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Implications of the WHO Child Growth Standards in rural Honduras

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Abstract

Objective: The present study analysed the impact of using the 2006 WHO Child Growth Standards ('the WHO standards') compared with the 1977 National Center for Health Statistics (NCHS) international growth reference ('the NCHS reference') on the calculated prevalence of chronic malnutrition in children aged 6·0–59·9 months.
Design: Anthropometric data were collected as part of a cross-sectional study exploring the association between household environments and nutritional status of children. *Z*-scores were computed for height-for-age (HAZ), weight-for-age (WAZ) and weight-for-height (WHZ) using each reference/standard. Results were compared using Bland–Altman plots, percentage agreement, kappa statistics, line graphs and proportion of children in *Z*-score categories.
Setting: The study was conducted in thirteen rural villages within Honduras's department of Intibucá.
Subjects: Children aged 6·0–59·9 months were the focus of the analysis, and households with children in this age range served as the sampling unit for the study.
Results: The WHO standards yielded lower means for HAZ and higher means for WAZ and WHZ compared with the NCHS reference. The WHO standards and NCHS reference showed good agreement between *Z*-score categories, except for HAZ among males aged 24·0–35·9 months and WHZ among males aged >24·0 months. Using the WHO standards resulted in higher proportions of stunting (low HAZ) and overweight (high WHZ) and lower proportions of underweight (low WAZ). The degree of difference among these measures varied by age and gender.
Conclusions: The choice of growth reference/standard employed in nutritional surveys may have important methodological and policy implications. While ostensibly comparable, data on nutritional indicators derived with different growth references/standards must be interpreted cautiously.

Keywords
Child health
Nutrition
Global health

In 2006, the WHO released new Child Growth Standards ('the WHO standards') for assessing child growth around the world. These standards were developed to replace the 1977 National Center for Health Statistics (NCHS) international growth reference ('the NCHS reference'), which comprises longitudinal and cross-sectional data on children in the USA[1]. At a population level, growth references/standards are used to calculate estimates for predicting nutrition-related emergencies, planning for equitable distribution of economic resources, assessing appropriate weaning practices, and screening and monitoring at-risk populations for growth deficiencies or excesses. Additional applications exist for individual children, including growth monitoring, determining best practices for introducing complementary feeding, evaluating lactation outcomes, or identifying growth problems[2]. With the availability of a new growth standard, it is important to analyse the implications of its adoption for specific applications. The present report analyses the impact of using the 2006 WHO standards on measures of chronic malnutrition among a population of children in rural Honduras.

A detailed account of the development of the new standards is provided by de Onis *et al.*[3]. Briefly, the new standards aimed to improve upon the existing NCHS reference by describing how all children should grow, rather than how children from a specific region grow at

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a particular time, by including mothers/children from both developed and developing nations based on rigorous health standards (including mothers who breast-fed and did not smoke) and by increasing the number of infant measurements and including assessment of achievements in motor development[3,4].

It is important to recognize that differences between the WHO standards and the NCHS reference vary depending on gender, age, anthropometric indicator and cut-off method used[3]. While an algorithm has been developed for calculating WHO estimates using NCHS-based prevalence estimates in the absence of raw data[5], the operational impact of using the WHO standards for nutritional assessment in comparison to the NCHS reference is greatly affected by the age, weight and height characteristics of the study population[6]. Populations with a larger proportion of children who are borderline for being diagnosed with malnutrition will experience greater changes in the calculated prevalence of malnutrition when different growth references/standards are applied[6]. Thus, it is important to review the impacts of the change in growth reference/standards in each unique population.

Since the WHO standards were released, several studies have assessed the impact of their adoption. The majority of these studies have focused on the prevalence of underweight and wasting in populations experiencing conditions of acute malnutrition[6–8]. One study explored impacts of the change on prevalence of overweight and BMI percentiles among a population of children in Canada[9]. A few studies have examined impacts on the prevalence of wasting, underweight and stunting[10–12]. While their findings documented differences between the measures depending on which growth reference/standards was used, differences were inconsistent across countries/studies and differences by gender were not described.

Changes in the growth reference/standards among chronically malnourished populations have important implications for breast-feeding recommendations, supplementary feeding practices and feeding programmes. The present study sought to determine the impact of the new growth standards on measures of chronic malnutrition among children in a low-income Latin American country by comparing anthropometric results using the 1977 NCHS reference and the 2006 WHO standards. Differences between the two are described through an analysis of agreement in *Z*-score categorization, a comparison of mean *Z*-scores and a comparison of the proportion of children in each *Z*-score category for measures of stunting, underweight and overweight.

Methods

Data were collected as part of a cross-sectional study exploring the association between household environments and nutritional status of children in thirteen rural villages within Honduras's department of Intibucá. Details of the cross-sectional study are provided elsewhere[13]. The sample size for the study was estimated to compare the proportion of stunted children among those who were exposed and unexposed to a variety of household sanitation factors (80 % power). The number of households needed from each village to reach sample size requirements was determined using systematic selection from a random start with probability of selection proportional to the number of eligible households in each village. Each village was analysed as a cluster using Taylor linearized variance estimates. Children under 5 years of age were the focus of the cross-sectional study, as their health status provides a good indicator of the overall health of a community[14].

Health promoters and teachers from the thirteen villages invited all primary caregivers of children aged 6·0–59·9 months, an estimated 554 households, to bring their children to a meeting in each village. Details about the study were given verbally to participants. Informed consent to participate and parental/caregiver permission for child measurements was indicated by an 'X' on a consent form prior to data collection. Institutional Review Boards from The University of Texas Health Science Center and the Western Region Ministry of Health in Honduras provided approval and ethical review for the research (HSC-SPH-08-0362).

Representatives from 386 households with a total of 588 children participated, yielding an estimated household response rate of 69·7 %. No caregivers who presented at the village meeting directly refused to participate. However, some participants left the meeting before completing all data collection activities. To ensure representativeness, a sample of eligible households that did not attend their village's meeting was visited and their participation requested; all of these households agreed to participate. Of the 588 children who participated, 500 met the age eligibility criteria (between the ages of 6·0 and 59·9 months). Of these, complete information was available for 489 children.

Local interviewers and Peace Corps Volunteers were trained to conduct household and demographic interviews, and the principal investigator and local physician completed anthropometric measurements in duplicate following standard procedures[15]. The measurer repeated measurements differing by more than 0·5 cm for height or circumferences or by more than 0·1 kg for weight until two measurements were obtained within these criteria. Mueller and Martorell's formula for calculating intra-observer technical error of measurement (TEM)[15] yielded TEM values within the acceptable measurement error standards for all measurements (0·3 cm for height/length, 0·2 cm for circumferences)[16]. The average of the two acceptable duplicate measures was used for analyses.

Height of children who could stand alone was measured to the nearest 0·1 cm. The height measurement was taken while children were standing barefoot against a stadiometer, with their heels together and touching the backboard, their scapulas and/or buttocks against the backboard and their head in a horizontal Frankfort plane. Height was measured using a locally constructed portable stadiometer consisting of a 2 ft × 4 ft board affixed with an ADC 396 woven tape measure and a Stanley torpedo level to ensure levelness. Weight and height were taken while each child was standing on an even surface. Recumbent length of children who could not stand was taken to the nearest 0·1 cm using a Seca 210 baby-length measuring mat. The child was placed in a supine position with his/her head flush with the top of the mat and the measurement taken at the point of the extended, flexed heel. Weight of children, barefoot with excess clothing removed, was taken to the nearest 0·1 kg using a LifeSource UC-322 digital load cell scale. For children who could not stand alone, weight was determined by subtracting the weight of the child while being held from the weight of the individual without the child. In one village, infant weight was measured to the nearest 100 g using a Salter hanging scale.

Intra-observer TEM was calculated using Mueller and Martorell's formula[15]. *Z*-scores (the number of standard deviations an individual is from the reference mean) were computed for height/length-for-age (HAZ) as an indicator of stunting, for weight-for-age (WAZ) as an indicator of underweight and for weight-for-height/length (WHZ) as an indicator of overweight. HAZ, WAZ and WHZ were determined using the NCHS reference through the Epi Info version 3·5·1 NutStat application (Centers for Disease Control and Prevention, Atlanta, GA, USA) and using the WHO standards through the Anthro version 2 STATA igrowup macro package (WHO, Geneva, Switzerland). Corrections were made for recumbent length measurements using NutStat and Anthro. No children were eliminated from analysis, as no children had implausibly high or low measurements.

All analyses were conducted using the Intercooled STATA statistical software package version 9·2 (Stata Corporation, College Station, TX, USA). Children were stratified by gender into four age categories: 6·0–23·9 months, 24·0–35·9 months, 36·0–47·9 months and 48·0–59·9 months. Means and 95 % confidence intervals for all measures were calculated by gender and age category. Bland–Altman analysis was performed to assess agreement between NCHS and WHO *Z*-scores continuously. Percentage agreement and kappa statistics were calculated to assess agreement between *Z*-score categories of ≤−4·00, −3·00, −2·00, −1·00, 0·00, 1·00, 2·00, 3·00 and ≥4·00. NCHS and WHO mean *Z*-scores and 95 % confidence intervals for HAZ, WAZ and WHZ were calculated by gender and age category and compared using line graphs. Finally, the proportion of children in each *Z*-score category as per the NCHS reference and WHO standards was calculated and compared for HAZ, WAZ and WHZ by age and gender. All standard errors and confidence intervals were adjusted for the loss of precision due to the village cluster sampling design using the SVY command in STATA. While multiple outcomes were examined in these analyses, statistical adjustment for multiple outcomes was not deemed necessary due to the descriptive nature of the analyses.

Results

Complete height and weight data for analysis were collected from 489 children aged 6·0–59·9 months. Mean height/length and weight values by gender and age category are provided in Table 1. All values show an expected upward trend with increasing age in males compared with females.

Bland–Altman analysis of the mean difference in *Z*-scores and corresponding limits of agreement (plus and minus two standard deviations of the mean difference) revealed a positive difference for HAZ results (Table 2). This suggested that the NCHS reference resulted in higher

Table 1 Mean values of anthropometric measures by gender and age category among children aged 6·0–59·9 months in Intibucá, Honduras, 2008

			Height/length (cm)		Weight (kg)	
Gender/age (months)	*n*	%	Mean	95 % CI*	Mean	95 % CI*
Total	489	100·0				
Males	252	51·5				
6·0–23·9	101	40·1	74·7	72·5, 76·9	9·5	8·9, 10·1
24·0–35·9	51	20·2	83·8	82·6, 85·0	11·9	11·4, 12·4
36·0–47·9	51	20·2	90·7	89·1, 92·4	13·6	13·2, 14·0
48·0–59·9	49	19·4	96·9	95·7, 98·2	15·3	14·7, 15·9
Females	237	48·5				
6·0–23·9	76	32·1	72·1	71·1, 73·2	8·8	8·4, 9·1
24·0–35·9	58	24·5	82·3	81·7, 82·9	11·1	10·7, 11·5
36·0–47·9	60	25·3	89·2	87·7, 90·7	12·8	12·3, 13·2
48·0–59·9	43	18·1	95·0	93·0, 97·0	14·2	13·5, 14·9

*Confidence intervals adjusted for clustered sampling design.

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Table 2 Bland–Altman analysis* of difference, agreement† and kappa statistics† comparing Z-scores calculated using the NCHS reference and WHO standards by age and gender for children aged 6·0–59·0 months in Intibucá, Honduras, 2008

Measure/age (months)	Males						Females					
	Mean		LOA				Mean		LOA			
	Difference	95 % CI	−2SD	+2SD	Agreement	κ	Difference	95 % CI	−2SD	+2SD	Agreement	κ
HAZ												
6·0–23·9	0·07	0·02, 0·12	−0·37	0·51	0·87	0·83	−0·02	−0·04, 0·01	−0·27	0·23	0·91	0·87
24·0–35·9	0·58	0·54, 0·62	0·27	0·89	0·51	0·34	0·40	0·36, 0·44	0·15	0·65	0·64	0·52
36·0–47·9	0·25	0·23, 0·26	0·06	0·43	0·79	0·71	0·20	0·18, 0·21	0·05	0·34	0·77	0·68
48·0–59·9	0·07	0·05, 0·08	−0·08	0·21	0·96	0·94	0·09	0·06, 0·11	−0·06	0·23	0·98	0·97
WAZ												
6·0–23·9	−0·32	−0·37, −0·28	−0·66	0·02	0·77	0·65	−0·35	−0·40, −0·31	−0·76	0·05	0·62	0·46
24·0–35·9	−0·21	−0·23, −0·19	−0·33	−0·09	0·83	0·73	−0·28	−0·31, −0·25	−0·49	−0·06	0·70	0·57
36·0–47·9	−0·17	−0·19, −0·16	−0·27	−0·07	0·82	0·70	−0·17	−0·19, −0·16	−0·31	−0·04	0·78	0·67
48·0–59·9	−0·16	−0·19, −0·14	−0·39	0·06	0·90	0·83	−0·04	−0·06, −0·01	−0·21	0·14	0·98	0·97
WHZ												
6·0–23·9	−0·25	−0·33, −0·17	−0·74	0·24	0·79	0·59	−0·21	−0·28, −0·15	−0·77	0·34	0·71	0·55
24·0–35·9	−0·57	−0·65, −0·49	−1·19	0·05	0·69	0·35	−0·52	−0·57, −0·47	−0·92	−0·13	0·74	0·47
36·0–47·9	−0·43	−0·47, −0·38	−0·74	−0·11	0·82	0·34	−0·33	−0·38, −0·29	−0·61	−0·06	0·88	0·69
48·0–59·9	−0·34	−0·38, −0·30	−0·63	−0·05	0·69	0·29	−0·20	−0·24, −0·17	−0·44	0·03	0·88	0·72

NCHS reference, 1977 National Center for Health Statistics international growth reference; WHO standards, 2006 WHO Child Growth Standards; LOA, limits of agreement; HAZ, height/length-for-age *Z*-score; WAZ, weight-for-age *Z*-score; WHZ, weight-for-height/length *Z*-score.
*Bland–Altman analysis includes the mean of differences between NCHS and WHO *Z*-scores and 95 % confidence intervals adjusted for clustered sampling design and their LOA, which are the mean difference plus and minus two standard deviations.
†Agreement and kappa statistics calculated based on *Z*-score categories ≤−4·00, −3·00, −2·00, −1·00, 0·00, 1·00, 2·00, 3·00 and ≥4·00.

Z-scores compared with the WHO standards. The most extreme difference in HAZ was seen in males aged 24·0–35·9 months, who showed a mean difference of 0·58 *Z*-score units with an upper limit of agreement of 0·89. Bland–Altman analysis revealed negative differences across nearly all age and gender categories for WAZ and WHZ, suggesting that the NCHS reference resulted in lower *Z*-scores compared with the WHO standards. The most extreme differences were seen for WHZ generally, and for males aged 24·0–35·9 months specifically, who showed a mean difference of −0·57 *Z*-score units with a lower limit of agreement of −1·19. For all three measures boys showed higher mean differences than girls, except for WAZ among those aged 36·0–47·9 months where mean differences were equal, and for HAZ for ages 48·0–59·9 months and WAZ for ages 6·0–35·9 months where girls showed higher mean differences than boys.

The percentage agreement between NCHS and WHO *Z*-scores ranged between 51 % for HAZ in males 24·0–35·9 months of age and 98 % in females 48·0–59·9 months of age for both HAZ and WAZ (Table 2). Kappa classification agreement values ranged from 0·29 for WHZ in males 48·0–59·9 months of age to 0·97 for both HAZ and WAZ in females 48·0–59·9 months of age. With the exception of WHZ for males, the 48·0–59·9 month age group showed the greatest overall agreement, and the 24·0–35·9 month age group showed the lowest overall agreement. While the kappa values were lowest overall for WHZ for both genders, the greatest differences in agreement appeared to occur across age groups rather than across measures or gender categories.

Line graphs comparing NCHS and WHO mean *Z*-scores showed significant differences in HAZ for males aged 24·0–35·9 months and in WHZ for both males and females aged 24·0–35·9 and 36·0–47·9 months (Fig. 1). No statistically significant differences in means were detected in the 48·0–59·9 month age group for any measure. The line graphs also demonstrated that NCHS means were consistently higher than WHO means for HAZ, while NCHS means were consistently lower than WHO means for WAZ and WHZ. This suggested that in this population, use of the WHO standards detected more chronically undernourished children (per HAZ) and fewer acutely undernourished children (per WAZ and WHZ) compared with the NCHS reference.

Differences in the proportion of children in each *Z*-score category between the NCHS reference and WHO standards ranged from 0·0 % for several categories to −19·0 % for WHZ between 1·00 and 1·99 in females aged 24·0–35·9 months (Table 3). Negative differences indicated that the proportion of children in the respective *Z*-score range was greater when using the WHO standards than when using the NCHS reference. Differences greater than or equal to ±5·0 % in *Z*-scores ≤−2·00 or ≥2·00 were considered of clinical importance as these *Z*-score cut-offs indicate a need for nutritional intervention. Clinically important differences in *Z*-scores ≤−2·00 were seen to the greatest extent in the 24·0–35·9 month age group for HAZ in males and females (*Z*-score of –3·99 to –3·00: −11·8 % for males and −6·9 % for females; *Z*-score of −2·99 to –2·00: −9·8 % for males and −5·2 % for females) and for WAZ in females (*Z*-score of −2·99 to −2·00: 13·3 %). Clinically important differences in

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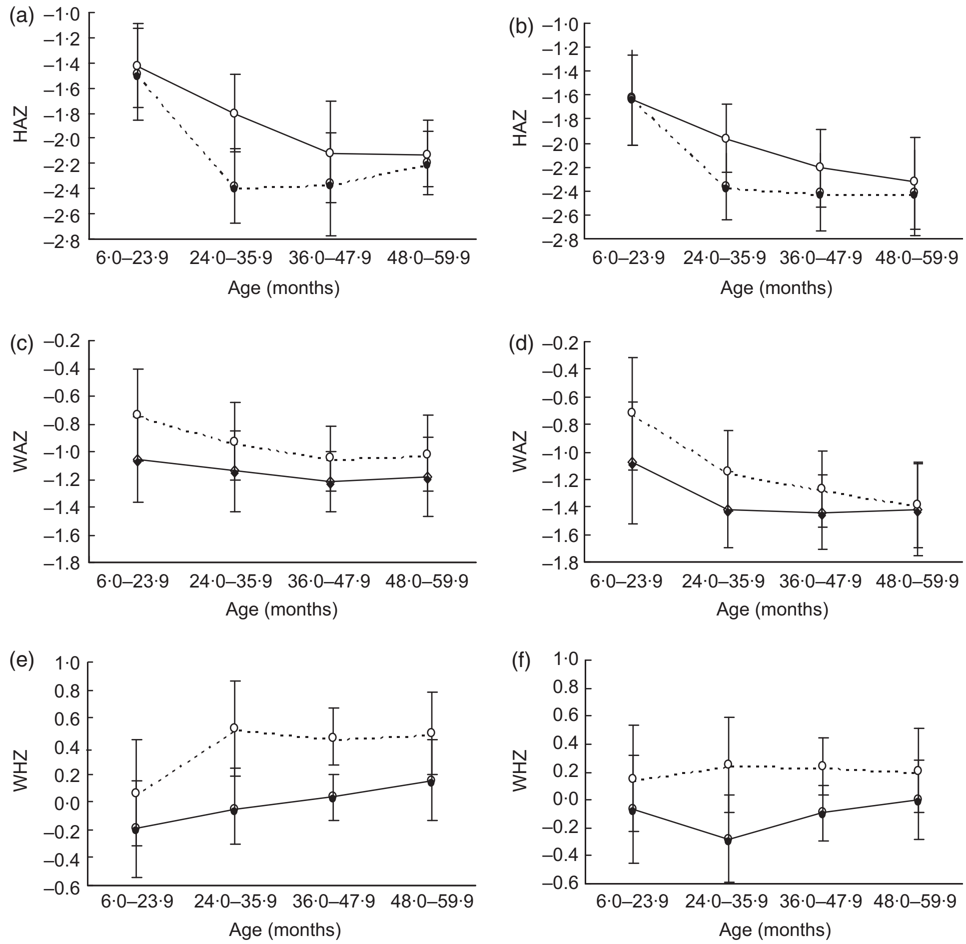

Fig. 1 Comparison of *Z*-scores for (a, b) height/length-for-age (HAZ), (c, d) weight-for-age (WAZ) and (e, f) weight-for-height/length (WLZ) by age category among males (a, c, e) and females (b, d, f) in Intibucá, Honduras, 2008: —○—, *Z*-scores calculated using the 1977 National Center for Health Statistics international growth reference; – – ● – –, *Z*-scores calculated using the 2006 WHO Child Growth Standards. Values are means, with 95 % confidence intervals adjusted for cluster sampling design represented by vertical bars

Z-scores between 2·00 and 2·99 were seen in WHZ for females 6·0–23·9 months of age (−5·3 %) and males 48·0–59·9 months of age (−4·1 %).

Discussion

The results of the present analysis show the impact of using the 2006 WHO Child Growth Standards on assessing nutritional status in a chronically malnourished population from a low-income country. For mean *Z*-scores, the WHO standards showed lower means for HAZ and higher means for WAZ and WHZ compared with the NCHS reference. The WHO standards and NCHS reference showed good or excellent agreement between *Z*-score categories, except among HAZ classifications for males aged 24·0–35·9 months and WHZ classifications for males older than 24 months. Comparing the proportion of stunted, underweight and wasted children, use of the WHO standards resulted in higher proportions of stunting (HAZ), lower proportions of underweight (WAZ) and higher proportions of overweight (WHZ). The degree of difference among these measures varied by age category and gender.

These findings are generally consistent with other studies that have assessed the impact of using the WHO standards in comparison to the NCHS reference[6–10]. Consistent with the findings in the present analysis, Fenn and Penny and Álvarez *et al.* showed that mean scores for HAZ were similar although slightly lower and for WAZ and WHZ were higher using the WHO standards compared with the NCHS reference[10,11].

A unique finding was noted in the mean HAZ scores for males and females aged 24·0–35·9 months, where the NCHS *Z*-score mean was above −2·00 while the WHO mean lay below −2·00. Since −2·00 is a commonly used cut-off indicating moderate stunting, different conclusions are likely to be drawn about the degree of stunting in the population depending on which growth reference/standards is used for this population. This suggests that

Table 3 Comparison of proportions in each *Z*-score category using the NCHS reference and WHO standards by age and gender for children aged 6·0–59·0 months in Intibucá, Honduras, 2008 Intibucá, Honduras, 2008

		HAZ						WAZ						WHZ					
		NCHS		WHO		Difference*		NCHS		WHO		Difference		NCHS		WHO		Difference	
Age (months)	*Z*-score	M%	F%	M%	F%	M%	F%	M%	F%	M%	F%	M%	F%	M%	F%	M%	F%	M%	F%
6·0–23·9	≤−4·00	1·0	1·3	1·0	1·3	0·0	0·0	0·0	0·0	0·0	1·3	0·0	−1·3	0·0	0·0	0·0	0·0	0·0	0·0
	−3·99 to −3·00	4·0	7·9	9·9	9·2	−5·9†	−1·3	2·0	2·6	2·0	0·0	0·0	2·6	0·0	0·0	0·0	0·0	0·0	0·0
	−2·99 to −2·00	29·7	26·3	26·7	27·6	3·0	−1·3	17·8	23·7	8·9	7·9	8·9†	15·8†	3·0	2·6	3·0	2·6	0·0	0·0
	−1·99 to −1·00	36·6	38·2	33·7	34·2	3·0	3·9	34·7	36·8	32·7	35·5	2·0	1·3	20·8	28·9	12·9	14·5	7·9	14·5
	−0·99 to 0·99	23·8	25·0	23·8	25·0	0·0	0·0	42·6	28·9	50·5	47·4	−7·9	−18·4	68·3	48·7	66·3	59·2	2·0	−10·5
	1·00 to 1·99	1·0	1·3	1·0	2·6	0·0	−1·3	2·0	2·6	5·0	2·6	−3·0	0·0	6·9	10·5	15·8	13·2	−8·9	−2·6
	2·00 to 2·99	3·0	0·0	1·0	0·0	2·0	0·0	1·0	5·3	1·0	5·3	0·0	0·0	0·0	5·3	1·0	10·5	−1·0	−5·3†
	3·00 to 3·99	1·0	0·0	3·0	0·0	−2·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	3·9	0·0	0·0	0·0	3·9
	≥4·00	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	1·0	0·0	1·0	0·0	0·0	0·0
24·0–35·9	≤−4·00	3·9	3·4	3·9	6·9	0·0	−3·5	0·0	1·7	0·0	1·7	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
	−3·99 to −3·00	9·8	13·8	21·6	20·7	−11·8†	−6·9†	1·9	5·0	0·0	5·0	1·9	0·0	0·0	0·0	0·0	0·0	0·0	0·0
	−2·99 to −2·00	25·5	31·0	35·3	36·2	−9·8†	−5·2†	17·3	21·7	13·5	8·3	3·8	13·3†	0·0	0·0	0·0	0·0	0·0	0·0
	−1·99 to −1·00	41·2	32·8	33·3	24·1	7·8	8·6	36·5	40·0	32·7	36·7	3·8	3·3	15·7	19·0	9·8	12·1	5·9	6·9
	−0·99 to 0·99	17·6	19·0	5·9	12·1	11·8	6·9	42·3	30·0	51·9	46·7	−9·6	−16·7	76·5	75·9	64·7	63·8	11·8	12·1
	1·00 to 1·99	2·0	0·0	0·0	0·0	2·0	0·0	1·9	1·7	1·9	1·7	0·0	0·0	2·0	3·4	17·6	22·4	−15·7	−19·0
	2·00 to 2·99	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	5·9	1·7	2·0	1·7	3·9	0·0
	3·00 to 3·99	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	2·0	0·0	−2·0	0·0
	≥4·00	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	3·9	0·0	−3·9	0·0
36·0–47·9	≤−4·00	1·9	1·6	5·8	1·6	−3·8	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
	−3·99 to −3·00	19·2	18·0	21·2	26·2	−1·9	−8·2†	0·0	3·3	0·0	1·7	0·0	1·7	0·0	0·0	0·0	0·0	0·0	0·0
	−2·99 to −2·00	36·5	37·7	40·4	44·3	−3·9	−6·6†	11·8	21·7	7·8	18·3	3·9	3·3	0·0	0·0	0·0	0·0	0·0	0·0
	−1·99 to −1·00	30·8	34·4	23·1	19·7	7·7	14·8	52·9	48·3	43·1	40·0	9·8	8·3	3·9	10·0	2·0	10·0	2·0	0·0
	−0·99 to 0·99	11·5	8·2	9·6	8·2	1·9	0·0	35·3	26·7	49·0	38·3	−13·7	−11·7	90·2	83·3	80·4	71·7	9·8	11·7
	1·00 to 1·99	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	1·7	0·0	−1·7	5·9	6·7	13·7	18·3	−7·8	−11·7
	2·00 to 2·99	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	3·9	0·0	−3·9	0·0
	3·00 to 3·99	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
	≥4·00	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
48·0–59·9	≤−4·00	0·0	4·4	0·0	4·4	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
	−3·99 to −3·00	24·5	22·2	24·5	22·2	0·0	0·0	0·0	4·7	0·0	4·7	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
	−2·99 to −2·00	36·7	40·0	38·8	40·0	−2·0	0·0	10·2	27·9	8·2	25·6	2·0	2·3	0·0	2·3	0·0	2·3	0·0	0·0
	−1·99 to −1·00	30·6	22·2	30·6	24·4	0·0	−2·2	51·0	34·9	46·9	37·2	4·1	−2·3	12·2	9·3	4·1	9·3	8·2	0·0
	−0·99 to 0·99	8·2	11·1	6·1	8·9	2·0	2·2	36·7	32·6	42·9	32·6	−6·1	0·0	79·6	81·4	69·4	69·8	10·2	11·6
	1·00 to 1·99	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	4·1	7·0	18·4	18·6	−14·3	−11·6
	2·00 to 2·99	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	2·0	0·0	−2·0	0·0	2·0	0·0	6·1	0·0	−4·1†	0·0
	3·00 to 3·99	0·0	0·0	0·0	0·0	0·0	0·0	2·0	0·0	0·0	0·0	2·0	0·0	2·0	0·0	2·0	0·0	0·0	0·0
	≥4·00	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0

NCHS reference, 1977 National Center for Health Statistics international growth reference; WHO standards, 2006 WHO Child Growth Standards; HAZ, height/length-for-age *Z*-score; WAZ, weight-for-age *Z*-score; WHZ, weight-for-height/length *Z*-score; M%, percentage of males; F%, percentage of females.
*Difference = NCHS proportion minus WHO proportion.
†Indicates a clinically important difference greater than or equal to ±5·0 % in *Z*-scores ≤−2·00 for HAZ and WAZ indicators and ≥2·00 for WHZ indicator.

the specific distribution of nutritional indicators among children in a particular population will have an important impact on the outcome of the direction and magnitude of changes detected between different growth standards/ references[6].

No other published literature was found assessing agreement between *Z*-score categories. Since findings from anthropometric assessments in communities are often summarized in *Z*-score categories, differences in agreement between the NCHS reference and the WHO standards could have an impact on which children are classified as over- or undernourished. The results of agreement from the current analysis can be used to describe deviations in agreement by age, gender and indicator categories for this chronically undernourished population.

The most common method used to describe the impact of using the new WHO standards in the published literature was to compare the proportion of children classified as moderately or severely malnourished (corresponding to *Z*-score categories of $-2\cdot00$ to $-2\cdot99$ and $\leq -3\cdot00$, respectively). When using the WHO standards compared with the NCHS reference, other studies also found a higher proportion of stunted children[9,10,12] and a lower proportion of underweight children[8–10,12]. However, the proportion of wasted children, indicated by a WHZ of $\leq -2\cdot00$, showed more variable results. Fenn and Penny observed a higher percentage of wasting using the WHO standards in two of three populations[10]. However, together with the third population studied by Fenn and Penny, Nash *et al.* and Prost *et al.* observed a lower percentage of wasted children[9,10,12]. When distinguishing between moderately and severely wasted children, multiple studies have shown that more children are classified as severely wasted using the WHO standards[6,7].

As the current study did not have any children with a *Z*-score of $\leq -2\cdot00$ for WHZ (indicating wasting), differences in the percentage of children with a *Z*-score of $\geq 2\cdot00$ for WHZ (indicating overweight) were also compared across studies. Consistent with the results of the current study, Nash *et al.* also found a higher percentage of overweight children using the WHO standards[9].

The findings of the present study are consistent with the WHO's statement that, compared with the NCHS reference, using the new WHO standards will result in higher classification of stunting, lower underweight after 6 months, and higher overweight to varying degrees. The WHO emphasizes that the magnitude of the changes observed in the anthropometric estimates between the NCHS reference and WHO standards varies depending on the indicator used, the gender and age of the child and the overall nutritional status of the population observed[3,17].

The current study provides valuable age- and gender-level detail on the impact of using the new WHO standards. However, a larger sample size would be ideal to achieve the degree of stratification desired for this analysis. Rigorous methods were used for completing all measurements, and inter-observer error was eliminated by having the primary investigator complete nearly all anthropometric measures. However, due to the limited budget and field-based nature of the study, some precision in measurements may have been lost on account of the instruments available for use.

While ostensibly comparable, data on nutritional indicators derived with different growth references/standards must be interpreted cautiously. The introduction of a new reference/standard adds an additional explanatory factor to be considered when assessing changes in nutritional status over time. If a programme was using the NCHS reference for previous analyses, it is important to re-evaluate prior nutritional data to avoid inaccurate conclusions of trend changes when switching to the new WHO standards[10]. With an additional reference option available for assessing population growth status, it will be ideal to generate a single standardized practice from which results across multiple studies can be compared. The new WHO standards offer a suitable possibility. While published literature assessing the practical implications of using the new WHO standards compared with the NCHS reference have shown generally consistent results, some inconsistent effects have been detected. It remains essential to carefully consider the unique conditions of each study population when determining the impact of using the new WHO standards.

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