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WHO 2006 Child Growth Standards overestimate short stature and underestimate overweight in Japanese children

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Abstract

Background: It is unclear whether the World Health Organization (WHO) 2006 Child Growth Standards are applicable to East Asian populations. We investigated the applicability of the WHO standards of length/height and weight to a cohort representing middle-class children in Japan.

Methods: A cohort of children aged 0–5 years (3430 boys, 3025 girls) in the Tokyo Child Care Center Survey consecutively recruited from 2007 to 2013 were studied. Age- and sex-specific z-scores of length/height, weight and weight for length/height were calculated relative to either the WHO standards or the Japanese 2000 Growth References (nationally representative cross sectional survey data).

Results: Compared with the WHO standards, Japanese children at birth, 1, 3, 5 years were shorter (length/height standard deviation score [SDS] −0.26, −0.82, −0.81, −0.63 for boys, and −0.15, −0.67, −0.84, −0.62 for girls, respectively) and lighter (weight SDS −0.62, −0.36, −0.34, −0.42 for boys and −0.60, −0.17, −0.29, −0.43 for girls, respectively). Weight for length/height showed smaller differences at various length/height points (SDS −0.05 to 0.15 for boys, 0.01 to 0.29 for girls, respectively).

Conclusions: Adoption of the WHO standards would substantially alter the prevalence of short stature, underweight and overweight in Japanese children 0–5 years of age. These findings advocate the use of the national references in Japan.

Keywords: Cohen's criteria; East Asian populations; infants and children; Japanese children; Japanese Growth Reference; WHO Growth Standards.

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Introduction

An international effort was began to develop a new international reference for assessing the growth of young children, in particular, for breastfed infants who appear to falter relative to the National Center for Health Statistics/World Health Organization (WHO) reference. Data for the WHO multinational study were collected at seven sites in China, India, Guatemala, Nigeria, Chile, Sweden and Australia over the period of April 1989 to December 1992 [1]. The growth curves of infants from all the sites except for China and India were strikingly similar, relative to the Australians (the reference category); however, Chinese infants were 3% shorter at 12 months of age and Indian infants 15% lighter. The WHO Working Group concluded that the growth of children from South and East Asian populations be rigorously assessed in the process of developing the new international reference.

WHO released the new WHO Child Growth Standards in April 2006 [2, 3]. The standards are based on multiple measurements on breastfed infants under optimum conditions. The data were collected from 8440 children in affluent households from widely differing ethnic backgrounds and cultural settings (Brazil, Ghana, India, Norway, Oman and the USA). The WHO claimed that the length of children is strikingly similar among the six sites with 3% of variability in length attributed to between-site differences compared to 70% to within-site differences; and concluded that the WHO Child Growth Standards have universal applicability. The WHO 2006 Child Growth Standards, however, did not represent populations from East Asian countries such as China. The WHO Working Group did not explicitly state why it excluded Chinese children from the sample population.

A Hong Kong Chinese birth cohort study [4] challenged the premise that clinically significant differences do not exist between growth patterns of a Hong Kong population and the WHO 2006 Growth Standards by demonstrating clinically significant differences in body size. The researchers described Hong Kong as an affluent society where children have been traditionally treasured and enjoy an optimal nurturing environment, although the breastfeeding rate was low.

The present study examines whether the new WHO Growth Standards are applicable to a Japanese population.

Materials and methods

Study population

We studied the 2007–2013 Tokyo Public Child Care Center Survey data based on length/height and weight measurements as collected each month by the regional government. Data included length/height and weight at birth and at, 6, 9, 12, 24, 36, 48 and 60 months. Length and weight at birth were obtained from records in the Mother-Child Booklet (government issued health passport); subsequent length/height and weight were measured, by childcare personnel using a standardized technique and equipment to 0.1 cm and 0.1 kg, respectively. There were 6455 children (3430 boys and 3025 girls) who were followed for the entire period, and a total of 99,736 measurements in boys and 86,669 measurements in girls (the observations above +3 SD and below –3 SD of the sample median were excluded, following the WHO 2006 Growth Standards [5]).

This study, based on the secondary analysis of data without individually identifiable information, was approved by the regional Ethics Committee.

Data analyses

For each child, z-scores for length/height, weight and weight for length /height were calculated by comparison with both the WHO 2006 Growth Standards [5] and the Japanese 2000 references (cross-sectional national survey data by the Japanese Ministry of Health, Labour and Welfare) [6].

Calculation of weight for length/height was limited to subjects 2–5 years of age and stature of 79–113 cm, since WHO study depends on age range of 2–5 years.

Centile and standard deviation (SD) values for length/height, weight and weight for length/height were calculated using the LMS method [7], which summarizes the centiles by three smooth curves representing skewness (L curve), the median (M curve) and coefficient of variation (S curve). The method is based on the Box-Cox power transformation, which transforms the data to follow a Gaussian distribution for each age. Calculation of standard deviation score (SDS) is based on the following equations: SD score (SDS) = $((X/M)^{L} - 1)/LS$, if $L \neq 0$, in which X is the measurement of interest (length/height, weight).

Cohen's criteria

When population measurements were demonstrated to have differences greater than ±0.5 SDS, those countries would be considered as candidates deviating from the WHO 2006 Growth Standards [8]. We adopted Cohen's criteria in the assessment of differences in length/height, weight and weight for length/height. According to Cohen [9], differences of 0.20 SD units are considered small, 0.50 SD medium and 0.80 SD large. In designing the WHO Multicentre Growth Reference Study, pooling of data was considered appropriate if differences were less than medium in size [2].

Comparison of prevalence

The prevalence of children below and above certain thresholds for length/height, weight and weight for length/height were obtained according to the WHO 2006 Growth Standards [5] and the Japanese 2000 references [6] in Japanese children (the Tokyo 2007–2013 Public Child Care Center Survey cohort): short stature, length/height <2nd centile, underweight, weight <2nd centile, overweight >98th centile. The relative risk for short stature, underweight and overweight was calculated by the standard 2 by 2 table method with each outcome by the WHO 2006 Growth Standards [5] divided by that of the Japanese 2000 references [6]. For studies where zero-cell counts were observed, a fixed value of 0.5 was added to all cells of the study results tables [10].

Results

Comparison with the Japanese 2000 references

At birth the 2007–2013 Tokyo Child Care Center cohort fitted well with the Japanese 2000 references as indicated by mean length and weight z-score being –0.09 and –0.06 in boys and –0.01 and –0.08 in girls, respectively (Table 1). From 6 to 24 months of age z-scores for length/height deviated as much as –0.60 in boys and –0.52 in girls, respectively, but z-scores for weight were –0.18 to 0.26 in boys and girls relative to the Japanese 2000 references. The differences in z-scores for length/height between the 2007 and 2013 Tokyo Child Care Center Survey data and the Japanese 2000 references gradually decreased from 6 months to 24 months. From 3 to 5 years z-scores for height ranged from –0.08 to 0.11 and that for weight ranged from –0.03 to 0.13 in boys whereas in girls each ranged from –0.03 to 0.07 and from 0.00 to 0.24, respectively. Table 2 shows mean z-scores for weight for length/height for boys and girls (the 2007–2013 Tokyo Child Care Center Survey data) compared with the Japanese 2000 references. Length/height was confined to 79–113 cm in determining weight-for-length/height.

Table 1: z-Scores for length/height and weight from birth to 60 months according to the WHO 2006 Child Growth Standards or the Japanese 2000 Growth References in Tokyo 2007–2013 survey cohort.

Age, months	Number of measurements	Length/height SDS		Weight SDS	
		WHO	Japan	WHO	Japan
Male					
Birth	3335	−0.26 (1.04)	−0.09 (0.63)	−0.62 (0.84)	−0.06 (1.00)
6	262	−0.53 (1.02)	−0.60 (0.94)	−0.14 (0.94)	−0.18 (1.01)
9	736	−0.69 (1.04)	−0.48 (0.96)	−0.23 (0.94)	−0.12 (1.03)
12	1371	−0.82 (0.99)	−0.46 (0.96)	−0.36 (0.90)	−0.05 (1.02)
24	2134	−0.84 (0.91)	−0.35 (0.98)	−0.26 (0.82)	0.19 (0.97)
36	2042	−0.81 (0.90)	−0.08 (0.99)	−0.34 (0.81)	0.13 (0.96)
48	1829	−0.72 (0.91)	−0.01 (1.00)	−0.44 (0.82)	0.00 (0.95)
60	1314	−0.63 (0.89)	0.11 (0.98)	−0.42 (0.85)	−0.03 (0.99)
Female					
Birth	2938	−0.15 (1.05)	−0.01 (0.68)	−0.60 (0.85)	−0.08 (0.98)
6	243	−0.38 (0.88)	−0.52 (0.84)	−0.01 (0.88)	−0.14 (1.07)
9	643	−0.52 (0.90)	−0.48 (0.92)	−0.07 (0.83)	0.00 (1.02)
12	1187	−0.67 (0.86)	−0.40 (0.91)	−0.17 (0.79)	0.06 (0.98)
24	1915	−0.79 (0.84)	−0.45 (0.97)	−0.12 (0.78)	0.26 (0.97)
36	1807	−0.84 (0.85)	−0.03 (1.00)	−0.29 (0.78)	0.24 (0.96)
48	1523	−0.76 (0.84)	0.07 (1.02)	−0.43 (0.79)	0.11 (1.00)
60	1059	−0.62 (0.84)	0.05 (1.05)	−0.43 (0.78)	0.00 (0.97)

Values are mean (SD). WHO, WHO 2006 Child Growth Standards; Japan, Japanese 2000 Growth References.

Table 2: z-Scores for weight-for-height from 79 to 113 cm in height according to the WHO 2006 Child Growth Standards or the Japanese 2000 Growth References in Tokyo 2007–2013 survey cohort.

Height, cm	Number of measurements	Weight for height SDS	
		WHO	Japan
Male			
79–81	435	−0.05 (0.79)	0.10 (0.92)
83–85	2909	0.13 (0.80)	0.31 (0.92)
87–89	5534	0.15 (0.83)	0.36 (0.93)
91–93	6322	0.12 (0.84)	0.25 (0.93)
95–97	6335	0.11 (0.83)	0.18 (0.92)
99–101	5884	0.07 (0.81)	0.11 (0.92)
103–105	4527	0.01 (0.81)	−0.04 (0.92)
107–109	2395	0.01 (0.84)	0.00 (0.96)
111–113	666	0.09 (0.88)	0.18 (0.99)
Female			
79–81	859	0.13 (0.78)	0.45 (0.96)
83–85	3529	0.29 (0.77)	0.55 (0.96)
87–89	5068	0.26 (0.78)	0.51 (0.97)
91–93	5375	0.19 (0.77)	0.39 (0.96)
95–97	5251	0.13 (0.77)	0.23 (0.94)
99–101	4686	0.10 (0.76)	0.15 (0.92)
103–105	3333	0.07 (0.78)	0.16 (0.92)
107–109	1481	0.12 (0.78)	0.25 (0.89)
111–113	361	0.01 (0.79)	0.12 (0.86)

Values are mean (SD), all subjects ≥2 years old. WHO, WHO 2006 Child Growth Standards; Japan, Japanese 2000 Growth References.

The differences between the Japanese 2000 references and the 2007–2013 Tokyo Child Care Center Survey data were smaller in boys than in girls. A peak z-score being 0.36 for height 87–89 cm in boys and 0.55 for height 83–85 cm in girls, respectively.

Comparison with the WHO 2006 Growth Standards

The 2007–2013 Tokyo Child Care Center Survey cohort had relatively low mean z-scores for birth length and birth weight compared with the WHO 2006 Growth Standards (Table 1). Mean z-scores for birth length and birth weight were −0.26 and −0.62 for boys and −0.15 and −0.60 for girls, respectively. After birth, z-scores for length/height and weight in Japanese children further declined to −0.84 and −0.26 at 2 years, −0.81 and −0.34 at 3 years, −0.72 and −0.44 at 4 years, −0.63 and −0.42 at 5 years in boys, and −0.79 and −0.12 at 2 years, −0.84 and −0.29 at 3 years, −0.76 and −0.43 at 4 years −0.62 and −0.43 at 5 years in girls, respectively. Table 2 shows mean z-scores for weight-for-length/height for the 2007–2013 Tokyo Child Care Center Survey data compared with the WHO 2006 Growth Standards. In comparison with length/height and weight, z-scores for weight-for-length/height of Japanese children deviated

less from the WHO 2006 Growth Standards: z-scores –0.05 to 0.15 in boys and 0.01 to 0.29 in girls, respectively.

Prevalence for short stature, or overweight or underweight

Percentages of children classified as having short stature, or being overweight or underweight, are shown in Table 3. Applying the WHO 2006 Growth Standards, Japanese children (2007–2013 Tokyo Child Care Center Survey data) were more likely to be classified as being short, length/height <2nd centile; 4.3% at birth, 10.3% at 12 months, 8.6% at 24 months, 6.4% at 60 months for boys, and 4.8% at birth, 5.9% at 12 months, 6.4% at 24 months, 4.3% at 60 months for girls, respectively (expected 2%). According to the WHO 2006 Growth Standards, the proportion of children classified as underweight (weight <2nd centile) from birth to 5 years of age was variable without clear trends, 1.5 –4.6% in boys and 0.4 –4.8% in girls. Relative risk ranged from 0.71 to 2.22 in boys and from 0.11 to 2.03 in girls, respectively. The proportion of Japanese children classified as overweight (weight for length/height >98th centile) was much smaller than expected at all ages examined (0–0.8% for boys and 0–0.4% for girls, respectively).

Discussion

The WHO Multicentre Growth Reference Study Group selected length/height as the most suitable measure to assess population differences of possible genetic or environmental origin among children of well-off families [2, 3]. Measurements from child populations in Ghana, USA, Oman, India, Brazil and Norway were examined for between-site differences in length/height. No site mean deviated by an absolute amount equal to or greater than 0.5 SD of the corresponding overall sample mean. Of 54 values examined, 20 were above 0.2 SD units, each difference were considered to be small [9], and of these only 10 were above 0.3 SD units. In designing the WHO Multicentre Growth Reference Study, pooling of data was considered appropriate if differences were less than medium in size (<0.5 SD). Japanese children had significantly low mean SD scores for length/height from birth to 5 years of age: the mean SD score was close to –1.0 SD while mean SD scores for weight ranged from –0.01 to –0.62 SD compared with the WHO 2006 Growth Standards. Based upon the above findings, we concluded that the new WHO Growth Standards do not fit with the Japanese children studied at ages between 0 and 60 months.

The applicability of the new WHO Child Growth Standards to East Asian population was first studied by Hui et al.

Table 3: Percentages of children classified as short stature, underweight, or overweight, according to the WHO 2006 Child Growth Standards and the Japanese 2000 Growth References in Tokyo 2007–2013 survey cohort.

Age, months	Short stature			Underweight			Overweight		
	WHO, %	Japan, %	RR (95% CI)	WHO, %	Japan, %	RR (95% CI)	WHO, %	Japan, %	RR (95% CI)
Male									
Birth	4.3	0.0	291.00 (16.12–4672.86)	4.6	2.1	2.22 (1.68–2.93)	0.0	2.1	0.01 (0.00–0.11)
6	6.9	6.1	1.13 (0.59–2.16)	1.9	2.7	0.71 (0.23–2.22)	0.4	1.1	0.33 (0.03–3.18)
9	8.6	5.0	1.70 (1.15–2.52)	2.9	2.9	1.00 (0.55–1.82)	0.8	2.2	0.38 (0.15–0.95)
12	10.3	4.2	2.47 (1.84–3.33)	2.8	2.2	1.27 (0.79–2.03)	0.0	2.6	0.01 (0.00–0.22)
24	8.6	3.6	2.41 (1.86–3.12)	1.5	0.7	1.94 (1.06–3.53)	0.0	3.0	0.01 (0.00–0.12)
36	8.2	2.8	2.90 (2.16–3.88)	2.2	1.3	1.67 (1.04–2.68)	0.0	2.6	0.01 (0.00–0.15)
48	7.7	2.3	3.36 (2.39–4.71)	3.0	1.9	1.59 (1.04–2.43)	0.0	1.8	0.01 (0.00–0.24)
60	6.4	2.4	2.71 (1.81–4.06)	2.7	2.2	1.21 (0.74–1.96)	0.2	1.8	0.08 (0.02–0.35)
Female									
Birth	4.8	0.2	20.29 (9.51–43.25)	4.8	2.3	2.03 (1.53–2.69)	0.0	1.8	0.01 (0.00–0.15)
6	3.3	3.3	1.00 (0.38–2.62)	0.4	3.7	0.11 (0.01–0.87)	0.4	2.9	0.14 (0.02–1.15)
9	4.8	4.8	1.00 (0.62–1.63)	0.6	1.7	0.36 (0.12–1.14)	0.2	2.3	0.07 (0.01–0.50)
12	5.9	3.0	1.94 (1.31–2.88)	0.7	1.0	0.67 (0.27–1.63)	0.0	1.9	0.02 (0.00–0.35)
24	6.4	4.4	1.45 (1.11–1.89)	1.0	1.2	0.83 (0.45–1.51)	0.0	3.0	0.01 (0.00–0.14)
36	7.7	2.4	3.23 (2.31–4.52)	1.8	1.3	1.38 (0.82–2.32)	0.0	2.0	0.01 (0.00–0.22)
48	5.8	2.2	2.62 (1.77–3.86)	2.6	2.4	1.05 (0.68–1.64)	0.0	1.8	0.02 (0.00–0.29)
60	4.3	2.4	1.84 (1.14–2.97)	2.3	2.3	1.00 (0.57–1.75)	0.0	1.1	0.04 (0.00–0.67)

WHO, WHO 2006 Child Growth Standards; Japan, Japanese 2000 Growth References; RR, relative risk for each outcome using the WHO 2006 Child Growth Standards, compared with the Japanese 2000 Growth References; short stature, stature <2nd centile; underweight, weight <2nd centile; overweight, weight >98th centile.

[4] who found that the Hong Kong Chinese children were generally shorter and fatter than the WHO standards. (1) Length/height of Hong Kong children deviated from the WHO Growth Standards (z-scores in height at 36 months of age, −0.34 for boys and −0.38 for girls, respectively), although the breast feeding rate is low (20.4% at 1 month) in Hong Kong [11]. (2) Weight for age was close to the 50th centile of the WHO Growth Standards for both boys (mean z-score 0.00) and girls (0.04) at each time 0 to 36 months of age.

If countries with a difference greater than ±0.5 SDS are considered candidates whose population measurements deviate from the new WHO Growth Standards [8], Japan would better qualify. The reasons for the differences in length/height between the two East Asian populations are unknown, but likely to be unrelated to the differences in feeding practices. Breast feeding rate was approximately 50% in 1–5 months of age as studied in 2010 in Japan [12]. Growth of breast-fed infants decelerates compared with that of formula-fed infants after 2–3 months of age and the differences between breast-fed and formula-fed infants were predominantly in weight, not in length [13].

A number of studies have been published indicating that the new WHO Growth Standards do not fit with national references: Danish [14], Dutch [8], Polish [15], German [16], Belgian and Norwegian [17]. Populations in these countries demonstrate tall stature and a large number of children have length/height above +2 SD according to the WHO 2006 Growth Standards. The study on the growth of Belgian and Norwegian children showed that the proportion of children below −2 SD of the WHO Growth Standards was lower and that above +2 SD of the WHO Growth Standards was higher in length/height, weight, BMI and head circumference [17]. In contrast, in countries in which populations demonstrate relative short stature, a higher proportion of children fall into the "lower" region of the growth chart, as exemplified by Japan. The UK study [18] represents a country with intermediate stature. After birth, as expected, length/height of UK children showed a good fit with the WHO Growth Standards from 4 months to 4–5 years. However, birthweight of UK children did not demonstrate a good fit with the WHO Growth Standards.

Our study has limitations. We used data from a ward in Tokyo which may not be nationally representative. However, the study subjects represent a healthy middle-class population in Tokyo, consisting of more than 1000 subjects per month (12–60 months), whereas the Japanese 2000 references consists of less than 70 subjects per month (24–60 months). Further, Tokyoites enjoy the highest mean annual income in Japan and the mean heights of children and adults in Tokyo are taller than those in the other prefectures [19, 20].

In summary, we showed that the WHO Growth Standards are not appropriate for clinical use in Japanese children. Misclassifying children as "short" or "normal weight" may lead to more anxiety for families or less alertness to trends towards overweight. More studies are needed on various East Asian populations for the applicability of the WHO Growth Standards.

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