 NCHS-2006 WHO) using 1977 NCHS Reference and 2006 WHO Standards.

	Height-for- age (HAZ)			Weight-for-height (WHZ)			Weight-for-age (WAZ)		
	Mean (SD) Z-score by 1977 NCHS References	**Mean (SD) Z-score by 2006 WHO Standards**	**Difference in the Mean (SD) Z-score between the two standards (1977 NCHS-2006 WHO)**	**Mean (SD) Z-score by 1977 NCHS References**	**Mean (SD) Z-score by 2006 WHO Standards**	**Difference in the Mean (SD) Z-score between the two standards (1977 NCHS-2006 WHO)**	**Mean (SD) Z-score by 1977 NCHS References**	**Mean (SD) Z-score by 2006 WHO Standards**	**Difference in the Mean (SD) Z-score between the two standards (1977 NCHS-2006 WHO)**
Azerbaijan 2007	-0.89 (1.50)	-1.03 (1.60)	0.13 (0.24)	0.04 (1.30)	0.26 (1.49)	-0.22 (0.39)	-0.55 (1.10)	-0.42 (1.09)	-0.13 (0.29)
Dominican Republic 2006	-0.26 (1.26)	-0.40 (1.33)	0.14 (0.24)	0.18 (1.13)	0.39 (1.17)	-0.21 (0.29)	-0.07 (1.22)	0.05 (1.12)	-0.12 (0.27)
Ethiopia 2005	-1.75 (1.74)	-1.92 (1.82)	0.17 (0.23)	-0.58 (1.20)	-0.45 (1.38)	-0.13 (0.39)	-1.52 (1.33)	-1.42 (1.33)	-0.09 (0.30)
India 2005-06	-1.69 (1.56)	-1.87 (1.63)	0.18 (0.23)	-1.07 (1.05)	-1.02 (1.22)	-0.05 (0.40)	-1.85 (1.16)	-1.78 (1.25)	-0.07 (0.32)
Liberia 2007	-1.35 (1.64)	-1.50 (1.74)	0.15 (0.25)	-0.31 (1.12)	-0.11 (1.28)	-0.20 (0.36)	-1.07 (1.25)	-0.95 (1.23)	-0.13 (0.28)
Mali 2006	-1.30 (1.74)	-1.43 (1.85)	0.13 (0.26)	-0.67 (1.25)	-0.59 (1.45)	-0.08 (0.40)	-1.32 (1.37)	-1.23 (1.36)	-0.09 (0.32)
Nepal 2006	-1.74 (1.29)	-1.92 (1.34)	0.18 ((0.18)	-0.95 (0.91)	-0.84 (1.06)	-0.11 (0.36)	-1.80 (1.05)	-1.69(1.08)	-0.10 (0.29)
Peru 2007	-1.16 (1.18)	-1.33 (1.24)	0.17 (0.18)	0.39 (1.01)	0.67 (1.03)	-0.28 (0.27)	-0.44 (1.16)	-0.29 (1.08)	-0.15 (0.26)
Swaziland 2006	-1.05 (1.31)	-1.19 (1.42)	0.14 (0.24)	0.33 (1.16)	0.56 (1.22)	-0.23 (0.30)	-0.42 (1.20)	-0.27 (1.12)	-0.14 (0.28)
Uganda 2006	-1.33 (1.45)	-1.51 (1.55)	0.18 (0.25)	-0.22 (1.12)	-0.01 (1.26)	-0.21 (0.37)	-1.01 (1.23)	-0.87 (1.20)	-0.13 (0.29)
Average Z-scores	**-1.25 (1.47)**	**-1.41 (1.56)**	**0.16 (0.21)**	**-0.29 (1.13)**	**-0.11 (1.26)**	**-0.17 (0.35)**	**-1.01 (1.21)**	**-0.89 (1.19)**	**-0.12 (0.29)**

Application of the Algorithm for Translating 1977 NCHS Reference Values into 2006 WHO Estimates

In the absence of 2006 WHO Standards-based estimates of malnutrition, Hong and de Onis (2008) recommend applying an algorithm to the 1977 NCHS Reference values in order to estimate equivalent values of malnutrition for the 2006 WHO Standards for the purpose of assessing trends. Applying this algorithm gives consistently higher prevalences for all the indices than do direct calculations using the 2006 WHO Standards. The greatest difference between the estimated and calculated prevalence values using the 2006 WHO Standards are for stunting, with an average of 1.6 percentage points higher for the algorithm-estimated value (Table 4a).

The Hong-de Onis algorithm was also applied separately for children in age groups 0-5 months, 6-23 months, and 24-59 months (Table 4b). For age 0-5 months, fewer children are classified as undernourished using the algorithm than from directly applying the 2006 WHO Standards. Wasting and underweight are about 12 percentage points less when estimated with the algorithm compared with directly applying the 2006 WHO Standards. For children age 6-23 months, using the algorithm produces a prevalence of underweight that exceeds the actual 2006 WHO Standards by about 3 percentage points, and a prevalence of stunting about 4 percentage points higher. The overestimate for wasting and overweight is less than 2 percentage points.

The closest results of the algorithm to the actual 2006 WHO Standards z-scores occur for children age 24-59 months, indicating that using the algorithm probably works better than directly applying the 2006 WHO standards for children age 2 years or older (Table 4b).

Table 4a: Prevalence estimates calculated using 1977 NCHS Reference based prevalence, to derive 2006 WHO Standards equivalent prevalence by using algorithm published by Yang and de Onis, 2008

Country, Year	Height-for-age Stunted (below -2SD)			Weight-for-height Wasted (below -2SD)			Weight-for-age Underweight (below -2SD)			Weight-for-height Overweight (+2SD)			Number of children
	1977 NCHS	2006 WHO (Pre-dicted)	2006 WHO (From data)	1977 NCHS	2006 WHO (Pre-dicted)	2006 WHO (From data)	1977 NCHS	2006 WHO (Pre-dicted)	2006 WHO (From data)	1977 NCHS	2006 WHO (Pre-dicted)	2006 WHO (From data)	
Azerbaijan 2006	20.8	26.5	23.1	5.5	6.8	6.9	9.5	8.3	7.8	7.2	10.9	10.5	1,919
Dominican Republic 2007	7.1	10.3	9.5	1.9	2.6	2.2	4.2	3.7	3.0	6.3	9.7	8.1	8,675
Ethiopia 2005	46.1	51.8	50.8	10.3	12.1	11.8	38.0	34.1	33.3	2.6	4.4	3.6	4,255
India 2005-06	42.4	48.3	47.9	16.9	19.0	19.7	47.7	43.3	42.6	1.0	1.9	1.2	44,546
Liberia 2007	33.3	39.5	32.5	6.2	7.6	7.5	22.3	19.6	18.1	2.0	3.5	3.5	4,102
Mali 2006	33.6	39.8	37.5	13.5	15.5	15.3	31.7	28.2	26.9	2.8	4.7	3.6	10,614
Nepal 2006	42.6	48.5	49.3	11.7	13.6	12.7	44.8	40.5	38.5	0.5	1.0	0.6	4,998
Peru 2007	23.7	29.6	29.6	1.0	1.4	1.0	7.5	6.6	5.3	6.3	9.7	8.9	3,565
Swaziland 2006	22.1	27.9	26.9	2.2	2.9	2.5	6.4	5.6	5.0	7.5	11.3	10.0	2,044
Uganda 2006	31.3	37.5	37.1	5.4	6.7	6.4	20.0	17.6	15.8	3.1	5.2	4.3	2,367
Average Percentage	**30.3**	**36.0**	**34.4**	**7.5**	**8.8**	**8.6**	**23.2**	**20.8**	**19.6**	**3.9**	**6.2**	**5.4**	**87,085**

Note: Excel file of the algorithm used here to calculate the predicted 2006 WHO column can be downloaded from [http://www.biomedcentral.com/content /supplementary/1471-2431-8-19-S1.doc]

Table 4b: Prevalence estimates calculated using 1977 NCHS Reference based prevalence, to derive 2006 WHO Standards equivalent prevalence by using algorithm published by Yang and de Onis, 2008, by **children's age.**

0-5 months children

Algorithms	1977 NCHS based prevalence (%)	2006 WHO-prevalence predicted from the algorithm	2006 WHO prevalence from the data	Difference (Predicted - Actual) prevalence	95% CI predicted WHO prevalence	
					Lower limit	Upper limit
Stunting	7.7	11.1	12.8	-1.7	9.2	13.4
Wasting	5.7	7.1	19.3	-12.2	5.1	9.6
Underweight	4.6	4.0	15.7	-11.7	2.4	6.7
Overweight	7.0	10.7	7.1	3.6	6.7	16.5

6-23 months children

Algorithms	1977 NCHS based prevalence (%)	2006 WHO-prevalence predicted from the algorithm	2006 WHO prevalence from the data	Difference (Predicted - Actual) prevalence	95% CI predicted WHO prevalence	
					Lower limit	Upper limit
Stunting	32.4	38.6	34.2	4.4	33.7	43.7
Wasting	15.6	17.6	16.4	1.2	13.2	23.1
Underweight	33.7	30.0	26.6	3.4	20.1	42.3
Overweight	3.0	5.0	3.5	1.5	3.1	8.0

24-59 months children

Algorithms	1977 NCHS based prevalence (%)	2006 WHO-prevalence predicted from the algorithm	2006 WHO prevalence from the data	Difference (Predicted - Actual) prevalence	95% CI predicted WHO prevalence	
					Lower limit	Upper limit
Stunting	37.2	43.3	43.5	-0.2	38.2	48.6
Wasting	9.8	11.6	10.3	1.3	8.5	15.5
Underweight	34.6	30.9	29.6	1.3	20.8	43.2
Overweight	1.8	3.2	3.0	0.2	2.0	5.2

Bivariate Relationships with Mean Differences in Z-Scores between Standards, according to Child Characteristics

Tables 5a, 5b, and 5c present the bivariate results for differences between the mean z-scores by standard used for height-for-age (HAZ), weight-for-height (WHZ), and weight-for-age (WAZ), according to various background characteristics. Since the 2006 WHO Standards value is subtracted from the 1977 NCHS Reference value, a positive difference indicates a higher 1977 NCHS value4 (i.e. a positive value indicates that children are better nourished or less malnourished using the 1977 NCHS Reference than using the 2006 WHO Standards).

1. Height-for-age

In children's first 6 months of life, all of the 10 surveys show a somewhat lower mean HAZ difference by the 2006 WHO Standards (Table 5a). However, for age 6-17 months the mean HAZ is slightly higher with the 2006 WHO Standards. This difference is especially notable in Azerbaijan 2007 and Dominican Republic 2006 for children age 6-11 months. The mean HAZ difference takes its most positive values for children age 24-36 months.

[4] NCHS (mean z-score) – WHO (mean z-score) = Mean z-score difference
Example: (-0.89) – (-1.03) = 0.13
(-0.95) – (-0.84) = -0.11

Table 5a: Difference in the mean z-scores for height-for-age of the children 0-59 months by various background characteristics.

	Mean difference in height-for-age z-score (1977 NCHS-2006 WHO)										
	Azerbaijan 2007	**Dominican Republic 2006**	**Ethiopia 2005**	**India 2005-06**	**Liberia 2007**	**Mali 2006**	**Nepal 2006**	**Peru 2007**	**Swaziland 2006**	**Uganda 2006**	**Average**
Child's Age											
0-5	0.13	0.09	0.09	0.16	0.06	0.04	0.16	0.17	0.12	0.14	0.12
6-11	-0.11	-0.12	0.06	0.04	-0.02	-0.05	0.05	0.01	-0.07	0.00	-0.02
12-17	-0.05	-0.08	0.03	0.02	-0.03	-0.04	0.06	0.03	-0.04	0.04	-0.01
18-23	-0.03	-0.03	0.07	0.07	0.03	0.01	0.13	0.09	0.00	0.04	0.04
24-29	0.37	0.42	0.45	0.48	0.45	0.43	0.43	0.42	0.42	0.51	0.44
30-35	0.38	0.39	0.41	0.41	0.42	0.39	0.37	0.36	0.38	0.43	0.39
36-47	0.23	0.23	0.21	0.22	0.22	0.24	0.22	0.23	0.24	0.24	0.23
48-59	0.10	0.12	0.08	0.07	0.08	0.10	0.07	0.10	0.11	0.09	0.09
Residence											
Urban	0.12	0.13	0.13	0.16	0.14	0.12	0.16	0.15	0.12	0.18	0.14
Rural	0.15	0.15	0.17	0.18	0.15	0.14	0.19	0.19	0.14	0.18	0.16
Mothers Education											
None	0.16	0.14	0.17	0.19	0.16	0.14	0.19	0.21	0.18	0.18	0.17
Primary	0.12	0.15	0.17	0.18	0.15	0.12	0.17	0.19	0.14	0.18	0.16
Secondary or higher	0.13	0.13	0.13	0.16	0.12	0.10	0.16	0.15	0.13	0.17	0.14
Sex											
Female	0.12	0.14	0.12	0.14	0.12	0.10	0.15	0.15	0.12	0.14	0.13
Male	0.15	0.13	0.22	0.21	0.17	0.17	0.22	0.19	0.16	0.21	0.18
Wealth Index											
Poorest	0.14	0.15	0.16	0.20	0.17	0.15	0.19	0.19	0.15	0.19	0.17
Poorer	0.15	0.14	0.17	0.19	0.15	0.14	0.20	0.19	0.15	0.15	0.16
Middle	0.14	0.14	0.17	0.18	0.14	0.14	0.17	0.17	0.12	0.18	0.16
Richer	0.14	0.13	0.18	0.16	0.14	0.14	0.18	0.15	0.15	0.19	0.15
Richest	0.10	0.11	0.16	0.14	0.12	0.11	0.16	0.13	0.13	0.16	0.13

To be continued....

Table 5a --- Continued

	Mean difference in height-for-age z-score (1977 NCHS-2006 WHO)										
	Azerbaijan 2007	**Dominican Republic 2006**	**Ethiopia 2005**	**India 2005-06**	**Liberia 2007**	**Mali 2006**	**Nepal 2006**	**Peru 2007**	**Swaziland 2006**	**Uganda 2006**	**Average**
Had diarrhea in 2 weeks preceding the survey											
No	0.14	0.14	0.17	0.18	0.14	0.14	0.19	0.17	0.15	0.18	0.16
Yes	0.10	0.11	0.17	0.17	0.17	0.12	0.17	0.17	0.11	0.16	0.14
Birth Order											
1	0.14	0.13	0.17	0.17	0.14	0.13	0.17	0.16	0.13	0.19	0.15
2-4	0.13	0.14	0.16	0.18	0.15	0.13	0.19	0.17	0.14	0.18	0.16
5 +	0.18	0.14	0.17	0.19	0.15	0.15	0.19	0.20	0.15	0.17	0.17
Age and method of measurement											
Age <24 mon & Lying	0.01	-0.02	0.09	0.11	0.04	0.04	0.10	0.07	0.03	0.07	0.05
Age <24 mon & Standing	-0.26	-0.25	-0.12	-0.15	-0.17	-0.17	-0.03	0.00	-0.15	-0.17	-0.15
Age >23 mon & Lying	0.35	0.45	0.50	0.50	0.47	0.51	0.11	0.17	0.44	0.51	0.40
Age >23 mon & Standing	0.24	0.23	0.22	0.22	0.22	0.24	0.23	0.24	0.25	0.22	0.23
Exclusive breastfeeding (children less than 6 months)											
No	0.15	0.09	0.04	0.16	0.06	0.04	0.18	0.12	0.15	0.20	0.12
Yes	0.02	0.07	0.18	0.16	0.05	0.04	0.13	0.19	0.06	0.10	0.10

Table 5b : Difference in the mean z-scores for weight-for-height of the children 0-59 months by various background characteristics

	Mean difference in weight-for-height z-score (1977 NCHS-2006 WHO)										
	Azerbaijan 2007	Dominican Republic 2006	Ethiopia 2005	India 2005-06	Liberia 2007	Mali 2006	Nepal 2006	Peru 2007	Swaziland 2006	Uganda 2006	Average
Child's Age											
0-5	0.44	0.24	0.44	0.70	0.30	0.48	0.54	0.14	0.17	0.37	0.38
6-11	-0.06	-0.13	0.19	0.26	0.06	0.17	0.21	-0.06	-0.05	0.11	0.07
12-17	-0.36	-0.36	-0.14	-0.09	-0.19	-0.10	-0.19	-0.33	-0.27	-0.21	-0.22
18-23	-0.34	-0.37	-0.27	-0.24	-0.33	-0.23	-0.35	-0.42	-0.30	-0.35	-0.32
24-29	-0.42	-0.42	-0.33	-0.23	-0.42	-0.29	-0.25	-0.50	-0.52	-0.47	-0.39
30-35	-0.42	-0.35	-0.35	-0.21	-0.41	-0.29	-0.26	-0.43	-0.46	-0.44	-0.36
36-47	-0.37	-0.22	-0.25	-0.16	-0.32	-0.23	-0.20	-0.33	-0.32	-0.32	-0.27
48-59	-0.17	-0.09	-0.16	-0.09	-0.21	-0.13	-0.14	-0.20	-0.18	-0.21	-0.16
Residence											
Urban	-0.23	-0.20	-0.17	-0.08	-0.19	-0.09	-0.18	-0.25	-0.18	-0.14	-0.17
Rural	-0.22	-0.23	-0.13	-0.03	-0.21	-0.08	-0.10	-0.29	-0.25	-0.21	-0.17
Mothers Education											
None	-0.45	-0.21	-0.12	-0.02	-0.21	-0.08	-0.09	-0.30	-0.22	-0.19	-0.19
Primary	-0.16	-0.21	-0.16	-0.05	-0.18	-0.08	-0.14	-0.29	-0.26	-0.22	-0.17
Secondary or higher	-0.22	-0.20	-0.20	-0.08	-0.20	-0.06	-0.13	-0.25	-0.23	-0.16	-0.17
Sex											
Female	-0.19	-0.15	-0.14	-0.05	-0.18	-0.07	-0.12	-0.22	-0.18	-0.18	-0.15
Male	-0.25	-0.26	-0.13	-0.05	-0.22	-0.09	-0.10	-0.32	-0.30	-0.22	-0.19
Wealth Index											
Poorest	-0.22	-0.23	-0.11	0.00	-0.21	-0.08	-0.10	-0.28	-0.25	-0.19	-0.17
Poorer	-0.20	-0.21	-0.11	-0.03	-0.20	-0.08	-0.09	-0.29	-0.26	-0.21	-0.17
Middle	-0.26	-0.18	-0.12	-0.05	-0.19	-0.09	-0.08	-0.28	-0.25	-0.22	-0.17
Richer	-0.21	-0.21	-0.16	-0.08	-0.21	-0.08	-0.10	-0.25	-0.21	-0.23	-0.17
Richest	-0.24	-0.20	-0.16	-0.12	-0.20	-0.08	-0.20	-0.24	-0.22	-0.16	-0.18

To be continued....

Table 5b --- Continued

	Mean difference in weight-for-height z-score (1977 NCHS-2006 WHO)										
	Azerbaijan 2007	Dominican Republic 2006	Ethiopia 2005	India 2005-06	Liberia 2007	Mali 2006	Nepal 2006	Peru 2007	Swaziland 2006	Uganda 2006	Average
Had diarrhea in 2 weeks preceding the survey											
No	-0.23	-0.20	-0.14	-0.06	-0.19	-0.08	-0.11	-0.27	-0.24	-0.22	-0.18
Yes	-0.19	-0.23	-0.09	0.04	-0.23	-0.07	-0.06	-0.29	-0.24	-0.14	-0.15
Birth Order											
1	-0.24	-0.20	-0.13	-0.06	-0.19	-0.05	-0.13	-0.26	-0.22	-0.19	-0.17
2-4	-0.22	-0.20	-0.13	-0.05	-0.20	-0.09	-0.11	-0.27	-0.24	-0.20	-0.17
5 +	-0.10	-0.23	-0.13	0.00	-0.21	-0.09	-0.07	-0.29	-0.25	-0.21	-0.16
Age and method of measurement											
Age <24 mon & Lying	-0.07	-0.17	0.08	0.17	-0.02	0.15	0.04	-0.18	-0.10	-0.02	-0.01
Age <24 mon & Standing	-0.19	-0.14	-0.09	-0.10	-0.14	-0.09	-0.33	0.00	-0.20	-0.14	-0.14
Age >23 mon & Lying	-0.49	-0.45	-0.40	-0.27	-0.47	-0.29	-0.45	-0.39	-0.46	-0.51	-0.42
Age >23 mon & Standing	-0.32	-0.21	-0.24	-0.14	-0.30	-0.22	-0.20	-0.33	-0.33	-0.29	-0.26
Exclusive breastfeeding (children less than 6 months)											
No	0.45	0.25	0.47	0.70	0.32	0.51	0.58	0.18	0.13	0.36	0.39
Yes	0.42	0.17	0.41	0.70	0.27	0.42	0.51	0.11	0.26	0.38	0.36

Table 5c : Difference in the mean z-scores for weight-for-age of the children 0-59 months by various background characteristics

	Mean difference in weight-for-age z-score (1977 NCHS-2006 WHO)										
	Azerbaijan 2007	**Dominican Republic 2006**	**Ethiopia 2005**	**India 2005-06**	**Liberia 2007**	**Mali 2006**	**Nepal 2006**	**Peru 2007**	**Swaziland 2006**	**Uganda 2006**	**Average**
Child's Age											
0-5	0.49	0.42	0.54	0.66	0.46	0.53	0.55	0.42	0.45	0.49	0.50
6-11	-0.12	-0.15	-0.04	0.00	-0.12	-0.05	-0.04	-0.16	-0.11	-0.10	-0.09
12-17	-0.46	-0.43	-0.38	-0.37	-0.43	-0.39	-0.39	-0.46	-0.46	-0.42	-0.42
18-23	-0.35	-0.33	-0.28	-0.24	-0.32	-0.28	-0.27	-0.35	-0.34	-0.33	-0.31
24-29	-0.25	-0.21	-0.23	-0.23	-0.25	-0.23	-0.25	-0.24	-0.24	-0.24	-0.24
30-35	-0.18	-0.17	-0.14	-0.12	-0.19	-0.16	-0.16	-0.21	-0.20	-0.19	-0.17
36-47	-0.15	-0.11	-0.10	-0.08	-0.13	-0.11	-0.10	-0.14	-0.15	-0.15	-0.12
48-59	-0.05	-0.02	-0.06	-0.05	-0.08	-0.06	-0.07	-0.05	-0.05	-0.08	-0.06
Residence											
Urban	-0.14	-0.11	-0.13	-0.11	-0.14	-0.12	-0.13	-0.13	-0.09	-0.07	-0.12
Rural	-0.12	-0.13	-0.09	-0.06	-0.12	-0.08	-0.09	-0.17	-0.15	-0.14	-0.12
Mothers Education											
None	-0.19	-0.12	-0.08	-0.04	-0.12	-0.09	-0.08	-0.17	-0.11	-0.13	-0.11
Primary	-0.13	-0.13	-0.12	-0.08	-0.13	-0.10	-0.11	-0.16	-0.17	-0.14	-0.13
Secondary or higher	-0.13	-0.11	-0.14	-0.12	-0.16	-0.10	-0.13	-0.13	-0.13	-0.10	-0.13
Sex											
Female	-0.13	-0.09	-0.12	-0.09	-0.14	-0.10	-0.12	-0.12	-0.11	-0.15	-0.12
Male	-0.13	-0.15	-0.07	-0.06	-0.12	-0.08	-0.08	-0.17	-0.17	-0.12	-0.12
Wealth Index											
Poorest	-0.14	-0.14	-0.09	-0.02	-0.11	-0.07	-0.08	-0.16	-0.16	-0.12	-0.11
Poorer	-0.11	-0.13	-0.08	-0.05	-0.11	-0.08	-0.09	-0.17	-0.16	-0.16	-0.11
Middle	-0.14	-0.10	-0.08	-0.08	-0.13	-0.10	-0.09	-0.15	-0.15	-0.14	-0.12
Richer	-0.13	-0.11	-0.10	-0.11	-0.14	-0.09	-0.11	-0.13	-0.11	-0.15	-0.12
Richest	-0.13	-0.10	-0.13	-0.14	-0.16	-0.12	-0.16	-0.10	-0.12	-0.10	-0.12

To be continued....

Table 5c --- Continued

	Mean difference in weight-for-age z-score (1977 NCHS-2006 WHO)										
	Azerbaijan 2007	Dominican Republic 2006	Ethiopia 2005	India 2005-06	Liberia 2007	Mali 2006	Nepal 2006	Peru 2007	Swaziland 2006	Uganda 2006	Average
Had diarrhea in 2 weeks preceding the survey											
No	-0.13	-0.11	-0.09	-0.08	-0.12	-0.08	-0.10	-0.14	-0.13	-0.12	-0.11
Yes	-0.14	-0.17	-0.11	-0.05	-0.18	-0.14	-0.11	-0.21	-0.21	-0.18	-0.15
Birth Order											
1.00	-0.14	-0.11	-0.08	-0.09	-0.13	-0.08	-0.12	-0.13	-0.15	-0.12	-0.12
2-4	-0.13	-0.12	-0.10	-0.08	-0.13	-0.10	-0.10	-0.15	-0.13	-0.13	-0.12
5 +	0.00	-0.14	-0.10	-0.02	-0.13	-0.09	-0.06	-0.16	-0.14	-0.14	-0.10
Age and method of measurement											
Age <24 mon & Lying	-0.09	-0.13	-0.02	0.04	-0.06	0.04	-0.05	-0.16	-0.08	-0.10	-0.06
Age <24 mon & Standing	-0.33	-0.23	-0.32	-0.32	-0.34	-0.33	-0.34	0.00	-0.38	-0.30	-0.29
Age >23 mon & Lying	-0.22	-0.19	-0.14	-0.08	-0.19	-0.14	-0.30	-0.26	-0.17	-0.20	-0.19
Age >23 mon & Standing	-0.14	-0.10	-0.12	-0.11	-0.14	-0.12	-0.13	-0.14	-0.14	-0.14	-0.13
Exclusive breastfeeding (children less than 6 months)											
No	0.51	0.43	0.52	0.67	0.48	0.55	0.60	0.40	0.43	0.52	0.51
Yes	0.35	0.38	0.56	0.66	0.43	0.50	0.50	0.44	0.49	0.46	0.48

Mean HAZ differences between the 1977 NCHS Reference and the 2006 WHO Standards are slightly greater for children in the poorest households compared with the wealthiest households. The differences in the HAZ using the two standards are also greater for children whose mothers had no education compared with those whose mothers who had secondary or higher education. The differences are also larger for rural children than children living in urban areas.

As mentioned, according to the 1977 NCHS Reference and the UNICEF guidelines for taking anthropometric measurements (UNICEF, 2006), children under age 24 months should be measured lying down, while older children should be measured standing up. Incompatibility between the child's age and how the child was measured leads to large differences in the mean z-scores, especially for children who were under age 24 months and were measured standing up, and for children over age 24 months who were measured lying down.

2. Weight-for-height

Table 5b presents differences in mean z-scores for weight-for-height (WHZ) between the 1977 NCHS Reference and the 2006 WHO Standards. By age, the greatest difference between the two standards occurs in ages 0-5 months, 18-23 months, 24-29 months, and 30-35 months. However, the differences are lower and are similar across all background variables, except for the form of measurement. Children age 24 months or older who were measured lying down differ by the greatest amount. The mean z-score by the 2000 WHO standard is higher by a value of 0.42 than the z-score by the 1977 NCHS reference, as shown by the negative difference. The large but similar differences between standards for both exclusively and non-exclusively breastfed children (0.39 for non-breastfed and 0.36 for breastfed) are because this variable was limited to children under age 6 months.

3. Weight-for-age

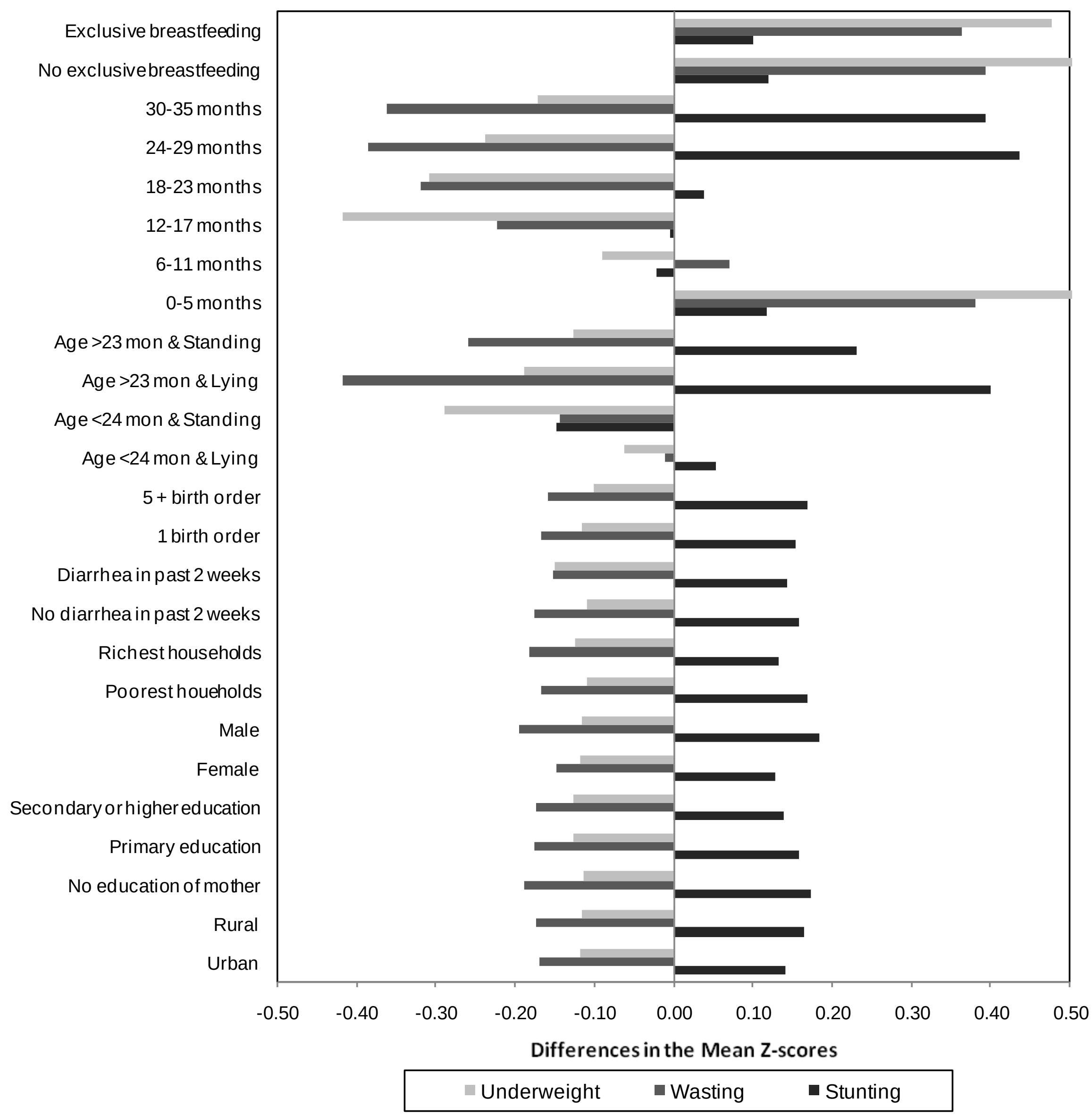
Similar to the findings for weight-for-height, the mean difference in the z-scores for weight-for-age (WAZ) comparing the two standards is greatest for infants under age 6 months, with the z-scores being higher for the 1977 NCHS Reference than the 2006 WHO Standards. For children age 12-23 months there are large differences in the opposite direction. By method of measurement, there is little difference between the two standards for children under age 2 years whose height was measured lying down but a relatively large difference for children under age 2 years who were measured standing up. This result is surprising because height does not enter into this index of nutritional status assessment. The other background variables do not show variations by category, but in general the 1977 NCHS Reference z-score for weight-for-age is lower than the 2006 WHO Standards z-score (Table 5c).

Table 6 and Figure 2 present the mean difference in the z-scores for HAZ, WHZ, and WAZ by the background characteristics for the 10 countries pooled together.

Table 6: Difference in the mean Z-scores for the three anthropometric indices of the children under 5 years of age by various background characteristics

	Average 10 countries		
Background characteristics	**Mean difference in height-for-age z-score (1977 NCHS-2006 WHO)**	**Mean difference in weight-for-height z-score (1977 NCHS-2006 WHO)**	**Mean difference in weight-for-age z-score (1977 NCHS-2006 WHO)**
Child's Age			
0-5	0.12	0.38	0.50
6-11	-0.02	0.07	-0.09
12-17	-0.01	-0.22	-0.42
18-23	0.04	-0.32	-0.31
24-29	0.44	-0.39	-0.24
30-35	0.39	-0.36	-0.17
36-47	0.23	-0.27	-0.12
48-59	0.09	-0.16	-0.06
Residence			
Urban	0.14	-0.17	-0.12
Rural	0.16	-0.17	-0.12
Mothers Education		0.00	
None	0.17	-0.19	-0.11
Primary	0.16	-0.17	-0.13
Secondary or higher	0.14	-0.17	-0.13
Sex			
Female	0.13	-0.15	-0.12
Male	0.18	-0.19	-0.12
Wealth Index			
Poorest	0.17	-0.17	-0.11
Poorer	0.16	-0.17	-0.11
Middle	0.16	-0.17	-0.12
Richer	0.15	-0.17	-0.12
Richest	0.13	-0.18	-0.12
Had diarrhea in 2 weeks preceding the survey			
No	0.16	-0.18	-0.11
Yes	0.14	-0.15	-0.15
Birth Order			
1	0.15	-0.17	-0.12
2-4	0.16	-0.17	-0.12
5 +	0.17	-0.16	-0.10
Age and method of measurement			
Age <24 mon & Lying	0.05	-0.01	-0.06
Age <24 mon & Standing	-0.15	-0.14	-0.29
Age >23 mon & Lying	0.40	-0.42	-0.19
Age >23 mon & Standing	0.23	-0.26	-0.13
Exclusive breastfeeding (children less than 6 months)			
No	0.12	0.39	0.51
Yes	0.10	0.36	0.48

Figure 2: Differences in the Mean Z scores by Background Characteristics

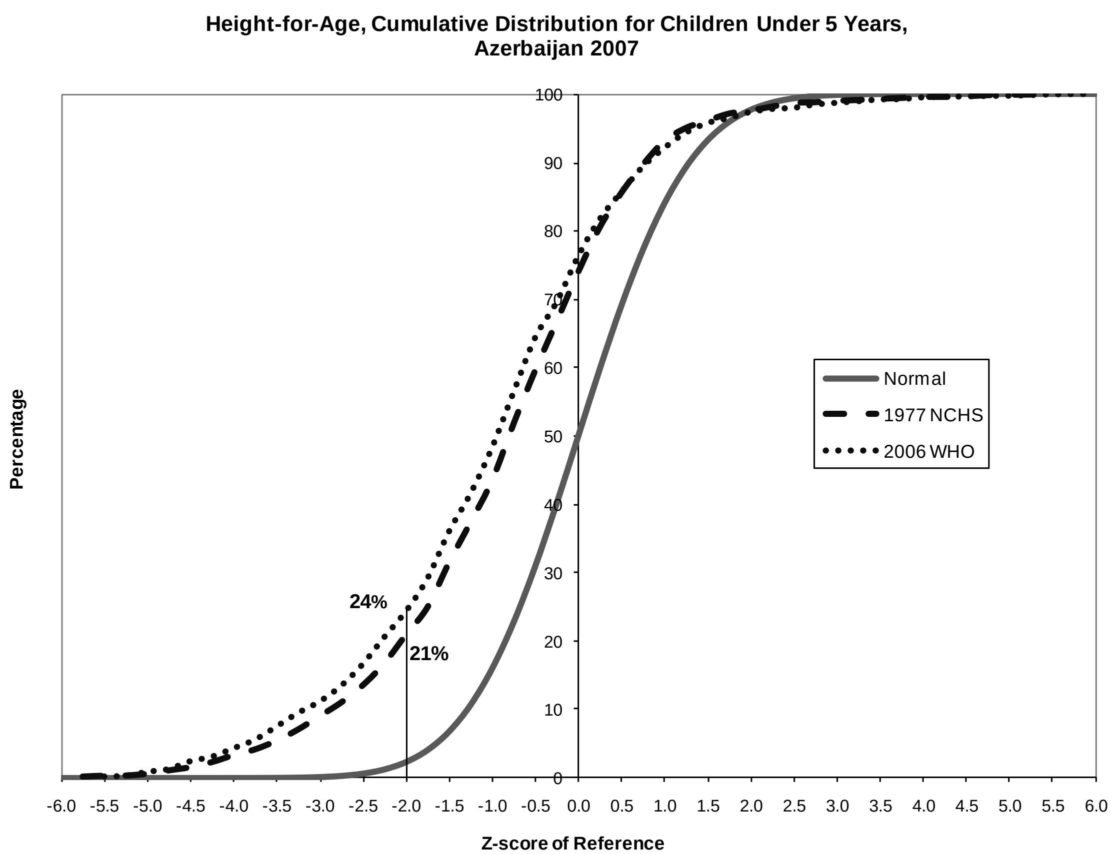


The maximum mean difference in the z-scores is observed for the WAZ index for children age 0-5 months, with a positive difference of 0.50. This finding indicates that there may be a higher prevalence of underweight by the 2006 WHO Standards in this age group. The other pronounced difference is in stunting for children age 24-35 months, where z-score is higher, perhaps an indication that using the 2006 WHO Standards produces a lower prevalence of stunting than using the 1977 NCHS Reference. Method of measurement shows large differences for the z-scores for height-for-age and weight-for-height for children age 24 months or older who were measured lying down, and for weight-for-height for children under age 24 months who were measured standing up. The other background characteristics do not show much variation between the two standards.

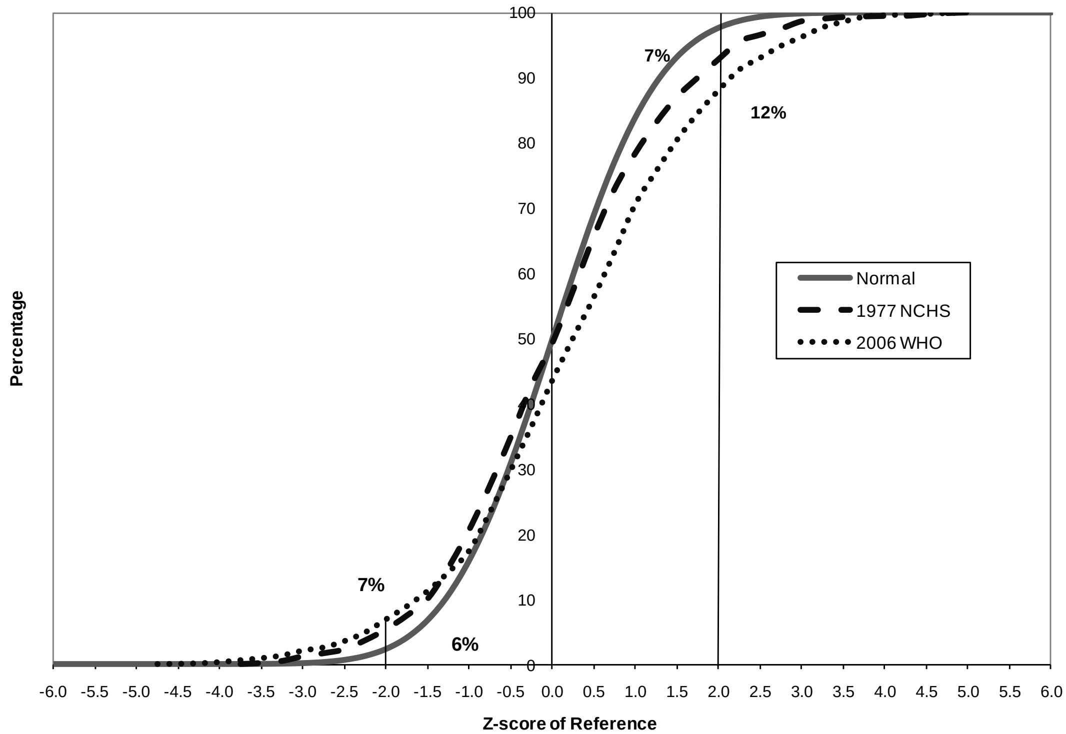
Graphical Comparison of the Standards by Country

Figures 3 through 12 compare the cumulative distributions of the z-scores of the three anthropometric indices by the two standards with the cumulative normal distribution curve for each of the 10 countries. If the children of a country are well nourished by one or the other standard, then the curve for the z-scores of that standard should follow the curve for the normal distribution.

Figure 3: Azerbaijan, 2007



Weight-for-Height, Cumulative Distribution for Children Under 5 Years, Azerbaijan 2007



Weight-for-Age, Cumulative Distribution for Children Under 5 Years, Azerbaijan 2007

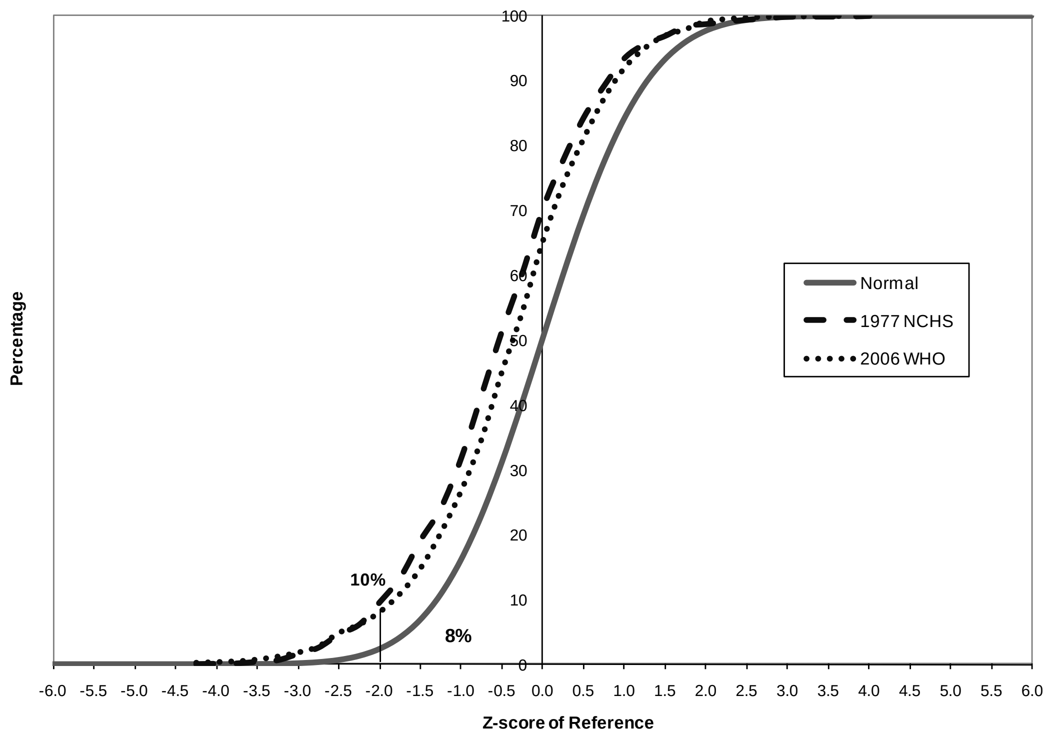
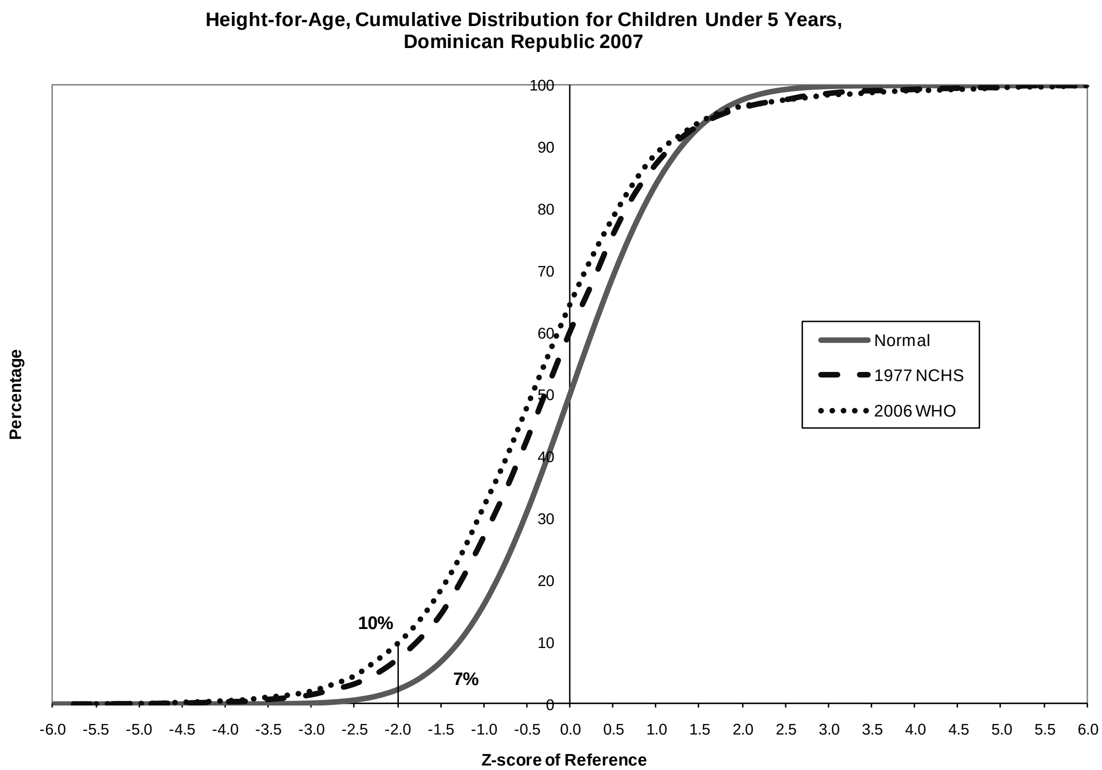
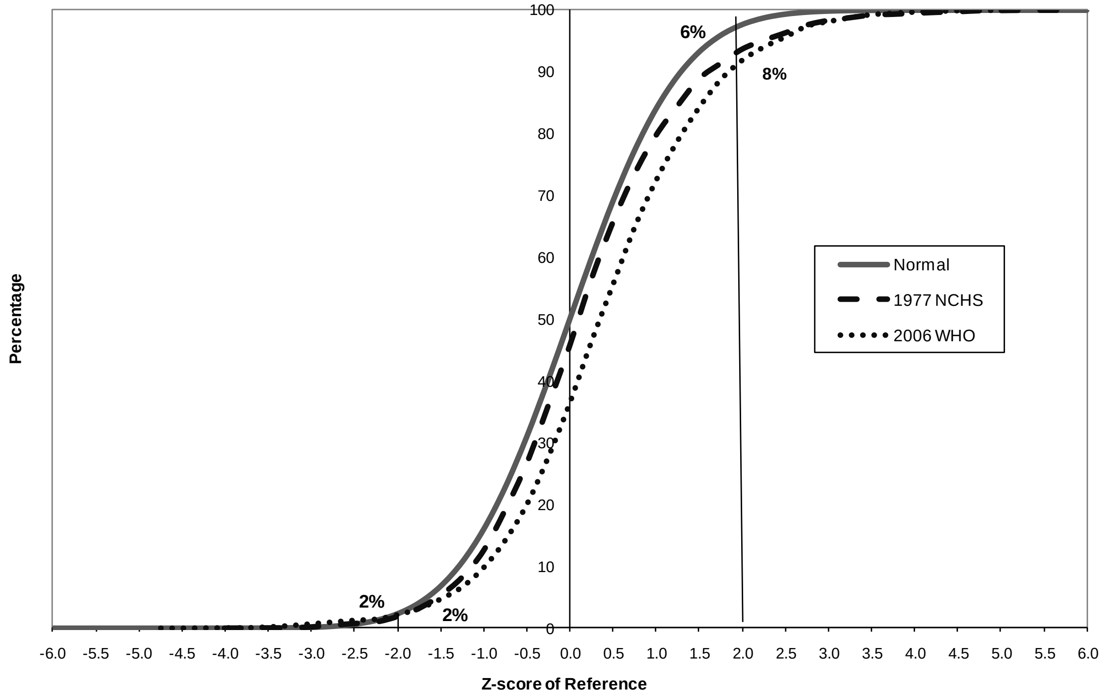


Figure 4: Dominican Republic, 2007



Weight-for-Height, Cumulative Distribution for Children Under 5 Years, Dominican Republic 2007



Weight-for-Age, Cumulative Distribution for Children Less than 5 Years of Age Dominican Republic 2007

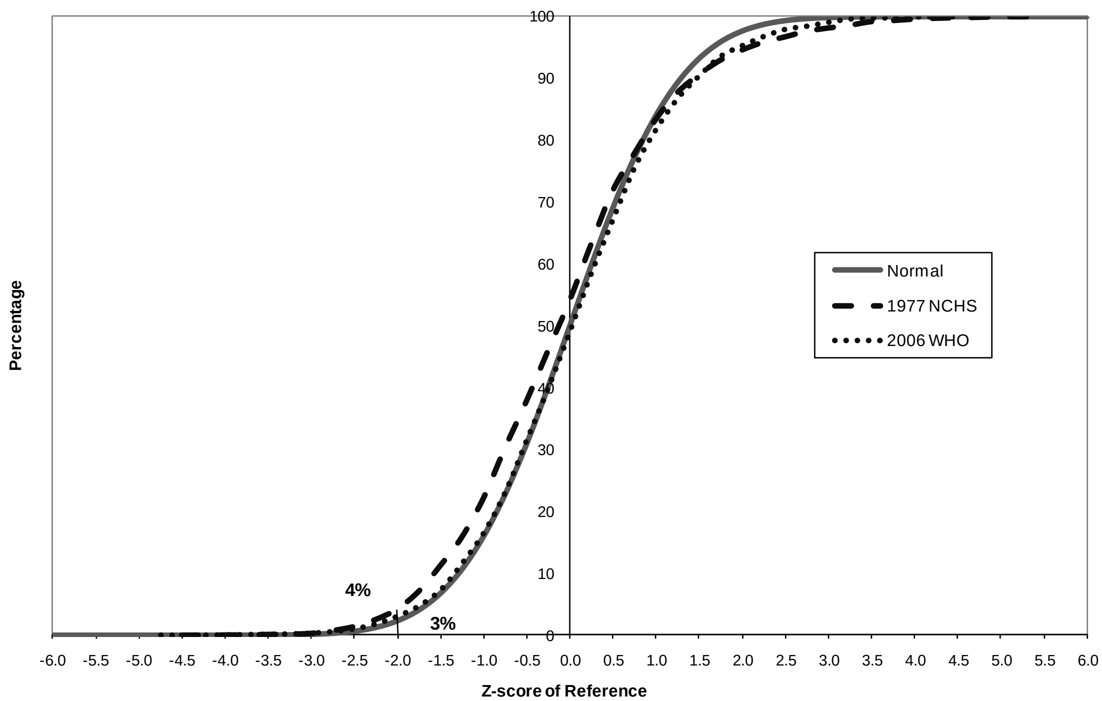
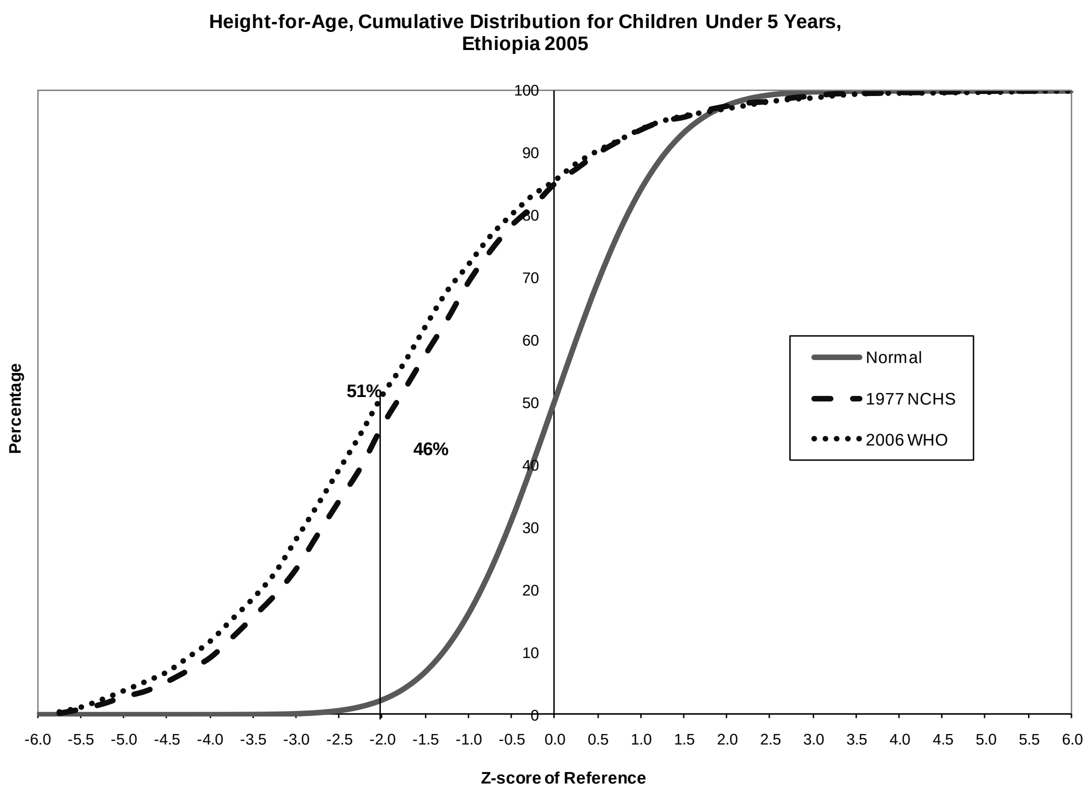
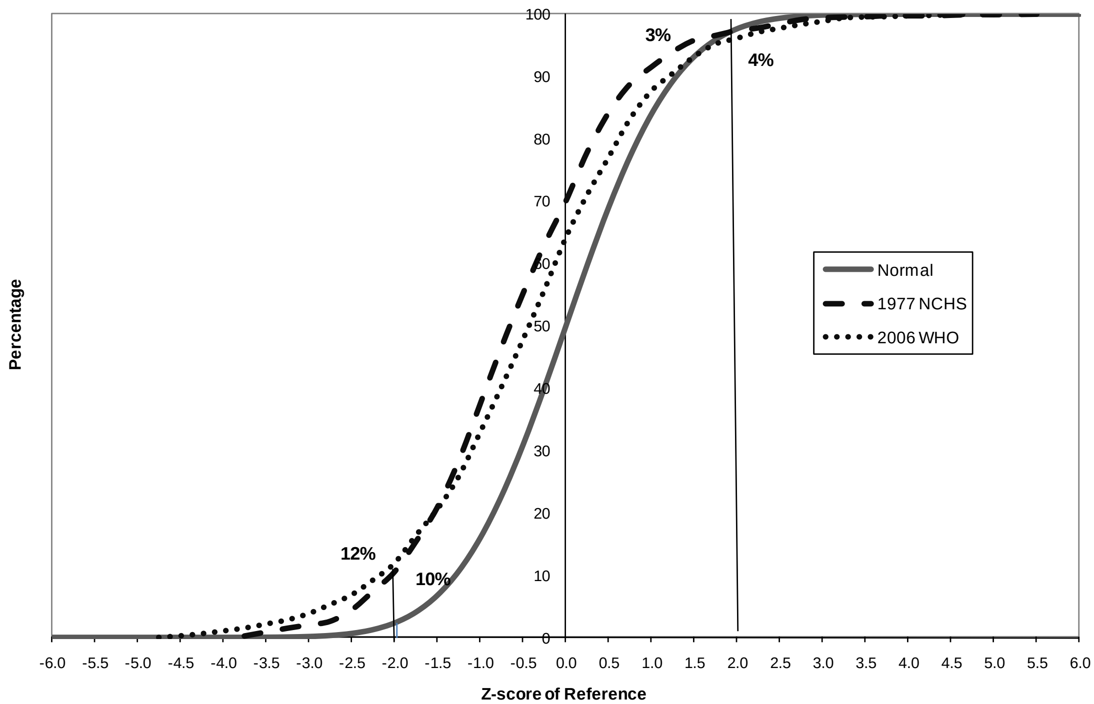


Figure 5: Ethiopia, 2005



Weight-for-Height, Cumulative Distribution for Children Under 5 Years, Ethiopia 2005



Weight-for-Age, Cumulative Distribution for Children Under 5 Years, Ethiopia 2005

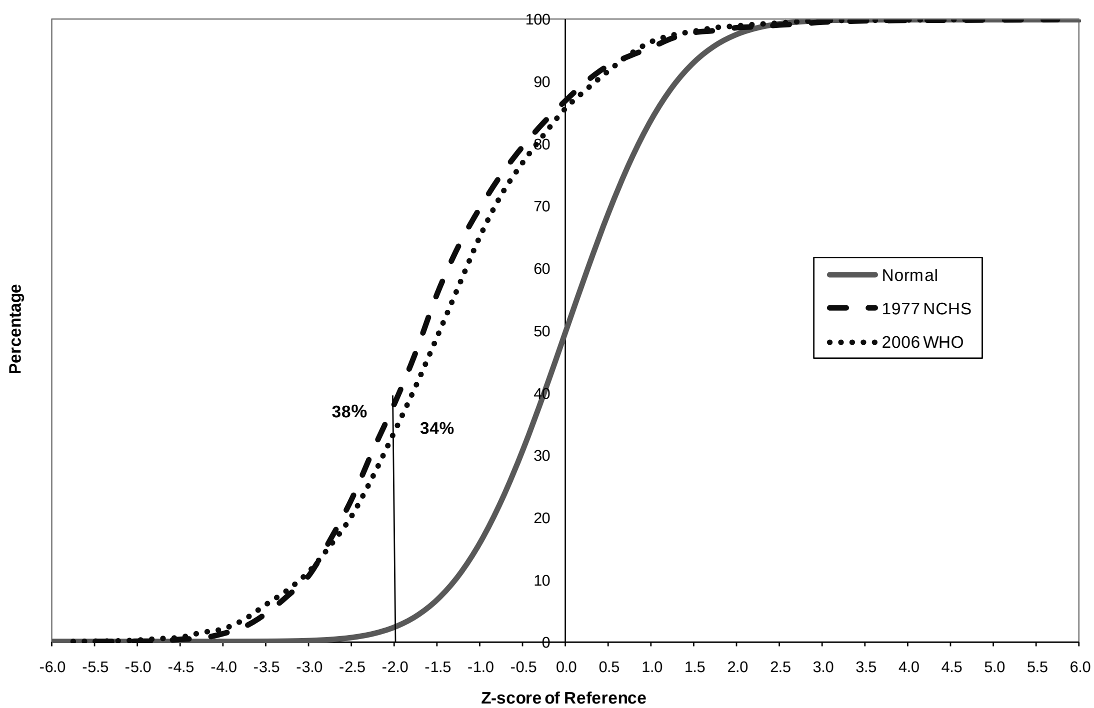
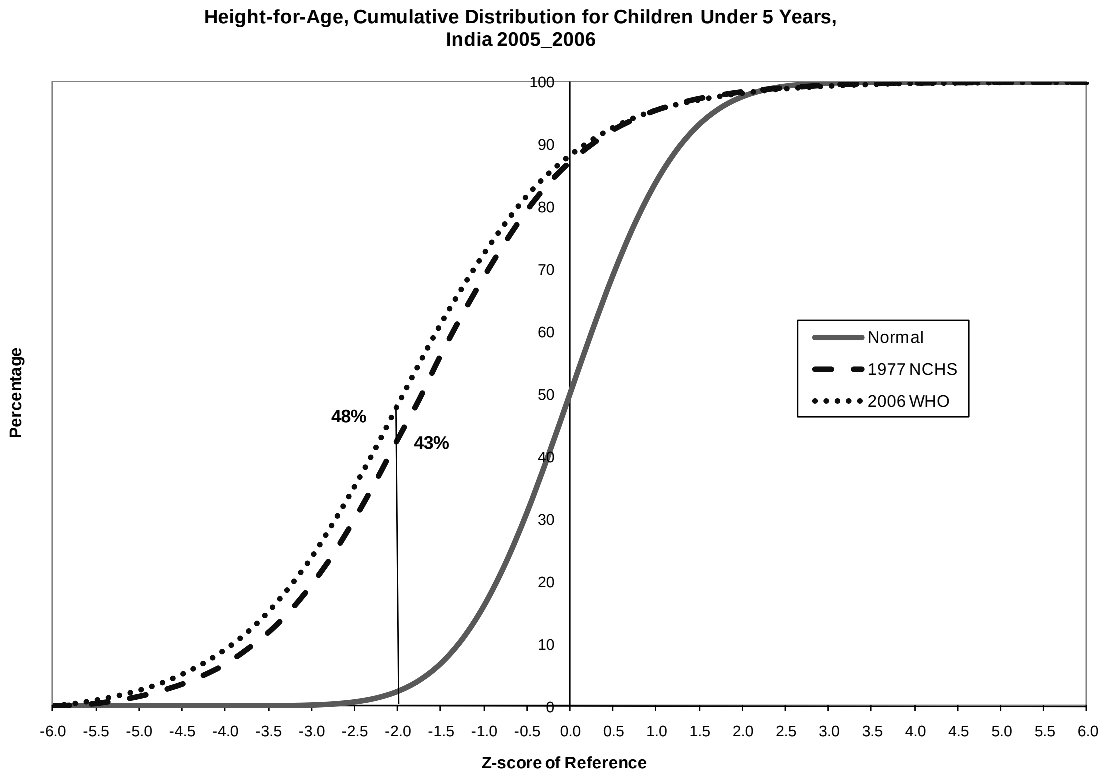
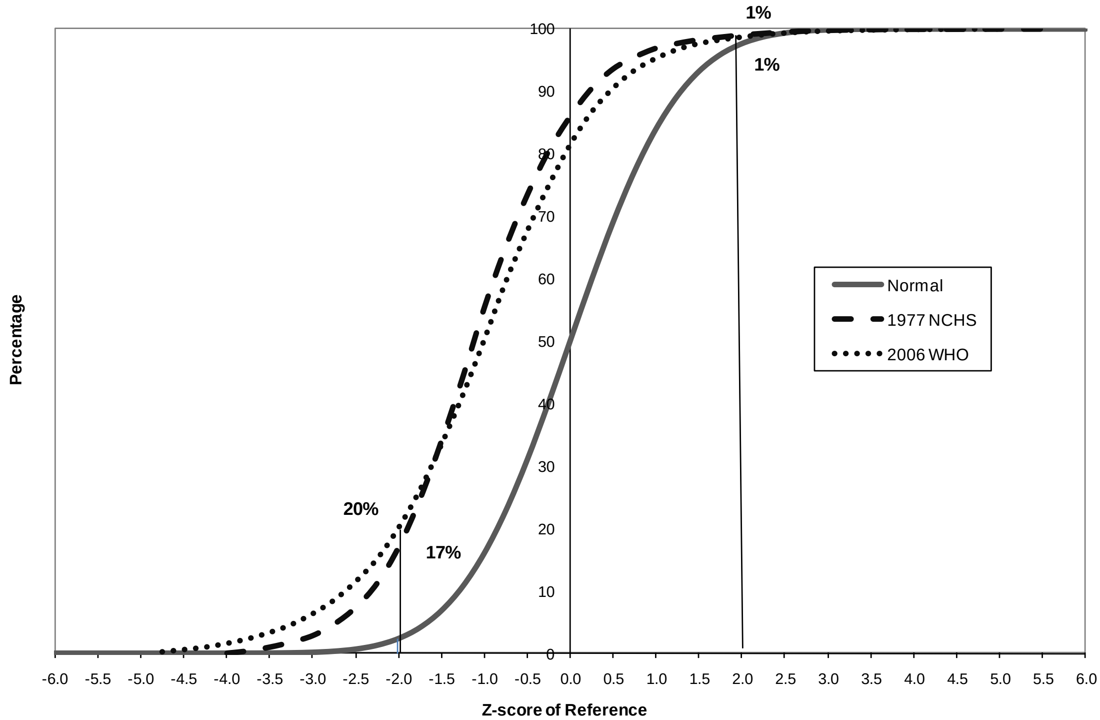


Figure 6: India, 2005/2006



Weight-for-Height, Cumulative Distribution for Children Under 5 Years, India 2005_2006



Weight-for-Age, Cumulative Distribution for Children Under 5 Years, India 2005_2006

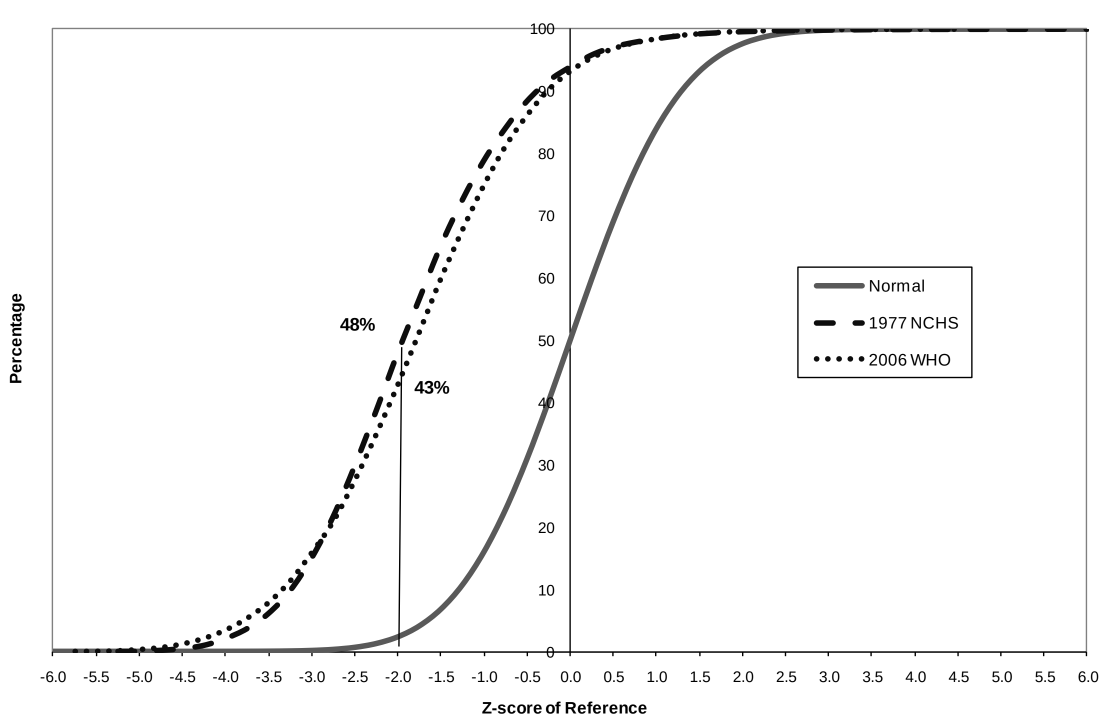
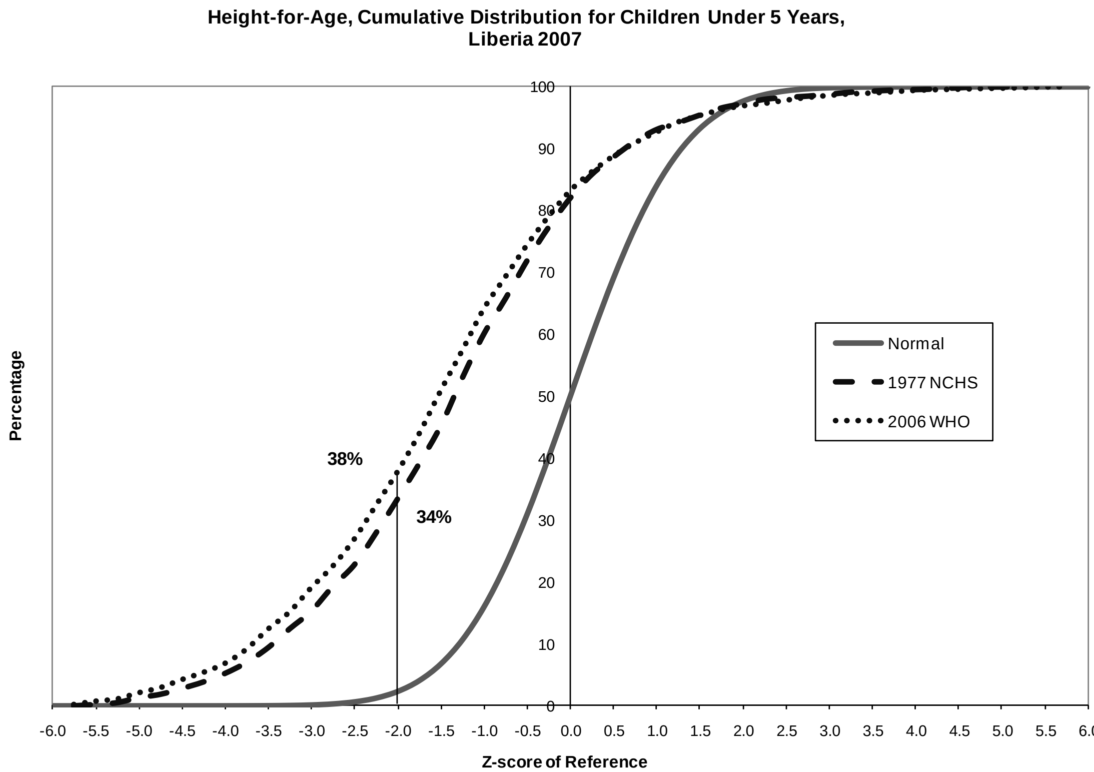
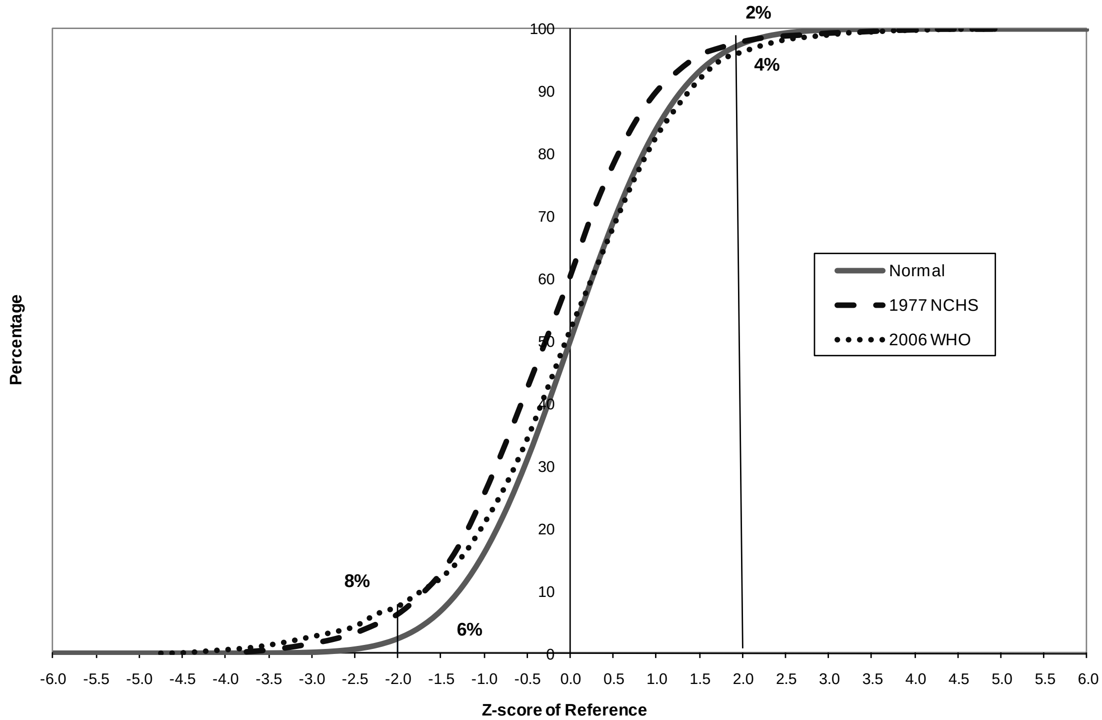


Figure 7: Liberia 2007



Weight-for-Height, Cumulative Distribution for Children Under 5 Years, Liberia 2007



Weight-for-Age, Cumulative Distribution for Children Under 5 Years, Liberia 2007

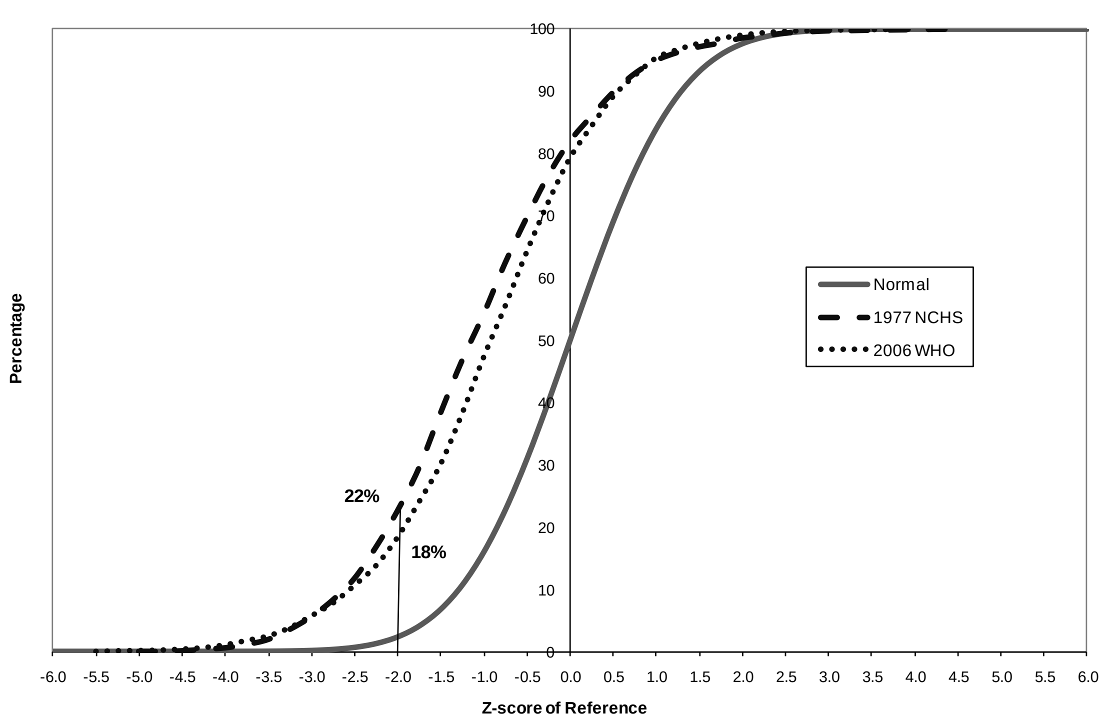
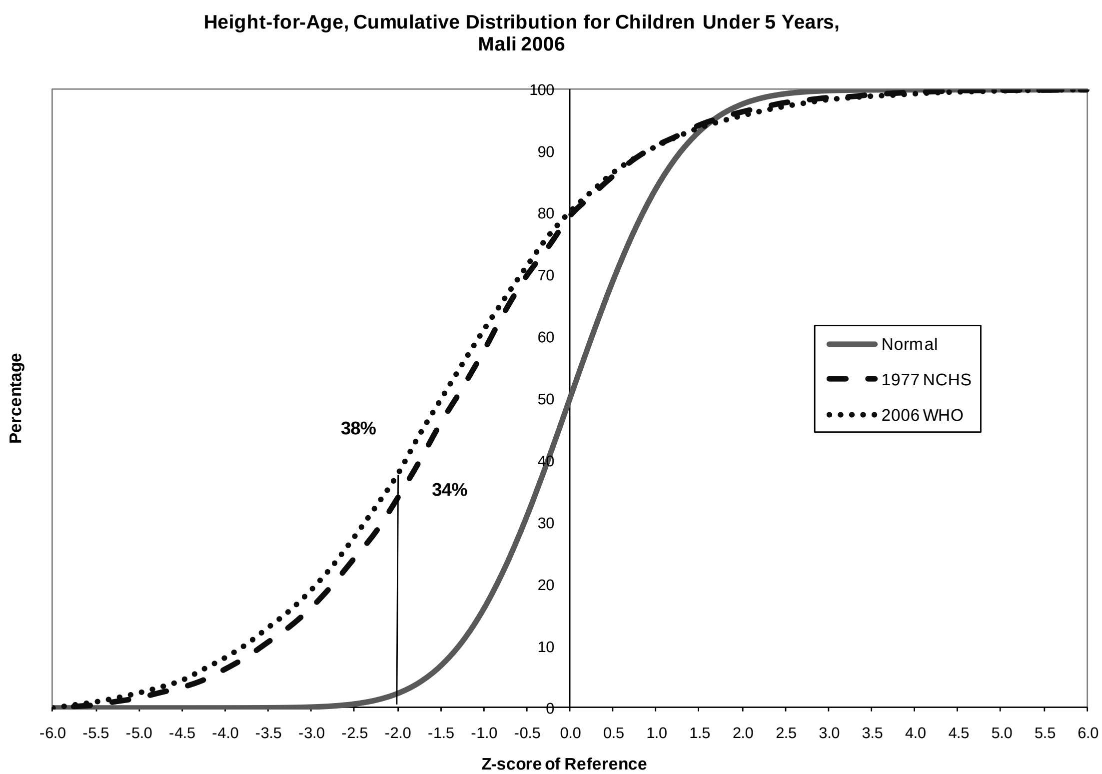
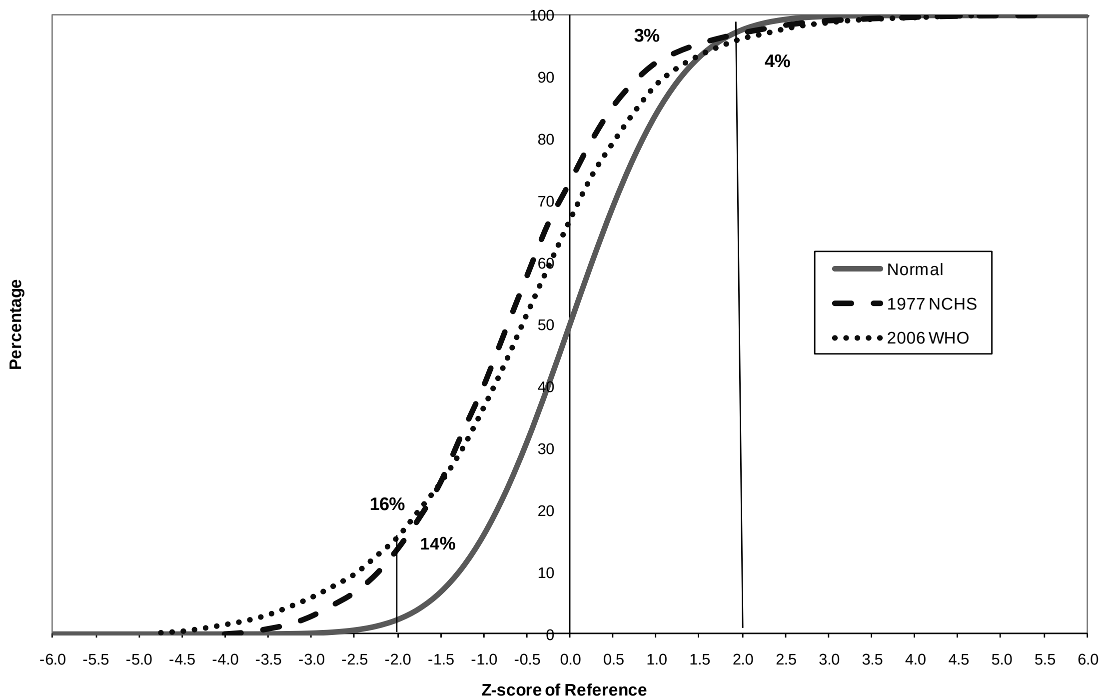


Figure 8: Mali, 2006



Weight-for-Height, Cumulative Distribution for Children Under 5 Years, Mali 2006



Weight-for-Age, Cumulative Distribution for Children Under 5 Years, Mali 2006

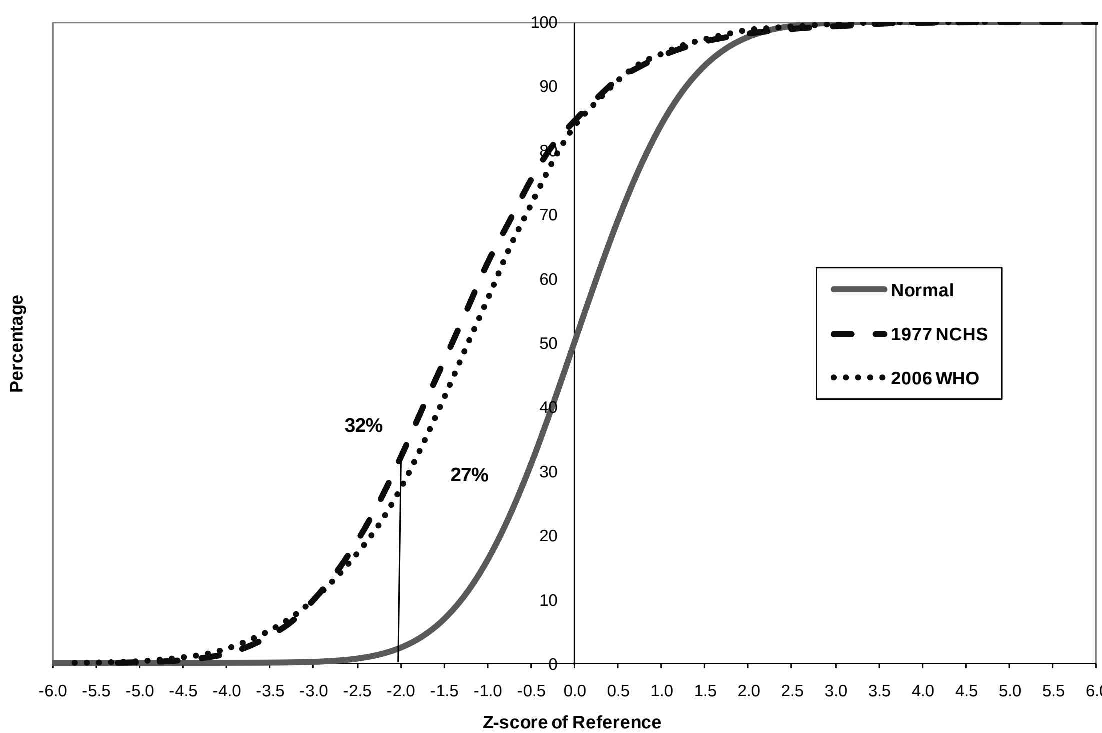
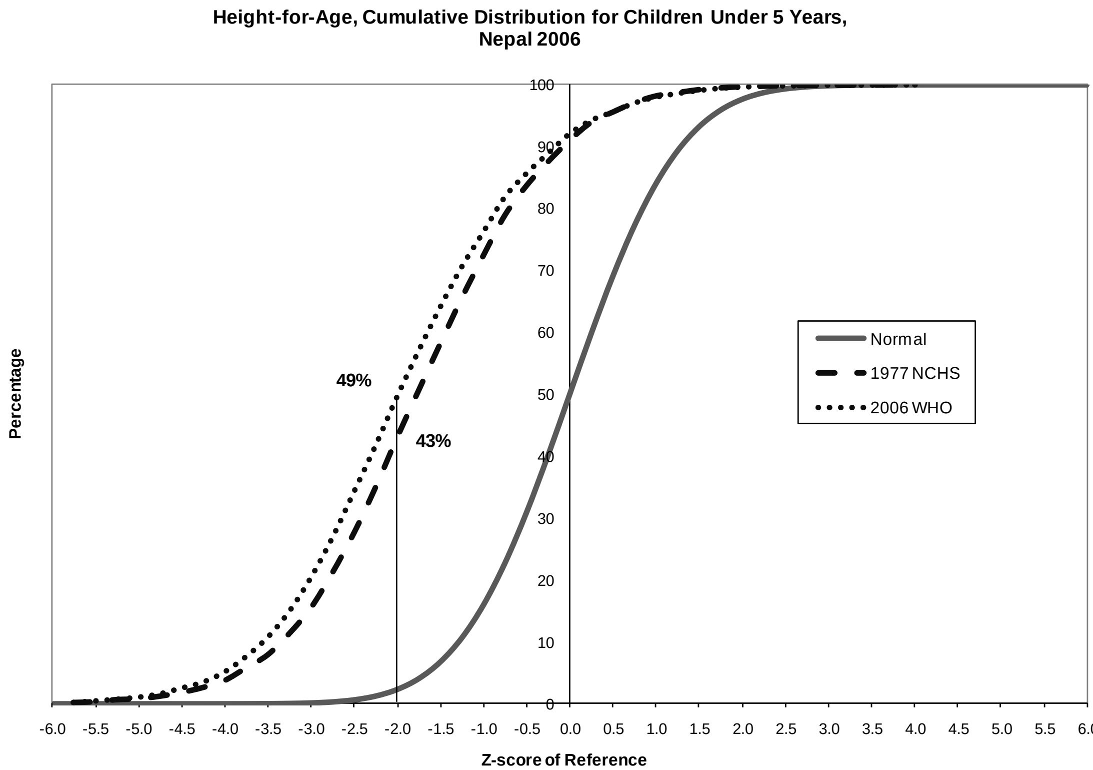
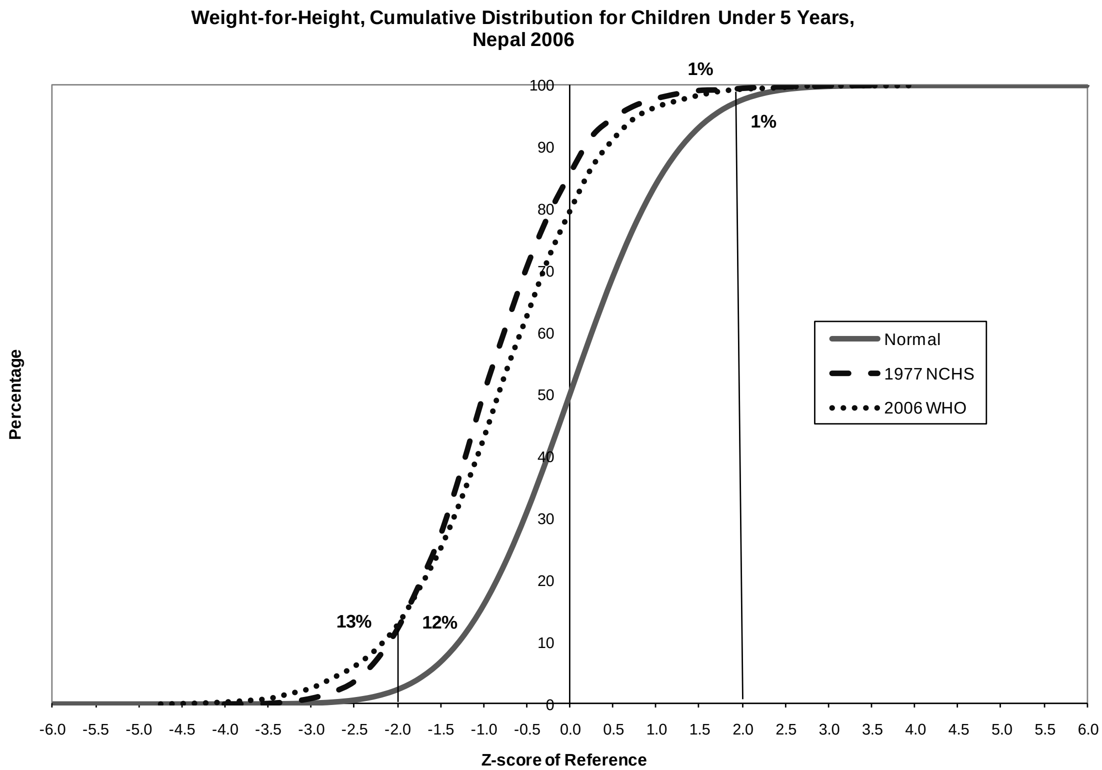


Figure 9: Nepal, 2006




Weight-for-Height, Cumulative Distribution for Children Under 5 Years,
Nepal 2006
Percentage
Z-score of Reference
Normal
1977 NCHS
2006 WHO
1%
1%
13%
12%
100
90
80
70
60
50
40
30
20
10
0
-6.0 -5.5 -5.0 -4.5 -4.0 -3.5 -3.0 -2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0

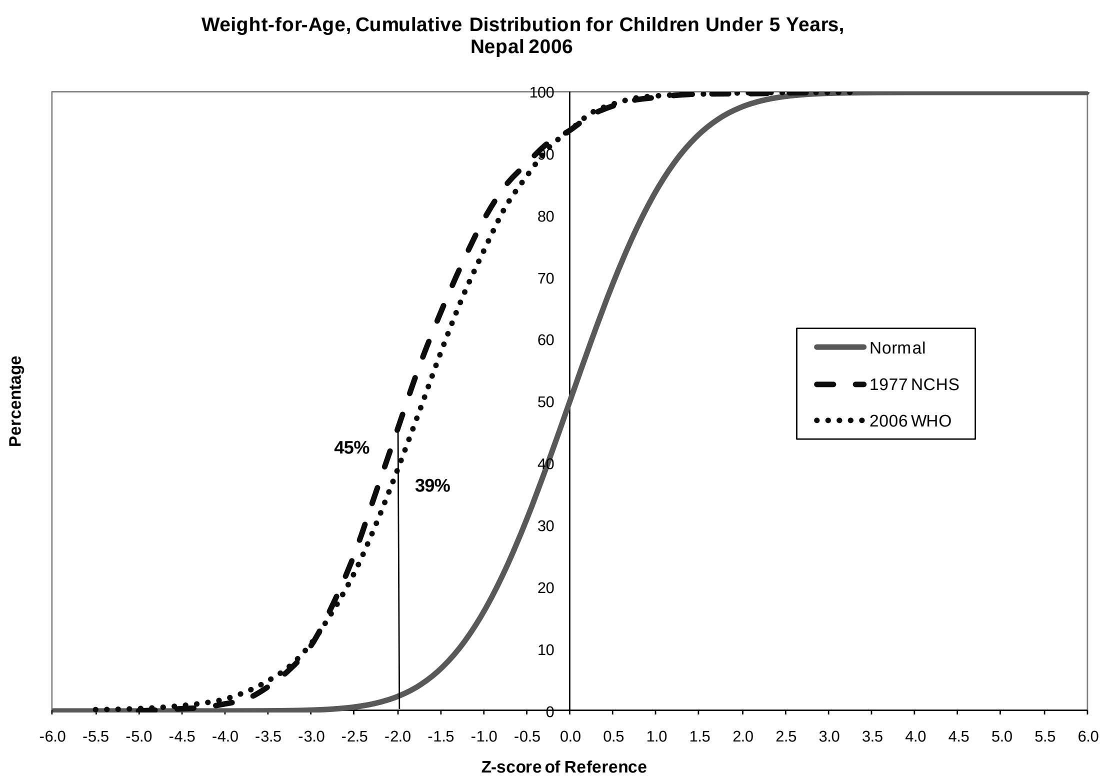
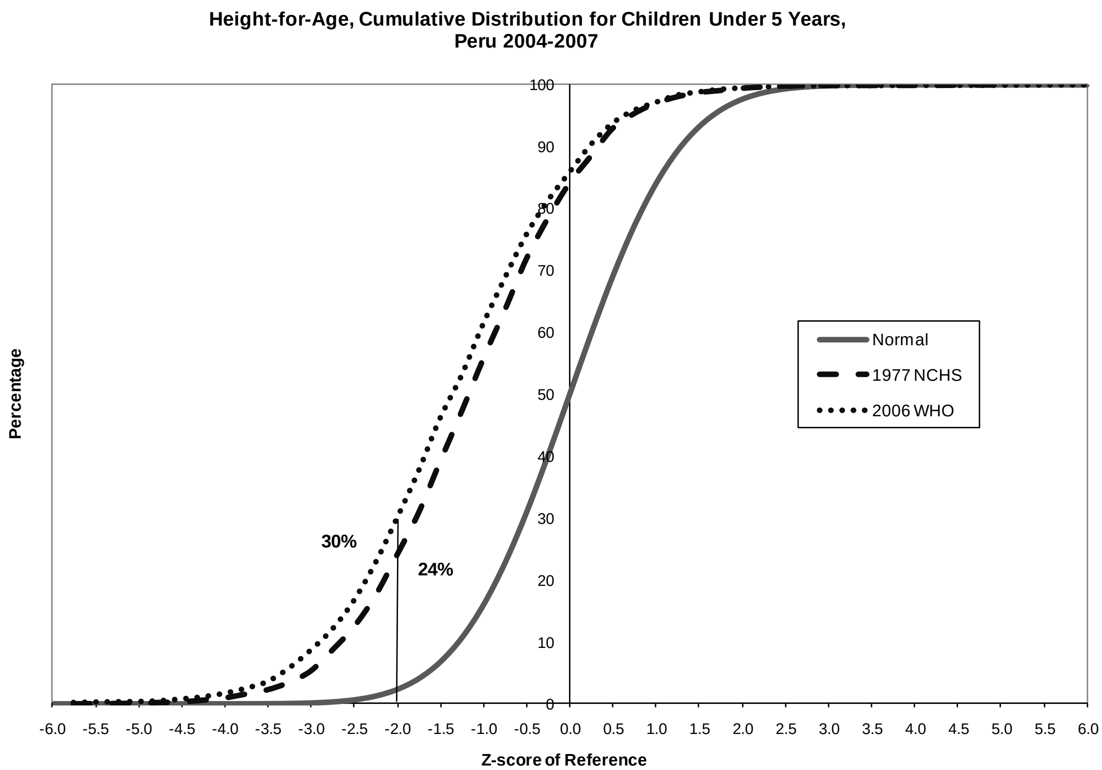
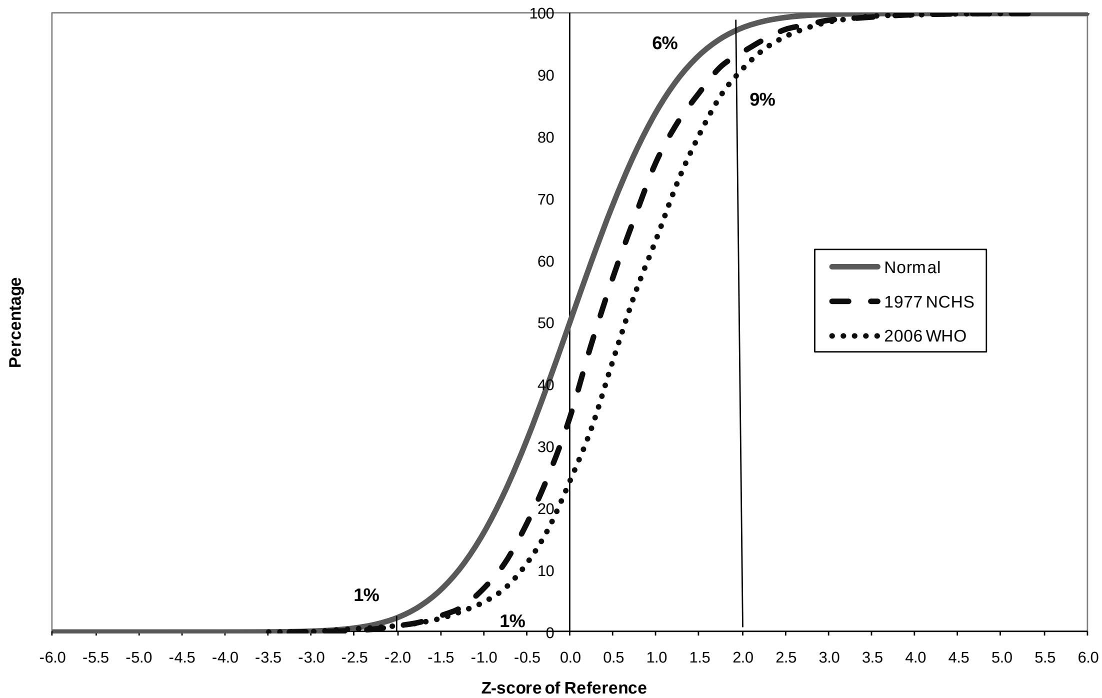

Weight-for-Age, Cumulative Distribution for Children Under 5 Years,
Nepal 2006
Percentage
Z-score of Reference
Normal
1977 NCHS
2006 WHO
45%
39%
100
90
80
70
60
50
40
30
20
10
0
-6.0 -5.5 -5.0 -4.5 -4.0 -3.5 -3.0 -2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0

Figure 10: Peru, 2004-2007



Weight-for-Height, Cumulative Distribution for Children Under 5 Years, Peru 2004-2007



Weight-for-Age, Cumulative Distribution for Children Under 5 Years, Peru 2004-2007

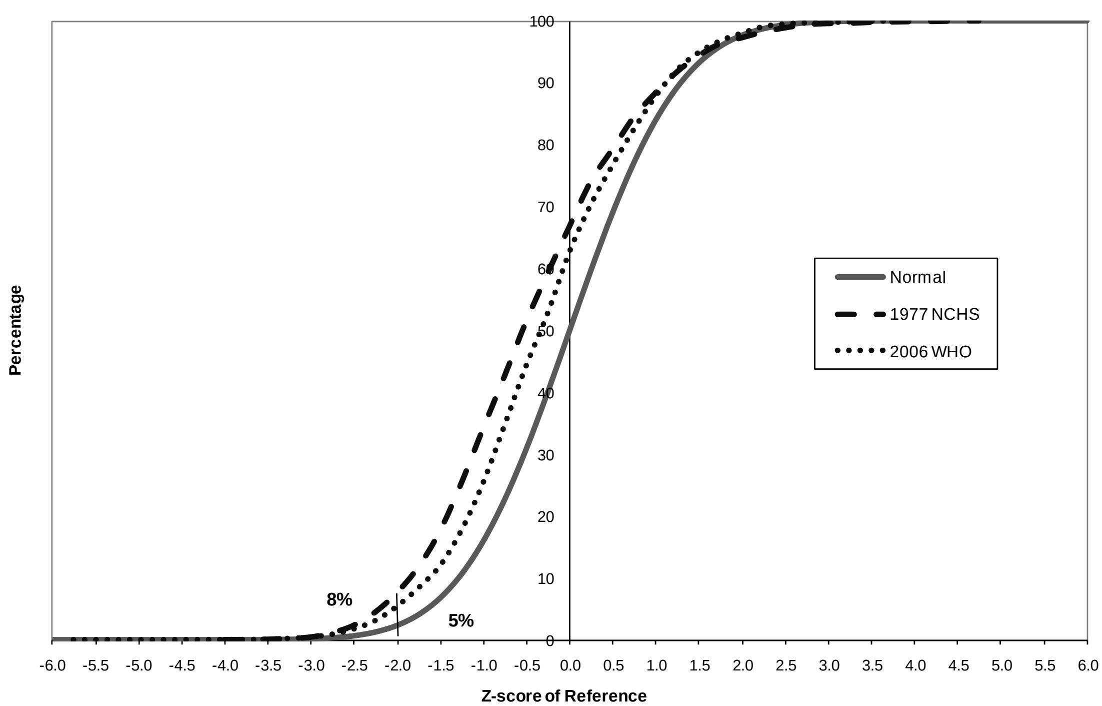
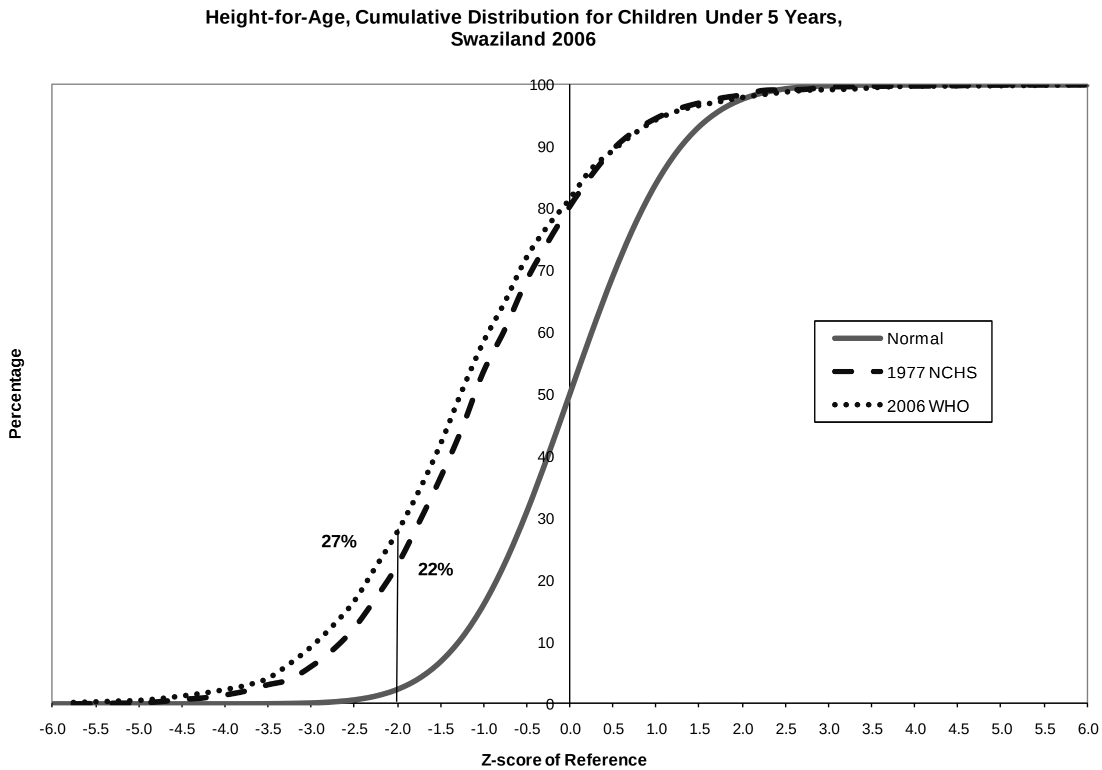
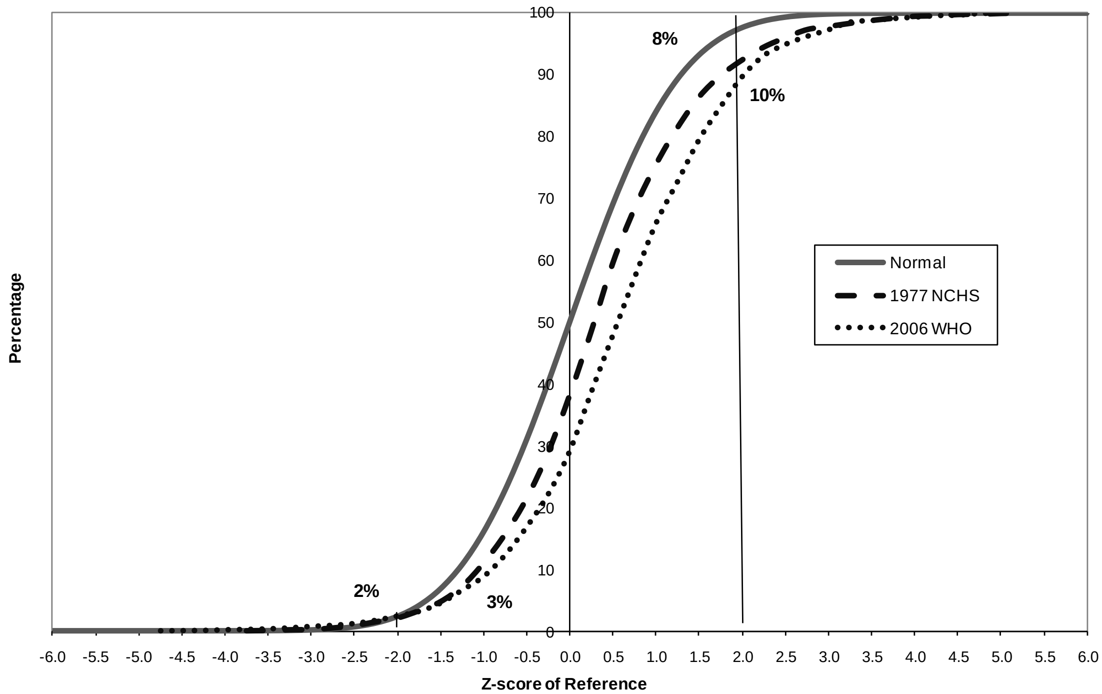


Figure 11: Swaziland, 2006



Weight-for-Height, Cumulative Distribution for Children Under 5 Years, Swaziland 2006



Weight-for-Age, Cumulative Distribution for Children Under 5 Years, Swaziland 2006

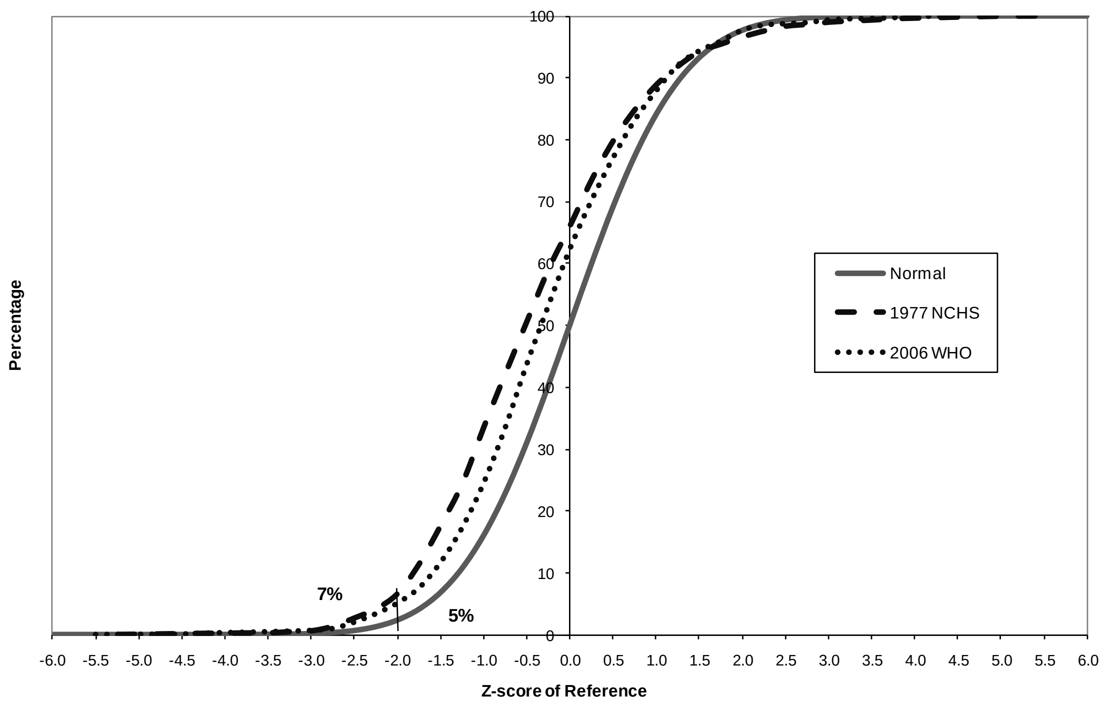
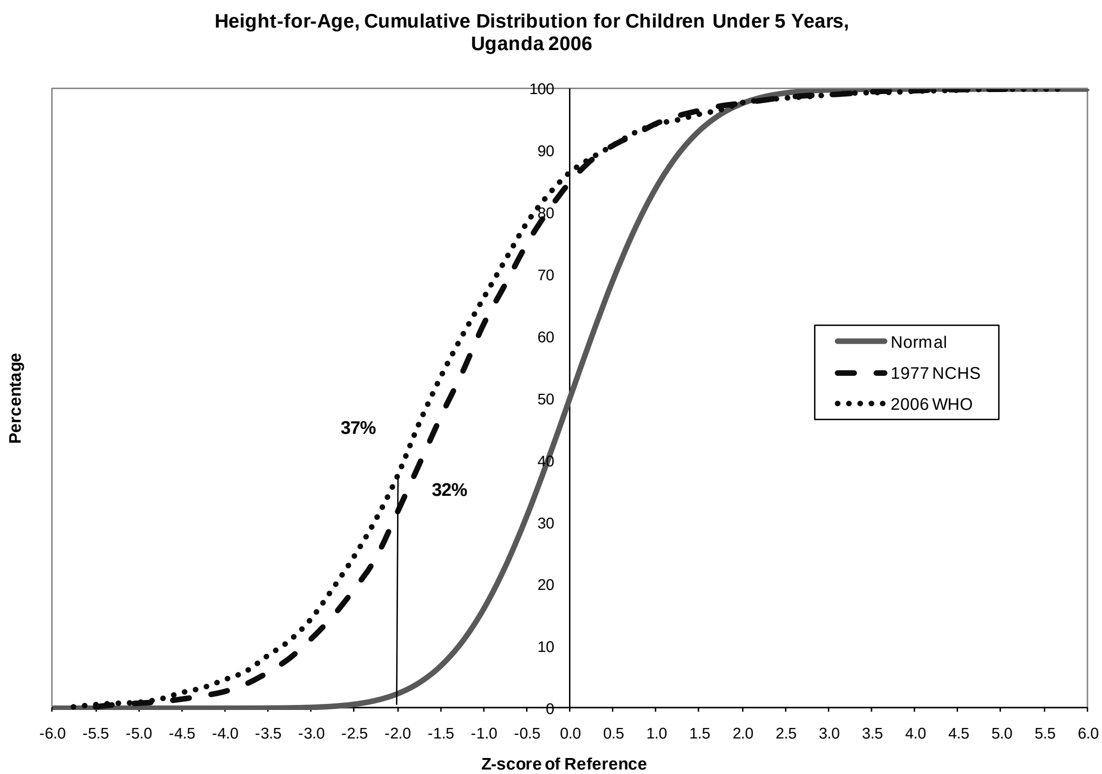
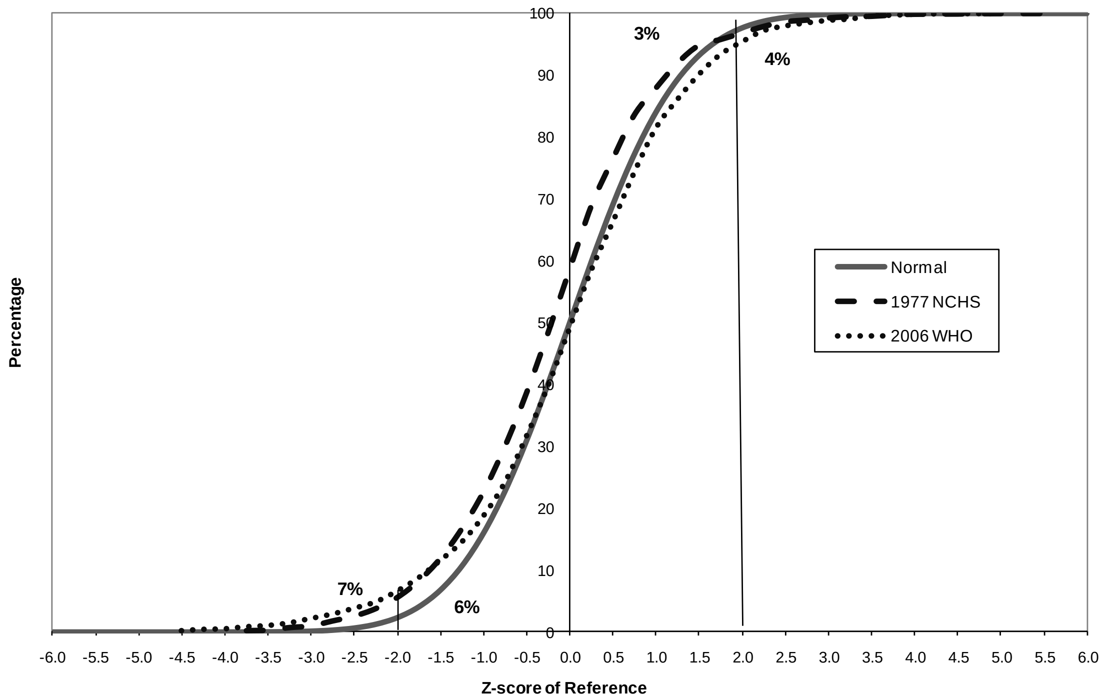


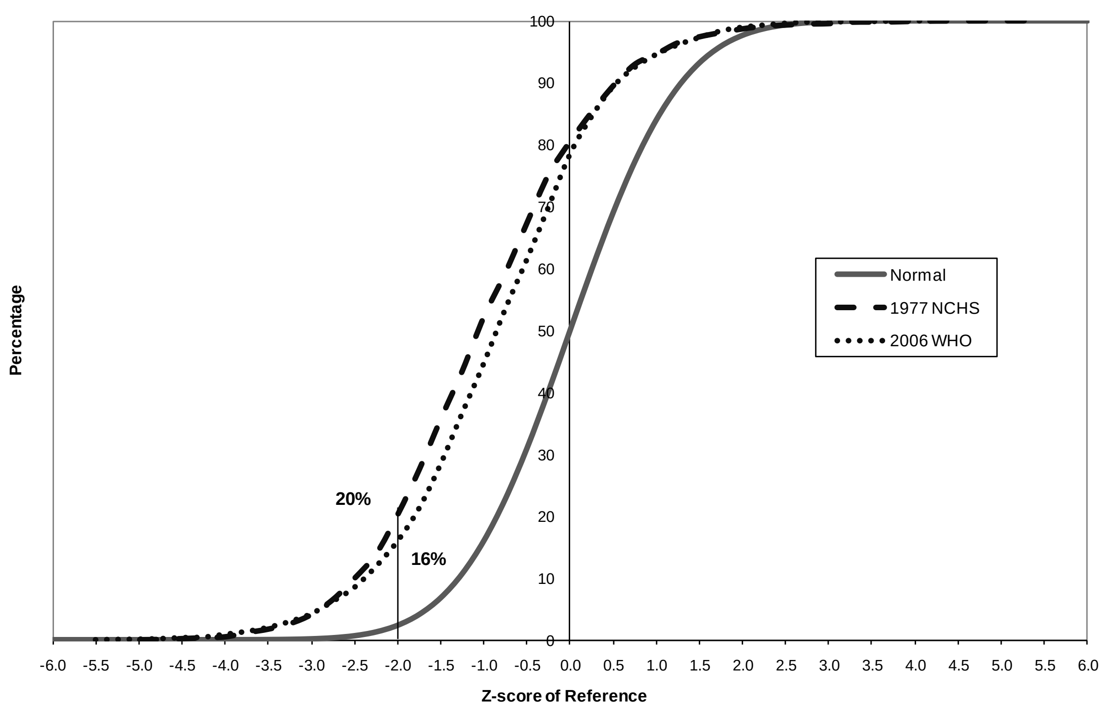
Figure 12: Uganda, 2006



Weight-for-Height, Cumulative Distribution for Children Under 5 Years, Uganda 2006



Weight-for-Age, Cumulative Distribution for Children Under 5 Years, Uganda 2006



The curves for height-for-age z-scores using the 1977 NCHS Reference and the 2006 WHO Standards appear very close to each other, failing to depict a clear difference in the stunting by two standards. However, they relatively clearly depict the problem of stunting in Ethiopia, India, Liberia, Mali, Nepal, Peru, Swaziland and Uganda, where the curves of both the 1977 NCHS Reference and the 2006 WHO Standards are far to the left of the cumulative normal distribution curves.

The shifting of the WHZ curves to the right of the normal distribution curve in the Dominican Republic, Peru, and Swaziland clearly show populations with overweight children by both of the two standards. Furthermore, using the 2006 WHO Standards, more children in these countries are categorized as overweight compared with the 1977 NCHS Reference (Figures 4b, 10b and 11b). In Liberia, although the weight-for-height curve of the 2006 WHO Standards is closer to the normal distribution (Figure 7b), slightly more children are wasted based on this standard than on the 1977 NCHS Reference (Table 1).

The difference between the two standards in the distribution of children for wasting is highest in Uganda (Figure 11b). The curve for the 1977 NCHS Reference is to the left of the normal curve by a large amount, indicating substantial wasting. The curve for the 2006 WHO Standards, however, is much less to the left of the normal curve, indicating much less wasting. Similar differences are observed for underweight status.

In most of the countries studied, the curves for underweight based on the 2006 WHO Standards fall closer to that of a normally distributed population, suggesting either that using the 1977 NCHS Reference overestimates the prevalence of underweight or that using the 2006 WHO Standards underestimate it.

Multivariate Analysis of Differences between the Standards

To ascertain which background characteristics are most associated with differences in nutritional status by type of standard used, we conducted a multivariate analysis of variance (ANOVA) with multiple classification analysis (MCA5 analysis). Multiple classification analysis is mathematically equivalent to dummy variable multiple regression analysis except that MCA uses deviations from the overall mean instead of deviations from a reference category. This analysis explores the relationship between the mean difference in the z-scores as the dependent variable and each background characteristic (predictor variable), while controlling for the effects of the other background characteristics.

The background characteristics included in this analysis are child's age, place of residence (rural or urban), mother's education, child's sex, birth order, whether the child had had diarrhea in the two weeks preceding the survey, household wealth quintile, and method of measuring height/length. The analysis was done on the pooled data set from the 10 DHS surveys. Since our interest is in ascertaining the relationships between the dependent and the predictor variables, the analysis is performed without using sample weights. Country-specific effects are taken into account by including a dummy variable for each country in the set of predictor variables.

---

[5] The advantage of Multiple Classification Analysis (MCA) over linear regression is that it accepts predictor variables measured on nominal, ordinal, and interval scales, and it does not assume linearity as linear regression does. Like linear regression, multiple classification analysis assumes that the effects of the predictors are additive i.e. that there are no interactions between predictors, unless especially included as interaction variables. It is designed for use with predictor variables.

Table 7: Multiple Classification Analysis (MCA): predicting the mean difference in the z-scores of the three anthropometric indices after controlling for the selected background variables

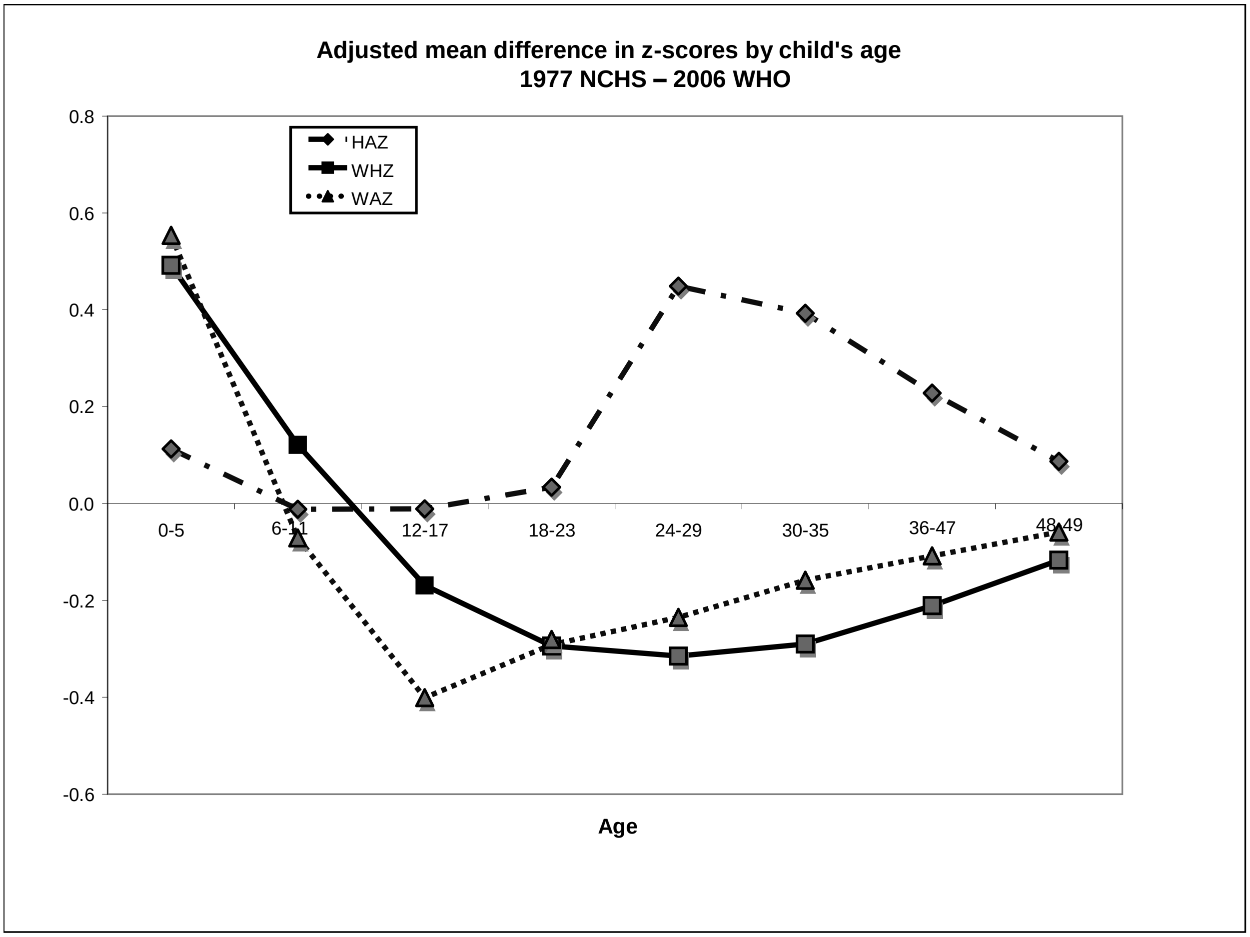
	Predicted mean difference after adjusting for the background variables			
	Mean Difference Height-for-age Z-score (1977 NCHS-2006 WHO)	**Mean Difference Weight-for-height Z-score (1977 NCHS-2006 WHO)**	**Mean Difference Weight-for-age Z-score (1977 NCHS-2006 WHO)**	**Number**
Age in months				
1 0-5	0.113***	0.492***	0.554***	7,338
2 6-11	-0.012***	0.121***	-0.071***	8,966
3 12-17	-0.011***	-0.169***	-0.401***	8,857
4 18-23	0.034***	-0.294***	-0.291***	8,264
5 24-29	0.449***	-0.315***	-0.235***	8,690
6 30-35	0.393***	-0.290***	-0.158***	8,258
7 36-47	0.228***	-0.211***	-0.108***	17,121
8 48-59	0.087***	-0.117***	-0.059***	16,676
Place of residence				
1.00 Urban	0.148	-0.134***	-0.118**	29,893
2.00 Rural	0.166	-0.109***	-0.095**	54,277
Mothers education				
.00 none	0.170***	-0.075***	-0.074***	34,597
1.00 primary	0.163***	-0.161***	-0.121***	18,211
2.00 secondary+	0.146***	-0.140***	-0.126***	31,362
.00 female	0.131***	-0.105***	-0.109***	40,787
1.00 male	0.186***	-0.130***	-0.098***	43,383
Had diarrhea in last 2 weeks				
.00 no	0.162***	-0.120***	-0.099***	73,275
1.00 yes	0.142***	-0.108***	-0.131***	10,895
Birth order				
1.00 1	0.153*	-0.119	-0.112*	23,626
2.00 2-4	0.163*	-0.111	-0.098*	49,293
3.00 5+	0.157*	-0.148	-0.109*	11,251
Wealth status				
1.00 Lowest/Poorest	0.175***	-0.104***	-0.080***	18,359
2.00 Second/Poorer	0.166***	-0.117***	-0.094***	17,422
3.00 Middle	0.163***	-0.118***	-0.103***	17,223
4.00 Fourth/Richer	0.154***	-0.121***	-0.115***	16,687
5.00 Highest/Richest	0.134***	-0.134***	-0.132***	14,479
Method of measurement				
1 Lying	0.108***	0.009***	-0.039***	31,262
2 Standing	0.190***	-0.193***	-0.142***	52,908
Country				
1.00 Azerbaijan 2007	0.143***	-0.223***	-0.128***	1,905
2.00 Dominican Republic 2006	0.144***	-0.208***	-0.120***	9,117
3.00 Ethiopia 2005	0.159***	-0.12***	-0.098***	3,800
4.00 India 2005-2006	0.167***	-0.066***	-0.091***	40,493
5.00 Liberia 2007	0.145***	-0.197***	-0.124***	4,187
6.00 Mali 2006	0.135***	-0.083***	-0.090***	10,428
7.00 Nepal 2006	0.182***	-0.112***	-0.101***	5,211
8.00 Peru 2007	0.175***	-0.275***	-0.154***	4,672
9.00 Swaziland 2006	0.137***	-0.241***	-0.144***	2,016
10.00 Uganda 2006	0.174***	-0.198***	-0.131***	2,341
Total adjusted mean	**0.1593**	**-0.1181**	**-0.1035**	**84,170**

Significant * *P<=0.05*, **p<=0.01, *** p<=0.001

Table 7 shows the results of the multiple classification analysis (MCA) as the predicted mean difference in z-score by standard for each category of the background variables. The predicted means are obtained by adding the adjusted deviations from the grand mean to the value of the grand mean. The pattern of predicted mean difference in z-score by age group is shown graphically in Figure 13.

There are strikingly different patterns between height-for-age on the one hand and weight-for-age and weight-for-height on the other. For children under age 6 months, there is a small positive difference for the height-for-age z-score, indicating that the 1977 NCHS Reference has a higher value than the 2006 WHO Standards. The difference just about disappears for age 6-23 months but becomes a very large positive value for age 24-47 months. Further, the patterns for weight-for-age and weight-for-height are similar. There are very large positive differences for children under age 6 months, small differences for children age 6-11 months, and large and negative differences for children age 12-29 months for weight-for-age and age 12-47 months for weight-for-height.

Figure 13: Pattern of the predicted mean diffference between the 1977 NCHS Reference and the 2006 WHO Standards in the z-scores by age groups of children



Comparing the 2006 WHO Standards with the 1977 NCHS Reference:

- There is a greater difference in weight-for-height and weight-for-age in urban areas than in rural areas, but no significant difference in height-for-age.
- The differences in HAZ become greater as the level of mother's education becomes lower, but the opposite is true for WHZ and WAZ.
- Boys tend to have greater differences than girls in z-scores for HAZ and WHZ, but not for WAZ.

- Having a recent bout of diarrhea is likely to lower a child's weight and should not impact HAZ or WAZ much. However, a large negative difference appears for children who had diarrhea in the two weeks prior to the survey compared with children who did not, indicating that the 1977 NCHS Reference z-scores may be more affected by recent diarrhea than the 2006 WHO Standards.
- Even though statistically significant, the differences by birth order are small for HAZ and WHZ.
- The difference in z-scores decreases monotonically with increasing household wealth for height-for-age, but they increase monotonically with increasing wealth for weight-for-age and weight-for-height.
- The difference is large if the child was measured standing up rather than lying down, even after controlling for age.

As for the other background variables, the results for height-for-age are in the opposite direction of those for weight-for-age and weight-for-height. After adjusting for all the background characteristics, the three countries with the greatest differences between the HAZ for each standard are Nepal, Peru, and Uganda. For WHZ, the three countries with the greatest differences are Peru, Swaziland, and Azerbaijan, and for WAZ, the top three differences are found in Peru, Swaziland, and Uganda.

The analysis of variance portion of the multivariate analysis indicates that all of the background characteristics have significant effects on the difference in z-score between the two standards, except for urban/rural residence for height-for-age and birth order for weight-for-height.

Analysis of the Elite Children

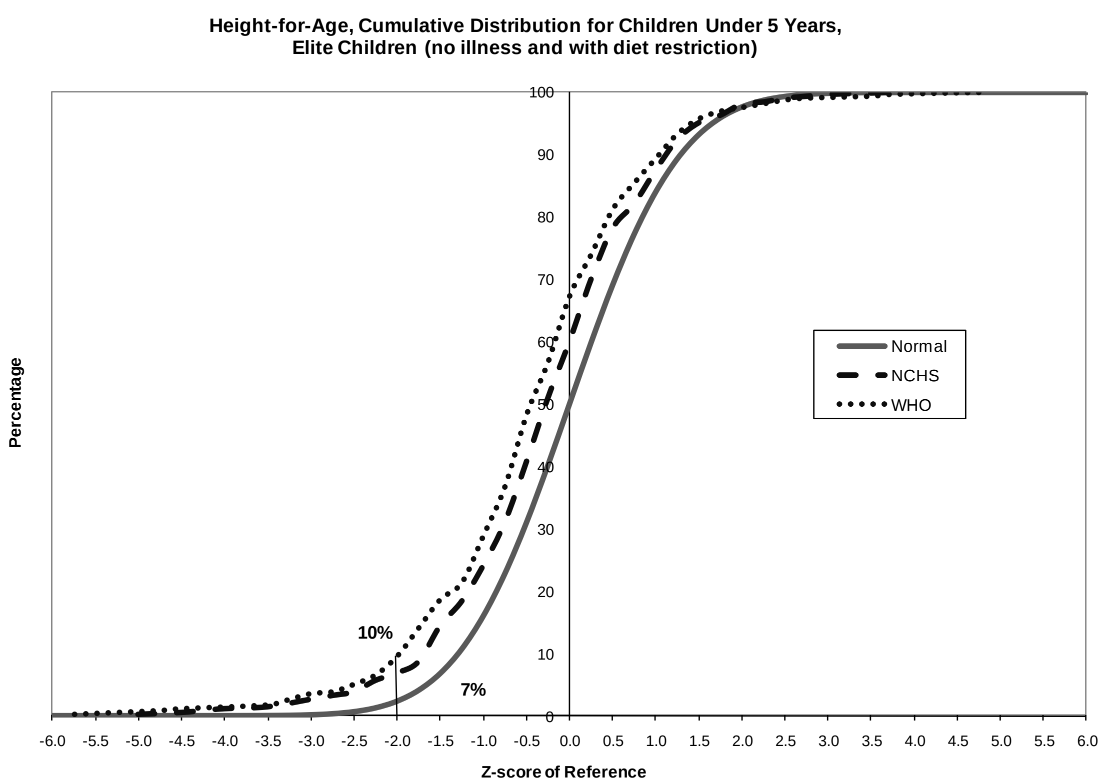
To simulate the population selected in the Multiple Growth Reference Study used in the development of the 2006 WHO Standards, we selected elite children (for definition see “Elite Children” in the Methods section of this paper) from the 10 DHS countries in our pool of data and prepared cumulative distribution curves using the 2006 WHO Standards and the 1977 NCHS Reference. We expect that the z-score values for the children selected would lie on the cumulative normal curve, indicating that they are well nourished and presumably are similar to the children on which the standards are based. Figure 14 and Table 8 depict our results.

The overall pattern remains the same as that observed for all children, i.e., stunting is higher with the 2006 WHO Standards than the 1977 NCHS Reference. Also, prevalence of wasting and underweight are higher with the 1977 NCHS Reference than the 2006 WHO Standards. However, all three curves do not overlap as expected. The elite children from the DHS population are slightly more stunted compared with the normal distribution curve. As for wasting, both standards indicate that the elite children do not track exactly along the normal distribution curve. Instead, some children lie on either side of the normal curve, representing more wasting in elite children than expected and also the emerging problem of overweight. The comparison of the cumulative weight-for-age curves with the cumulative normal curve shows similar results as for weight–for-height.

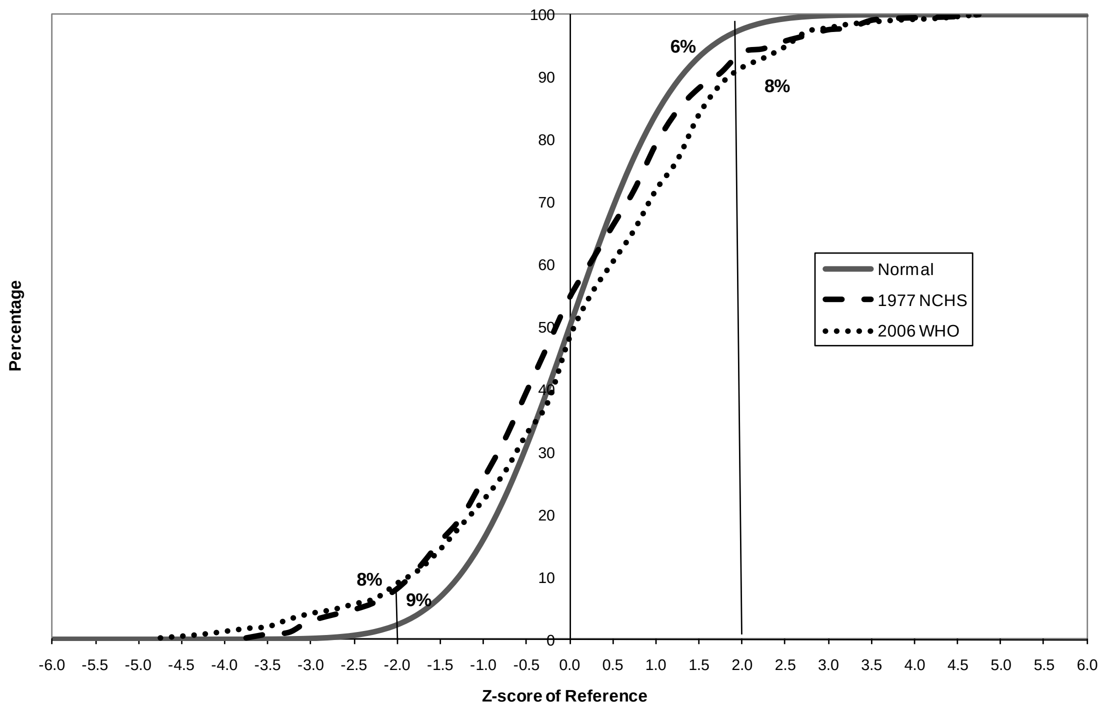
Table 8: Summary of HAZ, WHZ, and WAZ scores of the elite children when compared with the 1977 NCHS Reference and 2006 WHO Standards.

	1977 NCHS	**2006 WHO**
Height-for-age (HAZ)		
Percent stunted	6.9	9.7
Mean HAZ (SD)	-0.19 (1.2)	-0.35 (1.3)
Weight-for-height (WHZ)		
Percent wasted	8.2	9.1
Percent overweight	6.0	8.5
Mean WHZ	0.03 (1.4)	0.19 (1.56)
Weight-for-age (WAZ)		
Percent underweight	10.0	8.8
Mean WAZ	-0.2 (1.4)	-0.09 (1.3)
Number of children	**331**	**331**

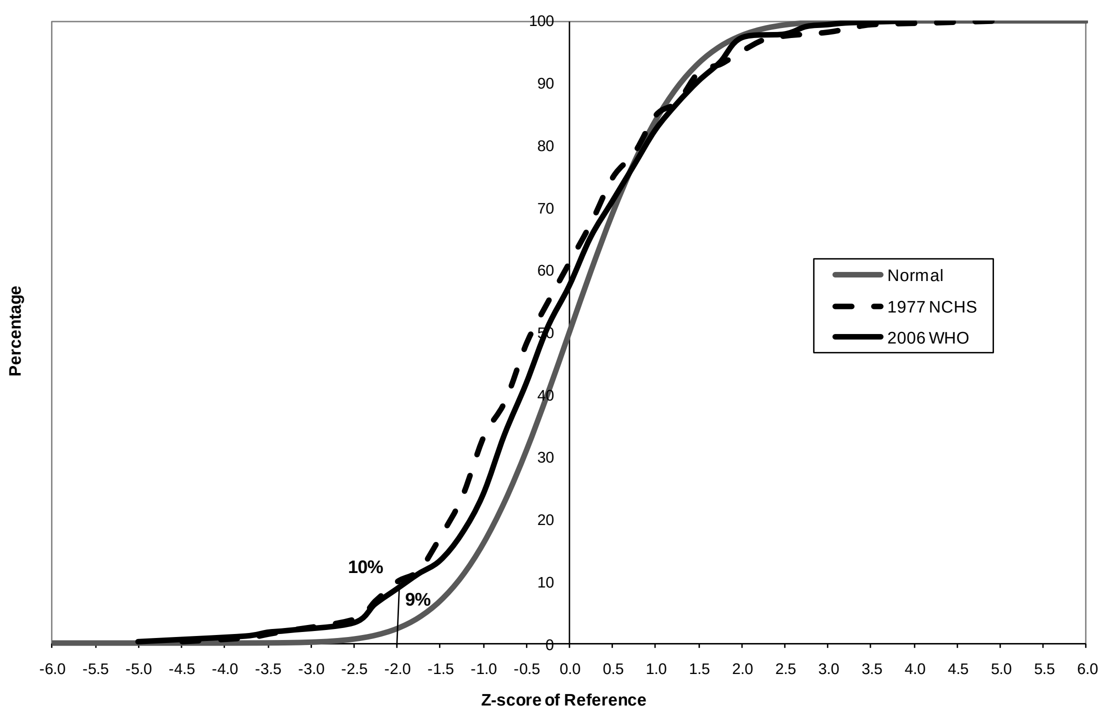
Figure 14: Elite Children (10 Countries)



Weight-for-Height, Cumulative Distribution for Children Under 5 Years, Elite Children (no illness and with diet restriction)



Weight-for-Age, Cumulative Distribution for Children Under 5 Years, Elite Children (no illness and with diet restriction)



DISCUSSION

Our results using DHS data support the findings from other studies (de Onis et al., 2006; Schwarz et al., 2008) that the prevalence of stunting in children under age 5 years is higher using the 2006 WHO Standards (Table 1). Our results also indicate that higher prevalence of underweight exists with the 1977 NCHS Reference except during the first 6 months of life, a finding similar to the one observed by Prost et al. (2008) in Malawi. Our study also finds that use of the 2006 WHO Standards results in classifying higher proportion of overweight and obese children, as was reported by de Onis, (2007).

We find that the use of the Hong and de Onis, (2008) algorithm suggested to convert a prevalence statistic based on the 1977 NCHS Reference into an estimate based on the 2006 WHO Standards yields higher levels of malnutrition than direct application of the 2006 WHO Standards. Moreover, the overestimation of malnutrition depends on the age of the child.

Bloem (2007) reports that the prevalence of wasting using either the 2006 WHO Standards or the 1977 NCHS Reference varies by setting. Hence, interpretation of these results is complex and reliance on a single algorithm is not justified. The use and interpretation of the prevalence using the 2006 WHO Standards derived from the suggested algorithm values should be done with caution, especially when determining trends.

We find that the mean z-scores for height-for-age are higher with the 2006 WHO Standards and that the mean z-scores for weight-for-age are higher with the 1977 NCHS Reference. However, the mean z-scores for weight-for-height are greater than zero using the 2006 WHO Standards in four of the countries in our study, and lower in the remaining six countries. The variation in weight-for-height by country could be because it is a sensitive indicator influenced by short-term events, and wasting can develop rapidly from fluctuations in food supply and prevalence of infectious diseases (Gibson, 1990).

The differences in the mean z-score between the 1977 NCHS Reference and the 2006 WHO Standards in height-for-age, weight-for-height, and weight-for-age are considerably higher during the first 6 months of life than later in childhood. These findings substantiate results reported by de Onis et al. (2006). For children age 24 months or older who were measured lying down, the differences in the mean z-scores are higher than for other age groups and for the other forms of measurement for all countries in our study except Nepal and Peru (Table 5a). Thus the method of data collection may influence the observed estimates of stunting, wasting, and underweight. However, it is likely that there is also a selection process involved, since tall children were measured standing up, even if they were younger than age 2 years.

Using the 2006 WHO Standards, mean differences according to form of measurement in the height-for-age z-scores are significantly greater for children age 24-36 months than when using the 1977 NCHS Reference. In the 1977 NCHS Reference there is a big difference in the height status of children right before and after age 24 months, at approximately half a standard deviation (WHO, 1995). This difference in height status does not exist for the 2006 WHO Standards, due to the design of the MGRS (de Onis, 2006).

However, the comparisons according to form of measurement by indicator, age, and growth standard show clearly that children measured standing up are different than those measured lying down. The children measured while standing are taller and weigh more. The effect of form of measurement is less for the 1977 NCHS Reference than for the 2006 WHO Standards in HAZ (and therefore less for stunting) but the effect is more for the 1977 NCHS Reference in weight for height (and wasting).

By background characteristics, we find greater differences in mean height-for-age z-scores for children age 24-35 months, children in rural areas, and children whose mothers have less education, as well as for male children, children of higher birth order, children whose form of measurement was inappropriate, and children who were not exclusively breastfed. However, we do not find noticeable variations in the differences of mean z-scores for weight-for-height and weight-for-age by background characteristics, with the exceptions of the age of the child and whether or not the child was exclusively breastfed. Although it is possible to interpret the above result as due to the inadequacy of 1977 NCHS Reference to assess the growth of breastfed infants (de Onis and Habicht, 1996), children under age 6 months and who are exclusively breastfed have a lower height-for-age z-score with both standards. This is an expected finding since the 2006 WHO Standards are based on breastfed infants.

Our multivariate analyses of all children under age 5 years indicate that child's age and sex, mother's level of education, and incidence of recent diarrhea, as well as household wealth status, form of measurement, and country of residence are good predictors for mean differences between the 1977 NCHS Reference and the 2006 WHO Standards for height-for-age, weight-for-height, and weight-for-age. Place of residence (rural versus urban) and birth order are not significant in predicting mean differences between the two standards.

A second set of multivariate analyses (not presented in the paper) was performed for children under age 6 months, given that this age group shows the largest differences in results between the standards. The results for these young children are different than those of all children under age 5 years. Among children under age 6 months, mother's education, child's sex, birth order, residence (urban versus rural), and country are good predictors for mean differences in stunting between the 2006 WHO Standards and the 1977 NCHS Reference. Type of feeding (exclusively breastfed or not), whether or not had recent diarrhea, and form of measurement are not significantly related to the differences in the height-for-age z-scores for these children.

Another way of comparing results between the two standards is via their application to an elite group of children, as discussed earlier—who are presumed to be well fed and who are expected to track along the standard curve for the well-nourished children. As mentioned, a similar study using the DHS data showed that these children did indeed track the 1977 NCHS Reference well (Rutstein et al., 1990). While in all countries included in our study both standards indicate some malnutrition even among this elite group, the elite children evaluated using the 1977 NCHS Reference are closer to the normal curve than when evaluated using the 2006 WHO Standards.

The United Nations Standing Committee on Nutrition and the International Pediatric Association recommend that the 2006 WHO Standards should now be used universally to assess nutritional status of children due to its robust methodology of development and its prescriptive approach. WHO endorses using the new standards wherever raw data on height, weight, and age are available and suggests using the algorithm when 1977 NCHS Reference data need to be converted to estimates based on the 2006 WHO Standards (Scientific Committee on Nutrition, 2008 and International Pediatrics Association, 2008). Our findings and the literature review indicate, however, that the effect of using one or the other standard for prevalence of wasting varies according to the setting. The effect also varies by the age of the child. Therefore, as suggested by Bloem (2007), the conversion of the 1977 NCHS data to 2006 WHO Standards estimates should not be based simply on the suggested algorithm.

CONCLUSIONS

Recent DHS reports use the new WHO Child Growth Standards (the 2006 WHO Standards) to evaluate nutritional status in place of the older International Growth Reference (the 1977 NCHS Reference). We therefore undertook this study to assess what effects this change makes on the DHS-based estimates of stunting, wasting, and underweight. Since previous DHS surveys have used the 1977 NCHS Reference, the analysis of trends has also been done using it. A lingering question is whether investigators should continue to use the 1977 NCHS Reference to examine trends or whether all survey data should be reanalyzed using the new 2006 WHO Standards.

Bloem (2007) recommends that both the 2006 WHO Standards and the 1977 NCHS Reference should be used until the implications of changing standards are completely understood. In light of our findings, we also recommend that DHS reports and further analysis studies include results based on both of the standards, so that trends in nutritional status can be assessed.

There is no doubt that using the 2006 WHO Standards will increase the estimated prevalence of stunting, wasting, and overweight in children. However, estimates of the proportion of children who are underweight will be lower, except for children under age 6 months.

Even though one of the major reasons for developing the new standards was that the 1977 NCHS Reference was not based on breastfed children, our analysis concludes that there is no noticeable difference in children's nutritional status by their breastfeeding status comparing the 1977 NCHS Reference with the 2006 WHO Standards.

We conclude from our analysis that the assessment of malnutrition using 2006 WHO Standards is closer to that of a healthy population than the 1977 NCHS Reference for weight-for-age and weight-for-height. However, the assessment of height-for-age using the 1977 NCHS Reference more closely follows that of a healthy population than the 2006 WHO Standards. The 2006 WHO Standards may also serve as a better tool to assess the emerging problem of overweight early in life.

These findings have implications for evaluating children's nutritional status and for trend analysis. We recommend that malnutrition tabulations should be made using both the 1977 NCHS Reference and the 2006 WHO Standards during the transition from use of the older "descriptive" reference to the new "prescriptive" standard. We also recommend not using the suggested algorithm for converting the 1977 NCHS point estimates into 2006 WHO Standards point estimates for assessing trends in malnutrition of young children.

REFERENCES

Bloem M. The 2006 WHO child growth standards. Have implications for nutrition programmes in emergencies. BMJ. 2007; 334:705-6.

de Onis M and Habicht JP. Anthropometric reference data for international use: Recommendations from a World Health Organization Expert Committee. Am J Clin Nutr. 1996; 64:650-8.

de Onis M, Garza C, and Habicht JP. Time for a new growth reference. Pediatrics 1997; 100:e8.

de Onis M, Garza C, Onyango AW, and Borghi E. Comparison of the WHO child growth standards and the CDC 2000 growth charts. J Nutr. 2007; 137(1):144-8.

de Onis M, Onyango AW, Borghi E, Garza C, and Hong Y. Comparison of the World Health Organization (WHO) child growth standards and the National Center for Health Statistics/WHO international growth reference: Implications for child health programmes. Public Health Nutr. 2006; 9(7):942-7.

de Onis M, Onyango AW, Borghi E, Siyam A, and Pinol A. World Health Organization. WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: methods and development. WHO, 2006a.

Fenn B and Penny ME. Using the new World Health Organization growth standards: Differences from 3 countries. J Pediatr Gastroenterol Nutr. 2008; 46(3):316-21.

Gibson RS. Principles of Nutritional Assessment. Oxford University Press. 1990.

Hong Y and de Onis M. Algorithms for converting estimates of child malnutrition based on the NCHS reference into estimates based on the WHO child growth standards. BMC Pediatrics. 2008; 8:19.

International Pediatric Association. Endorsement of the New WHO Growth Standards for Infants and Young Children. http://www.who.int/childgrowth/Endorsement_IPA.pdf. Accessed on October 21, 2008.

Macro International Inc. Anthropometry, Anemia and HIV Testing Field Manual. Calverton, Maryland: Macro International Inc. 2008.

Nuruddin R, Lim MK, Hadden WC, and Azam I. Comparison of estimates of under-nutrition for pre-school rural Pakistani children based on the WHO standards and the National Center for Health Statistics (NCHS) reference. Public Health Nutr. 2008; 27:1-7.

Ogden CL, Robert JK, Katherine MF, Zuguo M, Shumei G, et al. Centers for Disease Control and Prevention 2000 growth charts for the United States: Improvements to the 1977 National Center for Health Statistics version. Pediatrics. 2002; 109; 45-60

Prost MA, Jahn A, Flyod S, Mvula H, Mwaiyeghele E, Venance M, Mhango T, Crampin C, McGrath, Fine PEM, and Glynn JR. Implications of new WHO growth standards in identification of risk factors and estimated prevalence of malnutrition in rural Malawian infants. PLoS One. 2008; 3(7).

Prinja S, Jarnail ST, and Satpal SB. Pilot testing of WHO child growth standards in Chandigarh: implications for India's child health programmes. Bull World Health Organ. 2009;87:116-122.

Rutstein SO, Sommerfelt AE, and Boerma JT. The anthropometric status of elite children. Presented by S.O Rutstein at the meeting of the American Public Health Association in New York City, October 1990.

Schwarz NG, Grobusch MP, Decker ML, Goesch J, Postschke M, Oyakhirome S, Kombila D, Fortin J, Lell B, Issifou S, Kremsner PG, and Klipstein-Grobusch K. WHO 2006 child growth standards: Implications for the prevalence of stunting and underweight-for-age in a birth cohort of Gabonese children in comparison to the Centers for Disease Control and Prevention 2000 growth charts and the National Center for Health Statistics 1978 growth references. Public Health Nutr. 2008; 11(7):714-9.

Seal A and Kerac M. Operational implications of using 2006 World Health Organization growth standards in nutrition programs: secondary data analysis. BMJ. 2007; 334:733.

Standing Committee on Nutrition. SCN endorses the new WHO growth standards for infants and young children. Available at http://www.who.int/childgrowth/endorsement_scn.pdf.

UNICEF 2006. Multiple Indicator Cluster Survey Manual 2005- Monitoring the Situation of Children and Women (Division of Policy and Planning). Available at: http://www.childinfo.org/files/Multiple_Indicator_Cluster_Survey_Manual_2005.pdf.

WHO Expert Committee on Physical Status: The Use and Interpretation of Anthropometry. WHO Technical Report Series: 854. World Health Organization, Geneva, 1995.

WHO 2006. World Health Organization releases new child growth standards - Standards confirm that all children worldwide have the potential to grow the same. Available at: http://www.who.int/mediacentre/news/releases/2006/pr21/en/index.html.