

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

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Abstract

Objectives: To compare growth patterns and estimates of malnutrition based on the World Health Organization (WHO) Child Growth Standards ('the WHO standards') and the National Center for Health Statistics (NCHS)/WHO international growth reference ('the NCHS reference'), and discuss implications for child health programmes.

Design: Secondary analysis of longitudinal data to compare growth patterns (birth to 12 months) and data from two cross-sectional surveys to compare estimates of malnutrition among under-fives.

Settings: Bangladesh, Dominican Republic and a pooled sample of infants from North America and Northern Europe.

Subjects: Respectively 4787, 10 381 and 226 infants and children.

Results: Healthy breast-fed infants tracked along the WHO standard's weight-for-age mean Z-score while appearing to falter on the NCHS reference from 2 months onwards. Underweight rates increased during the first six months and thereafter decreased when based on the WHO standards. For all age groups stunting rates were higher according to the WHO standards. Wasting and severe wasting were substantially higher during the first half of infancy. Thereafter, the prevalence of severe wasting continued to be 1.5 to 2.5 times that of the NCHS reference. The increase in overweight rates based on the WHO standards varied by age group, with an overall relative increase of 34%.

Conclusions: The WHO standards provide a better tool to monitor the rapid and changing rate of growth in early infancy. Their adoption will have important implications for child health with respect to the assessment of lactation performance and the adequacy of infant feeding. Population estimates of malnutrition will vary by age, growth indicator and the nutritional status of index populations.

Keywords
Growth standards
Anthropometry
Underweight
Stunting
Wasting
Overweight

In April 2006 the World Health Organization (WHO) released new standards for assessing the growth and development of children from birth to 5 years of age^{1,2}. The WHO Child Growth Standards (hereafter referred to as the WHO standards) are the product of a detailed process initiated in the early 1990s involving various reviews of the uses of anthropometric references and alternative approaches to developing new tools to assess growth. The new standards adopt a fundamentally prescriptive approach designed to describe how all

children should grow rather than merely describing how children grew at a specified time and place³.

The WHO standards were developed to replace the National Center for Health Statistics (NCHS)/WHO international growth reference^{4,5} (hereafter referred to as the NCHS reference), whose limitations have been described in detail elsewhere⁶.

The NCHS reference is currently used in the national programmes of about 100 countries⁷. Since the evaluation of child growth trajectories and the interventions designed to improve child health are highly dependent on the growth charts used, it is important to understand the impact of using the WHO versus the NCHS charts on

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the assessment of growth and estimates of malnutrition. Direct comparisons between NCHS and WHO centiles have been published elsewhere¹. The present article focuses on differences in the rates of underweight, stunting, wasting, severe wasting and overweight, and evaluates the growth performance of healthy breast-fed infants according to the WHO standards and the NCHS reference.

Methods

WHO Child Growth Standards

The WHO standards are based on primary data collected through the WHO Multicentre Growth Reference Study (MGRS). The MGRS was a population-based study conducted between 1997 and 2003 in Brazil, Ghana, India, Norway, Oman and the USA⁸. The study combined a longitudinal follow-up from birth to 24 months with a cross-sectional component of children aged 18–71 months⁸.

Characteristics of the MGRS populations⁹ and data collection methods⁸ have been published. The final sample and the methods used to develop the standards are also described elsewhere^{1,10}. Weight-for-age, length/height-for-age, weight-for-length/height and body mass index-for-age percentiles and Z-score values were generated for boys and girls aged 0–60 months.

Test populations and descriptive comparisons

We selected three datasets from populations with widely different nutritional status profiles for the comparative estimates presented hereafter. We generated Z-scores and percentage estimates ($\pm 95\%$ confidence intervals (CI)) of underweight (percentage below -2 standard deviations (SD) from the median for weight-for-age), stunting (percentage below -2 SD from the median for length/height-for-age), wasting (percentage below -2 SD from the median for weight-for-length/height), severe wasting (percentage below -3 SD from the median for weight-for-length/height) and overweight (percentage above $+2$ SD from the median for weight-for-length/height) based on the WHO standards and the NCHS reference.

We used the 1996–1997 National Demographic and Health Survey from Bangladesh ($n = 4787$)¹¹ as the index population to compare estimates of undernutrition (i.e. underweight, stunting, wasting, severe wasting) derived from the NCHS reference and the WHO standards. To assess differences in estimates of overweight, we used the 2002 National Demographic and Health Survey from the Dominican Republic ($n = 10381$)¹². To evaluate the adequacy of the WHO standards versus the NCHS reference for assessing growth patterns of healthy breast-fed infants, we used data from a pooled sample of 226 healthy breast-fed infants from seven studies in North America and Northern Europe^{13,14}. The Bangladesh and

Dominican Republic datasets were obtained through cross-sectional surveys covering ages 0–60 months while the infants in the pooled breast-fed sample were followed from birth to age 12 months.

Results

Weight-for-age

Growth patterns in infancy differed substantially between the WHO standard and the NCHS reference. The average weight of infants included in the WHO standards was above the NCHS median during the first half of infancy, crossed it at about 6 months and tracked below thereafter. Figure 1 shows the pattern of growth in average weight during infancy of the pooled breast-fed sample based on the WHO standard and NCHS reference. As expected, the pooled breast-fed set tracked along the WHO standard's mean Z-score while appearing to experience growth faltering from 2 months onwards when compared with the NCHS reference.

As illustrated in the Bangladesh dataset, the prevalence of underweight during the first six months was much higher when based on the WHO standard, i.e. the WHO prevalence was 2.5 times that derived from the NCHS reference. Thereafter, underweight rates were slightly lower when the WHO standard was used (Fig. 2). Overall, the relative decrease in underweight prevalence from birth to 5 years of age was about 6% (from 56.5% using the NCHS reference to 52.9% using the WHO standards).

Length/height-for-age

Figure 3 shows the percentages of Bangladeshi children classified as stunted. The estimated prevalence of stunting was higher for all age groups when using the WHO standard, especially in early infancy and from 24 to 35 months. Overall, the prevalence increased from 54.4% (95% CI. 53.0–55.8%) when using the NCHS reference to

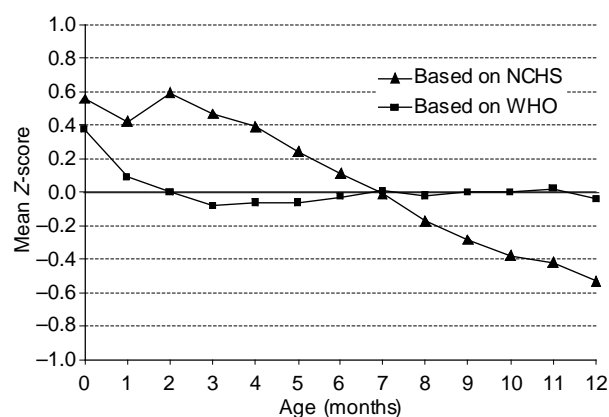


Fig. 1 Mean weight-for-age Z-scores of healthy breast-fed infants relative to the World Health Organization (WHO) standards and the National Center for Health Statistics (NCHS) reference

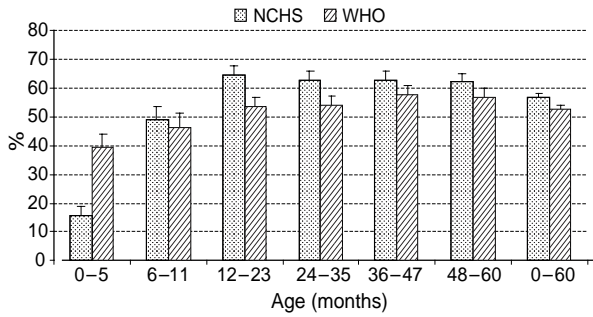


Fig. 2 Prevalence of underweight (below -2 standard deviations from the median for weight-for-age) by age based on the World Health Organization (WHO) standards and the National Center for Health Statistics (NCHS) reference in Bangladesh

60.1% (95% CI: 58.7–61.4%) when using the WHO standards, or a relative increase of about 10%.

Weight-for-length/height

Based on the same Bangladeshi sample, Fig. 4 shows the percentages of children classified as wasted and severely wasted. During the first six months of life, the prevalences of wasting and severe wasting using the WHO standards were, respectively, 2.5 and 3.5 times those estimated on the basis of the NCHS reference. The same pattern was sustained in the second half of infancy. Thereafter, although the prevalence of severe wasting according to the WHO standard continued to be 1.5 to 2.5 times that derived from the NCHS reference, wasting rates were similar or only slightly higher from the second year through to age 5 years.

Shifting to the upper end of the weight-for-length/height distribution, Fig. 5 shows the percentages of children from the Dominican Republic classified as overweight based on the WHO standard and NCHS reference. For all age groups, the prevalence was higher when estimated by the WHO standard. Overall, the prevalence increased from

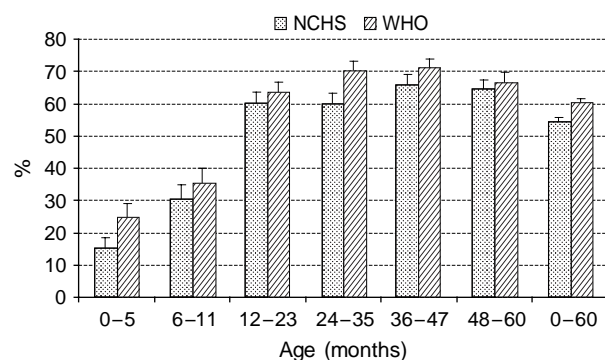


Fig. 3 Prevalence of stunting (below -2 standard deviations from the median for length/height-for-age) by age based on the World Health Organization (WHO) standards and the National Center for Health Statistics (NCHS) reference in Bangladesh

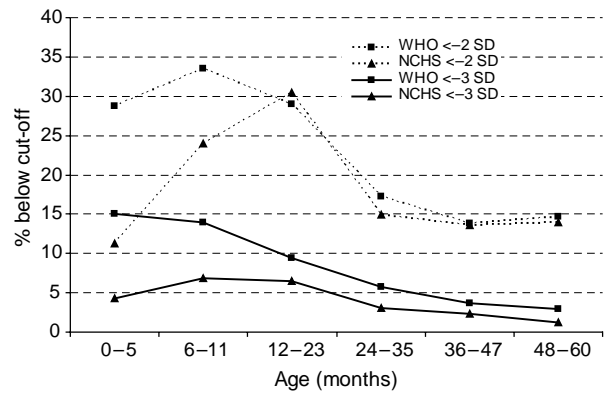


Fig. 4 Prevalence of wasting (below -2 standard deviations (SD) from the median for weight-for-length/height) and severe wasting (below -3 SD from the median for weight-for-length/height) by age based on the World Health Organization (WHO) standards and the National Center for Health Statistics (NCHS) reference in Bangladesh

6.4% (95% CI: 6.0–6.9%) to 8.6% (95% CI: 8.1–9.2%), i.e. a relative increase of 34% in this population.

For all results presented, patterns were the same when boys and girls were assessed separately (data available on request).

Discussion

As expected, there are important differences between the WHO standards and the NCHS reference that vary by age group, growth indicator, specific percentile or Z-score curve, and the nutritional status of index populations. Differences are particularly important during infancy, likely due to the inclusion of only breast-fed infants in the WHO sample and the predominance of formula-fed infants in the NCHS reference. Moreover, differences in measurement intervals between the two sets of curves (every 2 weeks in the first two months and monthly thereafter in the WHO standards vs. every 3 months in the NCHS reference) in a period of rapid growth also may explain the divergent

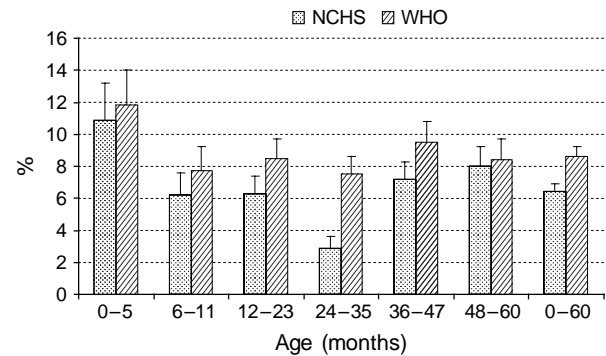


Fig. 5 Prevalence of overweight (above $+2$ standard deviations from the median for weight-for-length/height) by age based on the World Health Organization (WHO) standards and the National Center for Health Statistics (NCHS) reference in the Dominican Republic

growth patterns. Differences in the variability of normal growth depicted by the WHO standards and the NCHS reference likely are the result of the prescriptive approach and updated analytical methods on which the WHO standards are based. The difference in the shapes of the weight-based curves makes the interpretation of growth performance strikingly different depending on whether the WHO standard or the NCHS reference is used, which in turn has important implications for the advice given to mothers concerning lactation performance and the introduction of complementary foods.

Changes in the prevalences estimated from the test samples used in this paper are indicative of what may be expected in populations with similar nutritional status profiles. Variations in the ages of children studied, average attained length/height and proportions with excess or deficient weight-for-length/height make it impossible to define any algorithm that could be used to derive WHO standards-based prevalences from NCHS reference-based estimates.

It is expected though that stunting will increase throughout childhood when assessed using the WHO standards compared with the NCHS reference. Despite the close tracking of the WHO and NCHS medians (except from 24 to about 36 months when WHO children are on average taller due to the NCHS disjunction at this age), the tighter variability of the WHO standards affects the placement of the usual cut-off for stunting, i.e. $-2SD^1$. The finding that children in the WHO standards are of the same average length/height (or taller in some age groups) as those in the NCHS reference should dispel concerns that breast-fed infants might fail to meet their potential for growth of fat-free tissue because of marginal intakes of energy, protein and/or other nutrients.

Underweight rates generally will be higher when based on the WHO standard compared with rates based on the NCHS reference during the first half of infancy (i.e. 0–6 months) and lower thereafter. For wasting, the main difference between the new standard and the old reference is also during infancy (i.e. up to about 70 cm length) when wasting rates will be substantially higher using the WHO standard. Severe wasting, which is the criterion used for enrolling children in therapeutic feeding¹⁵, will also increase substantially throughout childhood when the WHO standard is applied.

The WHO weight-for-length curves go from 45 to 110 cm and the weight-for-height charts from 65 to 120 cm to facilitate their application in severely undernourished populations and emergency settings. The lower limit of the weight-for-length standards (45 cm) was chosen to include lengths down to $-2SD$ of girls' length at birth. The upper limit for the weight-for-height standards was influenced by the need to accommodate the tallest children at age 60 months (120 cm is approximately $+2SD$ of boys' height-for-age at 60 months). The extension of the WHO weight-for-length chart at both ends compared with the NCHS

reference (49 to 84 cm) was intended to facilitate assessment of stunted newborns, tall 2-year-olds and older children who are unable to stand for whatever reason (e.g. severe malnutrition and agitation during measurement). Similarly, the initiation of the weight-for-height chart at 65 cm (instead of 85 cm in the NCHS reference) was intended to facilitate the assessment of populations with high rates of stunting.

With respect to overweight, use of the WHO standards will result in a greater prevalence that varies by age and the nutritional status of the index population. In relation to age, the artificial drop in prevalence at 24 months seen with the NCHS reference⁶ was resolved by the design of the MGRS and the analytical techniques used to construct the WHO standards¹. The NCHS reference does not enable monitoring of BMI-for-age in pre-school age children and thus comparative results are not presented for this indicator. In the WHO standards, the BMI-for-age charts are available from birth to 60 completed months and are recommended for screening overweight throughout childhood.

The WHO standards are based on a sample of healthy breast-fed infants¹⁶ and, as shown in Fig. 1, they provide a better tool than the NCHS reference for monitoring the growth of breast-fed infants. The establishment of the breast-fed child as the norm for growth and development brings coherence among the tools used to assess growth and national¹⁷ and international¹⁸ infant feeding guidelines that recommend breast-feeding as the optimal source of nutrition during infancy. It also provides a basis for advocating the protection, promotion and support of breast-feeding and adequate complementary feeding. In this regard, the WHO standards are expected to make meaningful contributions to reducing child morbidity and mortality. Recognising the adequacy of human milk to support healthy growth and development^{17,19}, the new standards are recommended for application to all children independently of type of feeding.

The WHO standards demonstrate that healthy children from around the world who are raised in healthy environments and follow recommended feeding practices have strikingly similar patterns of growth²⁰. The ancestries of the children included in the WHO standards were widely diverse. They included peoples from Europe, Africa, the Middle East, Asia and Latin America. In this regard they are similar to growing numbers of populations with increasingly diverse ethnicities. The growth of the children in the various sites was very similar because their environments were similarly healthy. This indicates that we should expect the same potential for growth in any country. It also implies that deviations from this pattern must be assumed to reflect adverse conditions that require correction, e.g. lack of breast-feeding, nutrient-poor or energy-excessive complementary foods, unsanitary environments, deficient health services and/or poverty.

The NCHS reference is currently used in about 100 countries⁷. The shift to the WHO standards provides

a unique opportunity to underscore the importance and utility of monitoring linear growth; to rethink and redesign surveillance systems so that they are more useful in decision-making and less burdensome in terms of data collection; and, most importantly, to accelerate the integration of activities to promote infant and young child nutrition with broader efforts that encompass maternal and child health, full immunisation and adequate attention to physical, motor and cognitive development.

References

- 1 WHO Multicentre Growth Reference Study Group. *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*. Geneva: World Health Organization, 2006.
- 2 de Onis M, Garza C, Onyango AW, Martorell R, eds. WHO Child Growth Standards. *Acta Paediatrica. Supplementum* 2006; **450**: 1–101.
- 3 Garza C, de Onis M, for the WHO Multicentre Growth Reference Study Group. Rationale for developing a new international growth reference. *Food and Nutrition Bulletin* 2004; **25**(Suppl. 1): S5–14.
- 4 Hamill PVV, Drizd TA, Johnson CL, Reed RB, Roche AF, Moore WM. Physical growth: National Center for Health Statistics percentiles. *American Journal of Clinical Nutrition* 1979; **32**: 607–29.
- 5 Dibley MJ, Goldsby JB, Staehling NW, Trowbridge FL. Development of normalized curves for the international growth reference: historical and technical considerations. *American Journal of Clinical Nutrition* 1987; **46**: 736–48.
- 6 de Onis M, Yip R. The WHO growth chart: historical considerations and current scientific issues. *Bibliotheca Nutritio et Dieta* 1996; **53**: 74–89.
- 7 de Onis M, Wijnhoven TMA, Onyango AW. Worldwide practices in child growth monitoring. *Journal of Pediatrics* 2004; **144**: 461–5.
- 8 de Onis M, Garza C, Victora CG, Bhan MK, Norum KR, eds. WHO Multicentre Growth Reference Study (MGRS): Rationale, Planning and Implementation. *Food and Nutrition Bulletin* 2004; **25**(Suppl. 1): S1–89.
- 9 WHO Multicentre Growth Reference Study Group. Enrolment and baseline characteristics in the WHO Multicentre Growth Reference Study. *Acta Paediatrica. Supplementum* 2006; **450**: 7–15.
- 10 Borghi E, de Onis M, Garza C, Van den Broeck J, Frongillo EA, Grummer-Strawn L, *et al.*, for the WHO Multicentre Growth Reference Study Group. Construction of the World Health Organization child growth standards: selection of methods for attained growth curves. *Statistics in Medicine* 2006; **25**: 247–65.
- 11 National Institute for Population Research and Training. *Bangladesh Demographic and Health Survey 1996–97*. Demographic and Health Surveys. Dhaka: National Institute for Population Research and Training, 1997.
- 12 Molina Achécar M, Ramirez N, José Polanco J, Ochoa LH, Lerebours G, Garcia B. *Encuesta Demografica y de Salud, ENDESA 2002*. Demographic and Health Surveys. Santo Domingo, Republica Dominicana: Centro de Estudios Sociales y Demograficos, 2003.
- 13 WHO Working Group on Infant Growth. *An Evaluation of Infant Growth*. Geneva: World Health Organization, 1994.
- 14 Dewey KG, Peerson JM, Brown KH, Krebs NF, Michaelsen KF, Persson LA, *et al.* Growth of breast-fed infants deviates from current reference data: a pooled analysis of US, Canadian and European data sets. World Health Organization Working Group on Infant Growth. *Pediatrics* 1995; **96**: 495–503.
- 15 World Health Organization (WHO). *Management of Severe Malnutrition: A Manual for Physicians and Other Senior Health Workers*. Geneva: WHO, 1999.
- 16 WHO Multicentre Growth Reference Study Group. Breast-feeding in the WHO Multicentre Growth Reference Study. *Acta Paediatrica. Supplementum* 2006; **450**: 16–26.
- 17 American Academy of Pediatrics Policy Statement. Breast-feeding and the use of human milk. *Pediatrics* 2005; **115**: 496–506.
- 18 Fifty-fourth World Health Assembly. *Resolution WHA54.2, Infant and Young Child Nutrition*. Geneva: World Health Organization, 2001.
- 19 World Health Organization (WHO). *The Optimal Duration of Exclusive Breastfeeding*. Report of an Expert Consultation. Geneva: WHO, 2002.
- 20 WHO Multicentre Growth Reference Study Group. Assessment of differences in linear growth among populations in the WHO Multicentre Growth Reference Study. *Acta Paediatrica. Supplementum* 2006; **450**: 56–65.

Appendix – Members of the WHO Multicentre Growth Reference Study Group

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