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EDITORIAL

The World Health Organization child growth standards: expected implications for clinical and epidemiological research

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Abstract In 2006 and 2007, the World Health Organization (WHO) released two sets of child growth standards (World Health Organization, WHO Child Growth Standards. Methods and development. Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age. WHO, Geneva, 2006; World Health Organization, WHO Child Growth Standards: Methods and Development. Head circumference-for-age, arm circumference-for-age, triceps skinfold-for-age and subscapular skinfold-for-age. WHO, Geneva, 2007) to replace the National Center for Health Statistics references (Hamill et al., National Center for Health Statistics, Vital and Health Statistics Series 11, No 165, 1977) as an international tool for growth and nutritional assessment. This paper explores the scope of implications for future anthropometric research, highlighting foreseeable effects on the choice of research questions, choice of nutritional indices, training of measurers, and issues of internal and external validity of research results. The conclusion drawn is that the introduction of the WHO child growth standards is expected to have wide implications for growth and nutrition research. The full scope of this effect will gradually become clear while researchers, similar to health care workers, make the transition to using the new standards, re-evaluate results of past approaches, and explore the uses and functional validity of the standards, including those for indices that were not previously available.

Keywords Anthropometry · Growth · Growth references · Stunting · Wasting · WHO child growth standards

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Research questions and nutritional indices

In 2006 the World Health Organization (WHO) released growth standards for children 0–60 months that describe the distribution of weight, length, height, and body mass index (BMI) by age and sex as well as weight by length and sex [8]. These standards replace the former National Center for Health Statistics (NCHS) references [3] as an international tool for growth monitoring, nutrition screening, and surveillance, as a clinical tool to assist with the diagnosis of malnutrition, and as a tool for nutrition research. In 2007 a second set of standards was released describing the growth of head circumference, mid–upper arm circumference (MUAC), triceps skin-fold thickness (TST), and sub-scapular skin-fold thickness (SSST) [9]. These latter standards allow various aspects of body composition to be assessed. The two sets of new child growth standards released by WHO provide opportunities for the formulation of new research questions. In addition, as international standards for BMI-for-age and skin-fold thickness did not exist earlier, it is now possible to estimate *Z*-scores for BMI-for-age from birth and for MUAC-for-age, TST-for-age, and SSST-for age from the age of 3 months, thereby offering new prospects for assessing the nutritional status of children at a very early age and for comparing findings between various anthropometric indices. For example, it will be of interest to compare low BMI-for-age with low weight-for-length as indicators of ‘wasting’. It remains to be explored whether one standard will have any useful advantage over the other. In general terms, it is useful to explore the relative validity of new and old indices and definitions by studying their relation to morbidity and mortality [4].

Prevalence estimates

Research should focus on the extent to which the new standards affect the proportion of children classified as malnourished. Since the −2 *Z*-score reference line (the traditional cut line for under-nutrition) differs between the old and new standards, such differences are bound to exist but may vary with age and gender. It has already been shown that prevalence estimates of stunting (length/height-for-age <−2 *Z*-scores), wasting (weight-for-length/height <−2 *Z*-scores), and underweight (weight-for-age <−2 *Z*-scores) change considerably when the new standards are applied [2]. Stunting rates increase at all ages, while underweight rates increase until age 6 months and decrease thereafter. Wasting and severe wasting rates are now substantially higher, especially in early infancy.

Figure 1 shows the age-specific prevalence rates of severe wasting (weight-for-length/height <−3 *Z*-scores) in a group of about 5000 children under five years of age in the Democratic Republic of Congo (DRC) in an area with high malnutrition prevalence [5].

Strikingly, in the first 6 months of life the prevalence estimate based on the WHO standards is sevenfold higher than that based on the NCHS reference. Severe wasting requires urgent action in the form of both medical treatment and intensive nutritional rehabilitation. Hence, implementation of the new standards as a screening tool for severe wasting may have considerable effects on the numbers of children referred for treatment and, consequently, the resources required.

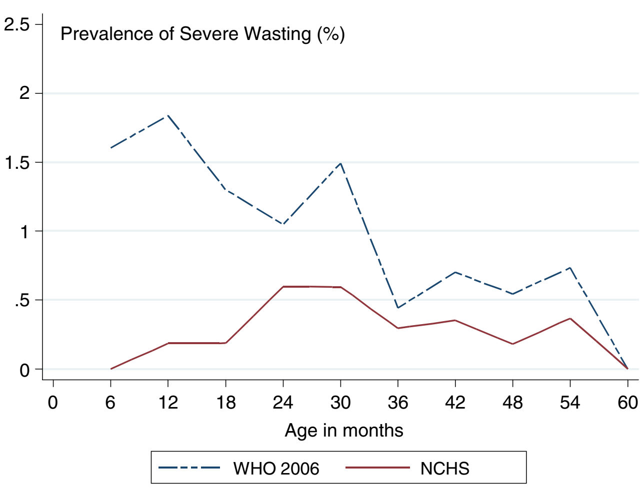

Fig. 1 Prevalence of severe wasting within 6-month age groups when the old growth reference and new growth standards are compared. *WHO* World Health Organization, *NCHS* National Centre for Health Statistics

It is important to note that there can be no fixed conversion rule to transform old prevalence estimates to new estimates because the proportions below extreme cut-points heavily depend on the specific form of the (tails of) the distribution of each study sample. This should be especially true for clinical nutrition research because of the often highly selective nature and very particular distributions of many clinical study samples. The new growth standards are considered to be more normative and more sensitive to malnutrition, hence re-calculation of old malnutrition prevalence estimates is imperative. In recognition of this, the WHO has updated the results of nutritional surveys included in the WHO global database on child growth and malnutrition [10].

Incidence estimates

Incidence estimates (and estimates of changes in prevalence) of malnutrition in longitudinal studies may change as well. This effect is expected to be greatest in age periods where there is a difference in the slope of the −2 *Z*-score line between old and new growth charts. Table 1 shows the cumulative incidence of underweight and wasting between 6 and 12 months among DRC study children. The results suggest that in this critical age group (weaning period), the rates of developing wasting have previously been under-estimated and that rates of developing underweight have been dramatically over-estimated with past methods. Conversely, rates of catch-up from below to above −2 *Z*-scores (a widely used operational definition of catch-up growth) may also be affected, and again, this is likely to be more an issue at ages where the slopes of the old and new growth curves differ.

Significance of risk factors in clinical-epidemiologic studies

There may be a need to re-evaluate epidemiological follow-up studies that have used anthropometric scores either as risk factors or as outcomes in order to check whether the nature and strength of the relationships remain unchanged when the new standards are used. It should be mentioned that old and new *Z*-scores are expected to maintain the ranking of individuals within each sex. Hence, whenever anthropometric scores were used as continuous variables in analyses, no appreciable change in study results is expected when a switch is made to the new standards, at least not in terms of the directions and strengths of the associations. In contrast, there is more potential for changed relationships if the earlier analysis used categorical variables classifying subjects above and below extreme *Z*-score cut-offs. In multiple logistic regression analyses of nutritional status, sex and age effects and interactions as well as adjustments for baseline anthropometry may yield different results with the two methods.

Table 1 Cumulative incidence of wasting and underweight in infants between 6 and 12 months of age included in the DRC study cohort [5]

	NCHS reference, % (95%CI)	WHO standards, % (95% CI)
Cumulative Incidence of wasting	6.3 (3.0–9.5) n=208	8.5 (4.7–12.4) n=199
Cumulative Incidence of underweight	37.1 (30.3–43.9) n=194	6.6 (2.9–10.4) n=166

95% CI, 95% confidence interval; n = number of children followed

Aspects of body composition

Several of the new indices are considered to be useful indicators of aspects of body composition. For example, high or low BMI-for-age, TST-for-age, and SSST-for-age are generally considered to indicate an excess or lack of fatness, respectively. Such use of anthropometry is likely to become increasingly important in view of the worldwide epidemic of obesity and the need for simple but valid diagnostic and prognostic tools for obesity. Validation studies using more direct measurements of body fatness will be needed to establish how well the newly available indices perform in that respect. Similar questions arise for the value of the new MUAC-for-age standard as an indicator of muscularity. Another question worth re-addressing is whether BMI-for-age is a sufficient assessment in a clinical context, or whether the addition of the new MUAC and skin-fold indicators is of any supplementary value in terms of diagnosis and prognosis of obesity. These issues may be of special importance to resource-poor clinical settings where sophisticated tools for body composition assessment are not affordable.

Relationship between anthropometry and physical assessment of nutritional status

The limitations of cross-sectional anthropometry for individual nutritional assessment are well known. In a specialized clinical context, anthropometry must be used along with physical and biochemical assessments to give a more complete evaluation of nutritional status. Among the limitations is the observation that children may display physical symptoms of malnutrition while remaining within the normal anthropometrical limits (clinical–anthropometrical mismatch) [6]. Table 2 illustrates that the frequency of this phenomenon did not change significantly when the new standards were applied to the DRC study data. Since the WHO standards are considered to be more valid and normative than the old NCHS reference, it will be interesting to further examine how they compare with determination of malnutrition by clinical evaluation. We performed a receiver operating characteristic (ROC) curve analysis (Fig. 2) to explore the ability of old versus new weight-for-age and weight-for-length/height to recognize children with physical signs of severe malnutrition. The two ROC curves are very similar, but the new standards tend to have somewhat higher sensitivity, especially at high levels of specificity.

Mixed nutritional classification systems

The Wellcome Classification [7] is a nutritional classification method that incorporates both clinical information and anthropometry. It is still used in some pediatric and nutritional rehabilitation wards. The clinical component involves a physical examination to detect the presence of edema, while the anthropometric component involves determination of weight-for-age (percentage of median) using Harvard references [7]. The percentage of median approach and Harvard references are currently considered to be obsolete. If there is a continued need for such a mixed classification system, then it is time to develop a new one. This new mixed classification system should involve a comparison of the prognostic performance of various candidate classifications in terms of health outcomes that are relevant to the contexts where they will be used. The complexity of Z-score calculation should not be a prohibiting factor since calculators for bed-side Z-score determination are available [11].

Table 2 Frequency of physical signs of severe malnutrition among children within normal anthropometric limits of weight-for-age and weight-for-length/height

	Anthropometric Index[a]	Number of children having a Z-score above −2	Number of children with physical signs of malnutrition	Percentage of children displaying mismatch (95%Cl)
NCHS reference	WFA	2275	33	1.45 (0.96–1.94)
	WFH	3192	139	4.35 (3.64–5.06)
WHO standards	WFA	2309	34	1.47 (0.98–1.96)
	WFH	3397	144	4.24 (3.56–4.92)

[a] WFA, Weight-for-length/height; WFA, weight-for-age

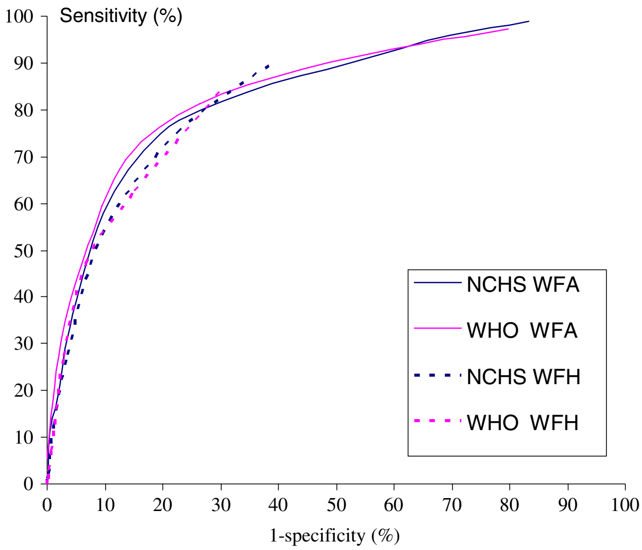

Fig. 2 Receiver operating characteristic curves for the ability of weight-for-age (*WFA*) and weight-for-length/height (*WFH*) standards to recognize children with physical signs of severe malnutrition

Transitional period

The WHO standards create an opportunity and a need for new methodological and operational research in the domain of growth and nutrition. In the transitional period researchers may take the opportunity to use and compare various indices and indicators, even if such comparisons are not the primary aim of the research. Infant body composition studies using dual energy X-ray absorptiometry (DEXA) scanning may provide the opportunity of including MUAC, TST, and SSST measurements so as to enable the validation of indices based on these measurements. While these issues will be addressed, the exact need and methods for the re-analysis of older scientific data will become progressively clearer. There may be room for meta-analyses of older articles addressing major issues in nutritional anthropometry.

Conduct of research studies

The impact of the WHO growth standards on research is likely to extend well beyond issues of use and usefulness of anthropometry as a public health or clinical tool. The importance of the Multicentre Growth Reference Study (MGRS), on which the new standards are based, may also reside in the area of growth research methodology.

Training and standardization

Similar to other landmark growth studies in the past, MGRS has used particularly refined and well-described anthropometric methods and has introduced a number of useful tools that are of potential interest to researchers [1]. For example, portable light-weight stadiometers have been developed specifically for this study and have already found other users worldwide. An anthropometry training video has been developed showing the detailed measurement techniques [12].

High levels of standardization were achieved in MGRS, and the accuracy of the final measurement values used for the construction of the growth charts was enhanced by averaging independent duplicate measurement values taken by two different observers. When scoring an individual measurement using the international standards, the validity of the resulting *Z*-score will be optimal only if the techniques used to take the measurements were the same as those used to construct the standards themselves. Thus, growth and nutrition researchers are highly advised to use instruments of similar quality, apply the same measurement standardization protocols, and take the average of independent replicate measurements as the final values for analysis. These recommendations mainly concern the desired level of standardization in clinical–epidemiological growth studies. A similar level of standardization will rarely be attainable in primary health care settings.

Data management and analysis

The WHO growth standards are useful for designing range and consistency checks for data entry in virtually all research using anthropometry in under-five children. This is a potential contribution to data quality and thus to the quality of growth and nutrition research in general. The WHO has developed macros that enable *Z*-scores in research datasets to be calculated easily [10]. These tools are available for a variety of statistical packages and are intended to replace the software that was used in conjunction with the old NCHS references.

Conclusion

The introduction of the WHO child growth standards is expected to have wide implications for growth and nutrition research. The full scope of this effect will gradually become clear while researchers, similar to health care workers, make the transition to using the new standards, re-evaluate results of past approaches, and explore the uses and functional validity (for etiognosis, diagnosis, and prognosis) of the standards, including for indices that were not available earlier.

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