

Comparison of the effects of different growth standards on infants in Urban Shanghai: a cluster-randomized controlled trial

Jun-Li Wang^{1,2}, Jing-Qiu Ma^{1,2}, Ming-Yu Xu^{1,2}, Feng Li^{1,2}, Fang Ren^{1,2}, Yan-Fei Guo^{3,4}, Xiao-Yang Sheng^{1,2}

¹Department of Child and Adolescent Healthcare, Xinhua Hospital Affiliated to Shanghai Jiao Tong University School of Medicine, Shanghai 200092, China;

²MOE-Shanghai Key Laboratory of Children's Environmental Health, Shanghai 200092, China;

³Shanghai Institute of Preventive Medicine, Shanghai 200336, China;

⁴Shanghai Municipal Center for Disease Control & Prevention, Shanghai 200336, China.

Abstract

Background: The Shanghai growth standards are higher than World Health Organization (WHO) growth standards, which may influence the feeding practices of the caregivers and increase the risk of overweight in these infants. This study aimed to compare the effects of different growth standards on childhood obesity in Shanghai metropolitan area.

Methods: This was a cluster-randomized controlled trial conducted in 2 downtown areas with 19 community health service centers in Shanghai from November 2013 to December 2015. Randomization was done at the level of the community. Infants (health newborns) were assessed and monitored by the Shanghai growth standards (S-group) and the 2006 WHO growth standards (W-group), respectively. Measurements were taken at 1.0, 2.0, 4.0, 6.0, 9.0 and 12.0 months of age during follow-up period. Based on the values of length and weight measurements, according to the group's growth standards, doctors provided the caregivers with corresponding clinical consultation. Changes in weight-for-age z-score (WAZ), length-for-age z-score (LAZ), and weight-for length z-score (WLZ) between 2 groups were assessed using mixed regression models. Overweight was compared between 2 group at all follow-up measurements.

Results: A total of 6509 infants (52.1% were boys) were in the W-group, and 8510 infants (51.4% were boys) were in the S-group. The overweight ratios between two groups were distinct at 9 months of age (3.4% in W-group and 4.3% in S-group) and 12 months of age (2.2% in W-group and 3.8% in S-group), and the differences were statistically significant ($P=0.020$ and $P<0.001$, respectively). Compared to W-group, the increase in WAZ (coefficient=0.04, $P=0.004$) and WLZ (coefficient=0.09, $P<0.001$) were significantly greater, and the LAZ was lower (coefficient=-0.04, $P=0.047$) in S-group (W-group values were used as reference in mixed regression models).

Conclusion: Compared to the Shanghai growth standards, the adoption of WHO 2006 growth standards would reduce the risk of infant overweight in Shanghai metropolitan area up to 1 year of age.

Trial registration number: ChiCTR1800015371, <http://www.chictr.org.cn/> Chinese Clinical Trial Registry.

Keywords: Overweight; community health; infant; growth standards

Introduction

Children's growth is a long and continuous process. In this process, regular assessment and monitoring of the growth index of children's body weight and height and other physical measurements are helpful in the early diagnosis of children's abnormal growth.^[1] This will, in turn, provide an opportunity for interventional procedures to ensure the healthy growth and development of children.^[2] Children's physical growth assessment should be based on growth standards, that is, according to the growth reference values for children of the same age and gender.

From 1997 to 2003, the World Health Organization (WHO) conducted a multicenter, longitudinal, long-term follow-up study consisting of participants ages 0–2 years in 6 countries around the world (the United States, India, Brazil, Norway, Oman, and Ghana).^[3] The WHO had developed a standard by selecting healthy children living in conditions that may be conducive to the full realization of their genetic growth potential.^[4] The study had a major discovery, that children ages 0–2 years from different parts of the world had almost the same growth rate. Therefore, many countries support and rely on this standard across

Access this article online

Quick Response Code:



Website:
www.cmj.org

DOI:
10.1097/CM9.0000000000000004

Correspondence to: Dr. Xiao-Yang Sheng, Department of Child and Adolescent Health Care, Xinhua Hospital Affiliated to Shanghai Jiao Tong University School of Medicine, MOE-Shanghai Key Laboratory of Children's Environmental Health, Shanghai 200092, China
E-Mail: shengxiaoyang@xinhuaumed.com.cn

Copyright © 2018 The Chinese Medical Association, produced by Wolters Kluwer, Inc. under the CC-BY-NC-ND license. This is an open access article distributed under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives License 4.0 (CCBY-NC-ND), where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially without permission from the journal.

Chinese Medical Journal 2019;132(1)

Received: 29-10-2018 Edited by: Xin Chen

the world. Since the WHO published child growth standards, 125 countries have adopted the standards, and 25 countries, including China, are considering doing so in the future.^[5]

The United Kingdom has adopted the standards, which suggested infants in the United Kingdom reducing weight gain from ages 4 months and up. The WHO standards would be able to identify more infants with a high body mass index (BMI), and these infants could have been given the instruction to prevent overweight in a timely manner.^[6] In contrast, Shanghai's reference values on child growth is higher than that of the WHO 2006 growth standards.^[7] For example, the mean weight and length of 4-month-old infants, according to Shanghai standards (2005 edition), are 7.89 kg and 65.84 cm, respectively, for boys (7.00 kg and 63.89 cm in WHO standards); and 7.22 kg and 63.96 cm, respectively, for girls (6.42 kg and 62.09 cm in WHO standards). In our previous study, we found that parents had a tendency to overfeed even when their children were of normal weight, and this, in turn, would increase the weight gain and BMI of their children.^[8] In China, due to the One-Child Policy starting in 1980s and the famine history in 1960s, parents and grandparents usually overlook the childhood obesity problem and even think that obesity is healthy.^[9,10] Presumably, as Shanghai's children growth reference values are so high, some children with normal growth could be mistakenly diagnosed for underweight and growth delay, which may strengthen the overfeeding behavior of the caregivers and lead to childhood obesity. Hence, the aim of this study was to compare the effects of different growth standards on childhood obesity in Shanghai metropolitan area.

Methods

Ethics statement

The data was obtained from the community child healthcare routine medical records and questionnaires. The samples were taken without any trauma to the child. Infants and their families participated in this study did not have any risk consequences. All information and records were strictly confidential. Prior to the start of the study, the research protocol was approved by the Ethical Committee of Xinhua Hospital affiliated to Shanghai Jiao Tong University School of Medicine (XHEC-C-2013-024). The free consent application for participants was approved and provided by the ethics committee.

Study protocol

A community-based cluster-randomized controlled trial was conducted in 2 downtown areas with 19 community health service centers in Shanghai from November 2013 to December 2015. These 19 community health service centers, providing basic medical services to the local community, were randomly divided into 2 groups: the S-group, consisting of 10 centers, was assessed and monitored by 2005 edition of Shanghai children growth standards for children ages 0–2 years; and the W-group,

consisting of 9 centers, used the 2006 WHO growth standards for children ages 0–2 years.

The sample calculation was based on the data of our prior study,^[11] which contained the data of infants from birth to 6 months old. The infant weight-for-age z-score (WAZ) growth value was 0.77 ± 0.88 , while the length-for-age z-score (LAZ) growth value was 0.66 ± 0.93 . Assuming that the LAZ growth values were consistent among the two groups of infants, the growth rate of WAZ in the infants of W-group relative to the infants of S-group decreased by 10%, that is, a decrease of 0.69. Thus, 3000 subjects were required in total, amounting to 1500 infants in each group.

Participants

All attending pediatricians and nurse practitioners from the 19 community centers were invited to participate in pre-research meeting and trainings. A total of 78 medical staff members were enrolled, representing nearly all eligible clinicians. There were evaluation quizzes (score > 90) for all participating clinicians, and we gave overweight prevention evaluations to doctors and physical examination evaluation to nurses.

Every month, approximately 200 infants were born in each community. The infants were divided into 2 groups according to previously described method. Inclusion criteria were as follows: (1) birth between November 2013 and November 2014; (2) single fetus with a gestational age of 37–42 weeks; (3) the birth weight of 2500–4500 g; (4) the community resident who was willing to come for the long-term follow-up of 1 year; (5) without congenital diseases, and genetic metabolic diseases; and (6) clinical consultation ≥ 3 times in 1 year.

Clinical consultation

The weight and length measurements were collected during monthly vaccination sessions at the community health centers. The infants were measured at the age of 1.0, 2.0, 4.0, 6.0, 9.0, and 12.0 months (within 1 week before and after). Those who did not attend were called again after 2 weeks (at 1.5, 2.5, 6.5, 9.5, or 12.5 months). Thus, each infant attended a health center at least 6 times at 1.0–1.5, 2.0–2.5, 4.0–4.5, 6.0–6.5, 9.0–9.5, and 12.0–12.5 months. At every clinical consultation, the doctors educated participants regarding nutrition guidelines, depending on the nutritional status of infants according to their group standards. The specific tasks at each time point in each clinical consultation included the following: (1) physical measurements, including height, weight, head circumference and chest circumference; as well as an record of feeding patterns; (2) the diagnosis of nutritional levels followed by group standards, including underweight, wasted, stunted, normal, and overweight; (3) the generation of a growth curve for every child and the provision of nutritional advices to caregivers based on the child's growth tendency; and (4) the provision of nutritional guidelines at different ages and the supply nutrition guidebooks at different age stages.

Anthropometry

The weight and length were obtained from the infant's birth record, and subsequently measured at age of 1.0, 2.0, 4.0, 6.0, 9.0, and 12.0 months using standardized procedures. Weight was measured to the nearest 0.01 kg using an electronic pediatric scale (Seca, Germany), and length was measured to the nearest 0.10 cm using a pediatric-length board (Seca, Germany) with the infant in a recumbent position.

Nutritional status

WAZ, LAZ, and weight-for-length z-score (WLZ) of infants at 1.0, 2.0, 4.0, 6.0, 9.0, and 12.0 months of age were calculated according to the 2006 WHO growth standards using the WHO Anthro 2009 software. The software measured the age to the nearest 0.01 month. Underweight, stunting, and wasting were defined as $WAZ < -2$, $LAZ < -2$, and $WLZ < -2$, respectively. Overweight was defined as $WLZ > +2$. Normal weight was defined as $-2 \leq WLZ \leq +2$.

Quality control

Quality control procedures are important to ensure data quality, which include the following: (1) Shanghai Municipal Health Bureau was responsible for data coordination, collection, and management; quality control; and advisory for groups; (2) lectures were given to the staff of each community by the director, and trainees underwent thorough training for standardizing the protocol regarding anthropometric measurements, recommendations for feeding methods, use of standard application and distribution of pamphlets; (3) pilot testing of study protocol was conducted (Kongjiang community); (4) monthly visits to study sites were made for calibrating measurement tools, assessing technology capacity and collecting data; (5) data quality assurance was completed through the calibration of equipment and the standardization of measurements, surveys, and the auditing data entry (data record included medical record books and electronic data in government system); (6) regular meetings, retraining, and random spot check were conducted.

Statistical analysis

Children were grouped into 6 age categories during the infancy period. Each age group includes half a month before and after. For example, ages from 0.5 month to 1.5 months are abbreviated as 1 month, and those from 5.5 months to 6.5 months are abbreviated as 6 months. If a child had been measured twice in a given age category, only the first measurement was counted. Measurements taken at 3.0, 5.0, 7.0, 8.0, and 11.0 months were excluded. All children were required to attend the clinical consultation in more than two age groups to ensure that the parents paid attention to the standard procedures.

The data with normal distribution were shown as mean \pm standard deviation (SD), and the data with non-normal distribution were shown as median (Q1, Q3). The Chi-squared test and one-way analysis of variance (ANOVA) were used to assess the differences in the demographic

characteristics, the Wilcoxon rank-sum test was used to compare the median differences of WAZ, LAZ, and WLZ between the two groups. Linear mixed-effect regression models for repeated measures using random effect at the community level (cluster) were used to compare the difference of WAZ, LAZ, and WLZ between the two groups at different time-point (PROC MIXED procedures). At individual level, models-controlled gender and weight at baseline as potential confounding factors. We used an unstructured covariance for the random effects at the child level, after comparing models with different covariance structures using the Akaike information criterion (AIC). All data analysis was performed using SAS Version 9.4 (SAS Institute Inc, Cary, North Carolina, USA). All *P* values were two-sided, and the level of statistical significance was set at $P < 0.05$.

Results

Study population

In this study, among the 15,286 infants from 19 community health service centers, only 267 infants did not receive enough clinical consultations in their age groups (<3 times). The remaining 15,019 infants (51.7% boys and 48.3% girls) provided valid data at birth and during follow-up. Among 15,019 infants, 6509 were in the W-group (including 3390 boys and 3119 girls,) and 8510 in the S-group (including 4374 boys and 4136 girls), there was no significant difference in gender between two groups ($\chi^2 = 1.081$, $P = 0.298$). The mean birth weights of the W-group and S-group were 3.38 ± 0.38 kg and 3.37 ± 0.39 kg, respectively ($t = 0.095$, $P = 0.924$).

The ratio of exclusive breastfeeding at 2 months in W-group infants was 55.5%, which was lower than that of S-group infants (65.4%, $\chi^2 = 56.265$, $P < 0.001$). At 4 months, only 52.2% of infants were exclusive breastfeeding in W-group, that was still lower than that of S-group (60.7%, $\chi^2 = 42.049$, $P < 0.001$).

Overweight

The overweight rates between the groups were distinct at 1.0, 9.0 and, 12.0 months of age, and the differences were statistically significant (all $P < 0.050$). The study found that the rate of overweight at 1 month of age in the W-group (1.3%) was higher than that of the S-group (0.7%, $P = 0.040$). The rates of overweight of the S- and W- groups at 2 months of age were as follows: 1.3% and 1.6%, but increased to 3.7% and 3.5% at 4 months of age. Compared with S-group, the rates of overweight decreased and had a downward tendency at 9 months of age in W-group (Table 1). Most of the children in both groups were healthy, and the rates of stunting, wasting, and underweight were very low (0%–0.4%). There were no significant differences between the groups in every age group (all $P > 0.050$, Table 1).

Growth parameters and results of linear mixed model

For WAZ values, the patterns of change in weight from 1.0 month to 6.0 months were similar between W-group and

Table 1: Nutritional status at each age stage in the W- and S-groups according to growth references of World Health Organization

Age (months)	Number		Overweight, n (%)				Underweight, n (%)				Stunting, n (%)				Wasting, n (%)			
	W-group	S-group	W-group	S-group	χ^2	P	W-group	S-group	χ^2	P	W-group	S-group	χ^2	P	W-group	S-group	χ^2	P
1	1791	2049	23 (1.3)	14 (0.7)	4.207	0.040	4 (0.2)	2 (0.1)	0.310	0.578	4 (0.2)	4 (0.2)	0.036	0.850	23 (1.3)	35 (1.7)	0.834	0.361
2	3284	4999	53 (1.6)	65 (1.3)	1.657	0.198	7 (0.2)	10 (0.2)	0.311	0.577	10 (0.3)	20 (0.4)	0.819	0.366	13 (0.4)	15 (0.3)	0.225	0.635
4	4749	6341	166 (3.5)	235 (3.7)	0.114	0.735	0 (0.0)	6 (0.1)	2.730	0.098	9 (0.2)	13 (0.2)	0.608	0.436	9 (0.2)	13 (0.2)	0.019	0.889
6	5055	6807	187 (3.7)	272 (4.0)	0.854	0.355	5 (0.1)	0 (0.0)	1.421	0.233	10 (0.2)	20 (0.3)	1.388	0.239	9 (0.1)	7 (0.1)	0.641	0.423
9	4100	5700	139 (3.4)	245 (4.3)	5.413	0.020	0 (0.0)	0 (0.0)	0.760	0.383	12 (0.3)	23 (0.4)	0.995	0.318	5 (0.1)	0 (0.0)	0.980	0.322
12	3908	5476	86 (2.2)	208 (3.8)	18.145	<0.001	0 (0.0)	5 (0.1)	1.542	0.214	16 (0.4)	22 (0.4)	0.151	0.697	0 (0.0)	5 (0.1)	1.832	0.176

Table 2: Median of WAZ, LAZ, and WLZ at each age in the W- and S- groups according to growth references of World Health Organization

Age	1 month	2 months	4 months	6 months	9 months	12 months
Number (n)						
W-group	1791	3284	4749	5055	4100	3908
S-group	2049	4999	6341	6807	5700	5476
WAZ						
W-group	0.28 (-0.23, 0.80)	0.54 (0, 1.03)	0.71 (0.11, 1.26)	0.72 (0.11, 1.29)	0.67 (0.07, 1.21)	0.64 (0.06, 1.18)
S-group	0.33 (-0.19, 0.81)	0.54 (0.04, 1.06)	0.71 (0.16, 1.30)	0.72 (0.14, 1.30)	0.70 (0.11, 1.26)	0.68 (0.13, 1.20)
Z	-1.925	-1.502	-1.263	-0.938	-2.570	-2.321
P	0.054	0.133	0.207	0.349	0.010	0.020
LAZ						
W-group	0.26 (-0.31, 0.84)	0.53 (-0.09, 1.14)	0.65 (0.04, 1.28)	0.67 (0.04, 1.33)	0.55 (-0.11, 1.21)	0.51 (-0.12, 1.16)
S-group	0.26 (-0.27, 0.88)	0.48 (-0.11, 1.09)	0.61 (0.01, 1.24)	0.64 (0.05, 1.26)	0.52 (-0.08, 1.16)	0.46 (-0.16, 1.11)
Z	-0.881	1.549	2.296	1.512	0.412	2.148
P	0.378	0.121	0.022	0.131	0.680	0.032
WLZ						
W-group	0.08 (-0.50, 0.62)	0.27 (-0.32, 0.83)	0.46 (-0.13, 0.99)	0.54 (-0.05, 1.09)	0.59 (-0.01, 1.09)	0.55 (0, 1.03)
S-group	0.14 (-0.38, 0.60)	0.35 (-0.23, 0.87)	0.53 (-0.09, 1.08)	0.60 (-0.01, 1.13)	0.64 (0.06, 1.19)	0.64 (0.08, 1.13)
Z	-1.451	-3.373	-3.583	-2.791	-3.667	-4.391
P	0.147	0.001	<0.001	0.005	<0.001	<0.001

The data were shown as median (Q1, Q3). Wilcoxon rank-sum test. LAZ: length-for-age z-score; WAZ: weight-for-age z-score; WLZ: weight-for-height z-score.

S-group, and the differences were not statistically significant (all $P > 0.050$; Table 2). The differences in WAZ value were statistically significant at the 9- and 12-month age between 2 groups ($Z = -2.570$, $P = 0.010$ at 9 month and $Z = -2.321$, $P = 0.020$ at 12 month; Table 2). The increase in WAZ value was significantly greater in S-group, compared to W-group (coefficient=0.04, $P = 0.004$; Table 3). These findings suggested that the weight gain in infants of S-group were slightly higher than that of infants in the W-group.

For LAZ values, the patterns of change in height from 1 month to 12 months of age were also similar between W-group and S-group (Table 2). The differences in LAZ value were not significant at all age stages between 2 groups, except for the 4- and 12-months age ($Z = 2.292$, $P = 0.022$ at 4 month, and $Z = 2.148$, $P = 0.032$ at 12 months; Table 2). In total, the mean LAZ values in the W-group were higher than those in the S-group for most age stages. The LAZ value was increased significantly by 0.04 in W-group, compared to S-group ($P = 0.047$; Table 3). It meant that the height gain infants of W-group were higher than that of infants in the S-group.

As shown in Table 2, the WLZ values between the 2 groups were significantly different from 2 months of age (Table 2). For the WLZ values, the mean values in S-group were greater than those of W-group (coefficient=0.09, $P < 0.001$; Table 3).

Discussion

Approximately 120 million children in China were found to be overweight or obese.^[12] As it is a global public health problem, attention needs to be paid to the rise in the number of obese children. Rapid weight gain during infancy is the beginning of childhood obesity. According to research, being overweight in the first 2 years of life was a strong predictor of obesity at age 5 and was associated with an increased risk for metabolic disease later in life.^[13-15] However, the interventions for overweight in infancy were indeed limited,^[16] and the most common recommended intervention was a proper clinical examination in local community.^[17,18]

The study was conducted to assess and monitor the growth of children using different child growth standards and to observe the impact of different growth standards on weight and length. This study found that using WHO standards, the infants were less likely to be classified as overweight. According to the results of this study, it could be said that the decline in weight gain was not correlated with loss of height gain, but rather promoted height growth. The application of the WHO standards was only for reducing overweight but not for increasing underweight or addressing stunting and wasting disease.

Routine growth assessment is a fundamental part of the monitoring of children's health. The pediatrician should

Table 3: Impact of different standards on WAZ, HAZ, and WLZ from birth to 12 months

Parameters	WAZ			LAZ			WLZ		
	Coefficient	SE	P	Coefficient	SE	P	Coefficient	SE	P
Intervention (reference: W-group)									
S-group	0.04	0.01	0.004	-0.04	0.02	0.047	0.09	0.01	<0.001
Age (reference: 1-month-old)									
2-month-old	0.24	0.01	<0.001	0.22	0.01	<0.001	0.20	0.02	<0.001
4-month-old	0.43	0.01	<0.001	0.36	0.01	<0.001	0.41	0.01	<0.001
6-month-old	0.43	0.01	<0.001	0.41	0.01	<0.001	0.47	0.01	<0.001
9-month-old	0.39	0.01	<0.001	0.3	0.01	<0.001	0.51	0.02	<0.001
12-month-old	0.36	0.01	<0.001	0.24	0.01	<0.001	0.49	0.02	<0.001
Gender (reference: male)									
Female	-0.02	0.01	0.102	0.06	0.01	<0.001	-0.06	0.01	<0.0001
Weight at baseline	0	0	<0.001	0	0	<0.001	0	0	0.015
Intercept	-0.01	0.06	0.836	-0.04	0.07	0.593	-0.05	0.06	0.352

P-values obtained with mixed regression models, using random effect at community-level to take into account correlations between repeated measures (unstructured matrix of variance-covariance) and random effect at the community-level (cluster). Only adjusted models on covariates are presented. LAZ: length-for-age z-score; SE: standard error; WAZ: weight-for-age z-score; WLZ: weight-for-height z-score.

inform parents about the physical growth of the baby, which could, in turn, affect the feeding practices by parents.^[19] Our previous study found “weight median value” was a strong stimulus for parents to overfeed, especially the caregivers of normal-weight infants who worried more about infants being “underweight” or “eating less”.^[8] In another preschool study, parents tended to underestimate their children’s weight as well as the potential harmfulness of childhood obesity.^[20] The reasonable application of growth standards is important to increase Chinese parents’ knowledge of healthy feeding practices and normal growth.

One contributing factor for the results of this study might be the reduction of overfeeding. Another one could be recognition of the growth velocity of children by caregivers. In Shanghai community health service centers, median weight and length were always used as the index to describe children’s nutrition level. For a child, whose weight was under the median value, the caregivers were likely to excessive feeding. In WHO standards group, the pediatricians used the growth curve to describe infant growth status which emphasizes the growth rate. The WHO growth standards use growth charts, which include sex-specific and age-specific growth curves. In China, growth curves have been formulated, but the implementation process needs to be strengthened. According to the 2012 review, the majority (79%) of the Chinese studies used a definition of >120% of the mean value of the National Center for Health Statistics reference population to diagnose childhood obesity and only 7 studies (9%) measured childhood obesity using age-specific and sex-specific BMI cutoffs.^[21]

On the other hand, we must face the fact that the WHO 2006 growth standards do not necessarily represent the level of growth in Shanghai infants. Compared with WHO growth standards, the infants of Shanghai presented with greater weight and length than the WHO median at the first year. The results were similar to the report of the 5th national survey on the physical growth and development of children in 9 cities of China.^[22] The differences in physical growth in Shanghai were mainly caused by the reference populations of different ethnic backgrounds as

reported by Zong *et al*’s study.^[23] The WHO Multicenter Growth Reference Study (MGRS) collected data of 8500 children who were exclusively breastfed for the first 4 months, and then 100% breastfed for 12 months by mothers who gave up smoking.^[4] Unlike the feeding practice of MGRS, the infants in Shanghai had a low level of exclusive breastfeeding. In 2013, the Analysis Report of National Health Services Survey in China reported that the rate of exclusive breastfeeding within 6 months after delivery was 60.2% in East China.^[24] However, the survey was conducted based on the response of parents on the question “how many months was the child breastfed?”, but did not inquire about the previous 24 hours of food intake, as recommended by the United Nations Children’s Fund and WHO. In our previous study, the rate of exclusive breastfeeding within 4 months was only 29% in a typical community of Shanghai.^[8] One reason for adopting WHO standards in many countries was to promote and protect breastfeeding.^[25] From 2 months of age to the end of the first year of life, breastfed infants demonstrated slower weight gain than their bottle-fed counterparts,^[26] with evidence suggesting that a longer duration of full breastfeeding was associated with lower childhood fat mass.^[27]

The uniqueness of WHO growth standards is that it provides a standard for growth pattern to answer the question of “how the children should grow”, which breaks the traditional view that growth standards should only describe immediate status of “how the children are growing”.^[28] The reference of Shanghai children growth was obtained through the National Survey on the Physical Growth and Development of Children in the Nine Cities of China (NSPGDC) every 10 years, in which Shanghai is one of the 9 cities. The anthropometric data of Shanghai children in 1975, 1985, 1995, and 2005 formed the reference edition and the reference value for each publication was higher than the previous one.^[23] Overall, the reference represents the cross-sectional data of Shanghai children’s growth, which is less than longitudinal observation data of WHO.^[7,28] In addition, with the Chinese booming economy, the increase in children’s average weight and height reflected the improvement of the nutritional status of children. But it also had some undesirable effects,

such as a low rate of exclusive breastfeeding and a higher tendency for overfeeding. From 2007 to 2010 in China, 1840 healthy breastfed infants living in “optimal” environment for favorable growth were followed up to 1 year of age. In comparison with the WHO growth standards, breastfed children in that study were heavier in weight, longer in length, and bigger in head circumference, and the results were similar to what we saw in the growth reference of the 2005 nine-city study.^[29] In that study and another study,^[30] researchers were concerned that there was a possibility to misclassify a few malnourished infants as normal by the infant growth standards based on the WHO MGRS study. Those infants, typically living in rural areas, might subsequently miss the opportunity for early intervention. However, in Shanghai, the rate of overweight and obese children is increasing, as reported in the 2015 NSPGDC.^[31]

For all practical purposes, it should be known that the WHO growth standards did not reflect the current growth status of infants in the urban areas of Shanghai. The solution was to choose reference and standards wisely. The findings of this study would help practitioners of community healthcare to choose the correct growth standards and to understand the cause for concern regarding average growth patterns and the risk of children obesity according to growth charts. We must face the problem squarely: the number of infants who were diagnosed as being on a trajectory toward childhood obesity was increasing in Shanghai.^[32] The adoption of the Shanghai standards would result in a decreased number of infants classified as overweight or obese, which might cost them the opportunity for an early intervention. In the United States,^[33] there was a similar situation in which the reference in CDC growth chart was slightly higher than those of WHO,^[34] they explained that “the WHO charts are growth standards describing the growth of healthy children in optimal conditions, the CDC charts are a growth reference, describing how certain children grew in a particular place and time”. In addition, the final guideline is that “clinicians should be aware that fewer U.S. children will be identified as underweight using the WHO charts, slower growth among breastfed infants during ages 3–18 months is normal, and gaining weight more rapidly than is indicated on the WHO charts might signal early signs of overweight”.

This study was not able to determine the factors responsible for the accelerated growth of Shanghai urban infants compared with the projections of the WHO charts, which was perhaps the greatest limitation of the study. Another limitation of this study was that we had not gathered the information regarding mothers' BMI and the follow-up period was only for 12 months. Many studies had reported that pre-pregnancy overweight/obesity increased the risk of macrosomia and offspring overweight/obesity.^[35,36] Hence, to reduce the effect of heredity on overweight in this study, we used a bigger sample size, which should mitigate the impact from the pre-pregnancy condition.

In conclusion, the results of this study demonstrated that the adoption of the WHO 2006 growth standards would reduce the proportion of overweight infants less than 1

year of age in urban areas of Shanghai. Even though the WHO 2006 growth standards did not represent the level of child growth in Shanghai, its adoption did not increase the rate of wasting, stunting and underweight children in Shanghai urban areas. On the other hand, it even promoted the height growth among those participating infants. Hence, we recommended that the WHO 2006 growth standards should be used in areas where infant growth is trending toward obesity.

Acknowledgements

The authors gratefully acknowledge the staff at the 19 community health centers and Shanghai Municipal Health Bureau for their assistance in our acquisition of data and in their completion of records. We also sincerely acknowledge the participating infants and their caregivers.

Funding

This study was supported by a grant from the National Natural Science Foundation of China (Nos. 81172686, 81302446, and 81703249).

Conflicts of interest

None.

Author contributions

Jun-Li Wang: provision of study, collection and assembly of data, data analysis and interpretation, manuscript writing; Jing-Qiu Ma: provision of study, collection and assembly of data, data analysis and interpretation; Ming-Yu Xu, Feng Li and Fang Ren: provision of study, collection and assembly of data; Yan-Fei Guo: data analysis and interpretation; Xiao-Yang Sheng: conception and design, data analysis and interpretation, manuscript writing.

References

- Whitehead RG. Growth in weight and length. *Acta Paediatr* 2003;92:406–408. doi: 10.1111/j.1651-2227.2003.tb00567.x.
- Nichols MR, Livingston D. Preventing pediatric obesity: assessment and management in the primary care setting. *J Am Acad Nurse Pract* 2002;14:55–62. quiz 63–55; doi: 10.1111/j.1745-7599.2002.tb00092.x.
- WHO Multicentre Growth Reference Study Group. WHO child growth standards based on length/height, weight and age. *Acta Paediatr Suppl* 2006;450:76–85. doi: 10.1111/j.1651-2227.2006.tb02378.x.
- de Onis M, Garza C, Onyango AW, Rolland-Cachera MF. WHO growth standards for infants and young children. *Arch Pediatr* 2009;16:47–53. doi: 10.1016/j.arcped.2008.10.010.
- de Onis M, Onyango A, Borghi E, Siyam A, Blossner M, Lutter C. Worldwide implementation of the WHO Child Growth Standards. *Public Health Nutr* 2012;15:1603–1610. doi: 10.1017/s136898001200105x.
- Wright C, Lakshman R, Emmett P, Ong KK. Implications of adopting the WHO 2006 child growth standard in the UK: two prospective cohort studies. *Arch Dis Child* 2008;93:566–569. doi: 10.1136/adc.2007.126854.
- Zhang J, Yao G, Fang B. Survey on physical development of children under 7-year-old in Shanghai. *J Clin Pediatr* 2007;25:684–688.
- Ma JQ, Zhou LL, Hu YQ, Liu SS, Sheng XY. Association between feeding practices and weight status in young children. *BMC Pediatr* 2015;15:97. doi: 10.1186/s12887-015-0418-4.

9. Li J, Lei J, Wen S, Zhou L. Sex disparity and perception of obesity/overweight by parents and grandparents. *Paediatr Child Health* 2014;19:e113–e116.
10. Min J, Li J, Li Z, Wang Y. Impacts of infancy rapid weight gain on 5-year childhood overweight development vary by age and sex in China. *Pediatr Obes* 2012;7:365–373. doi: 10.1111/j.2047-6310.2012.00074.x.
11. Ma JQ, Zhou LL, Hu YQ, Liu JR, Liu SS, Zhang J, et al. Feeding and growth of normal birth weight infants during the first year of life in Shanghai. *Early Hum Dev* 2012;88:831–836. doi: 10.1016/j.earlhumdev.2012.06.003.
12. Xie S, Wang J, Li N, Jiang W, Yang S, Li X, et al. Survey on overweight and obesity of preschool children in rural areas from ten provinces of China (in Chinese). *Chin J Epidemiol* 2014;35:425–428.
13. Rifas-Shiman SL, Gillman MW, Oken E, Kleinman K, Taveras EM. Similarity of the CDC and WHO weight-for-length growth charts in predicting risk of obesity at age 5 years. *Obesity (Silver Spring)* 2012;20:1261–1265. doi: 10.1038/oby.2011.350.
14. McCormick DP, Sarpong K, Jordan L, Ray LA, Jain S. Infant obesity: are we ready to make this diagnosis? *J Pediatr* 2010;157:15–19. doi: 10.1016/j.jpeds.2010.01.028.
15. Koletzko B, von Kries R, Closa R, Escribano J, Scaglioni S, Giovannini M, et al. Can infant feeding choices modulate later obesity risk? *Am J Clin Nutr* 2009;89:1502s–1508s. doi: 10.3945/ajcn.2009.27113D.
16. Koletzko B. Childhood obesity: current situation and future opportunities. *J Pediatr Gastroenterol Nutr* 2016;63 (Suppl 1):S18–S21. doi: 10.1097/mpg.0000000000001220.
17. Machuca H, Arevalo S, Hackley B, Applebaum J, Mishkin A, Heo M, et al. Well baby group care: evaluation of a promising intervention for primary obesity prevention in toddlers. *Child Obes* 2016;12:171–178. doi: 10.1089/chi.2015.0212.
18. Cloutier MM, Wiley J, Wang Z, Grant A, Gorin AA. The early childhood obesity prevention program (ECHO): an ecologically-based intervention delivered by home visitors for newborns and their mothers. *BMC Public Health* 2015;15:584. doi: 10.1186/s12889-015-1897-9.
19. Lundahl A, Kidwell KM, Nelson TD. Parental underestimates of child weight: a meta-analysis. *Pediatrics* 2014;133:e689–e703. doi: 10.1542/peds.2013-2690.
20. Wang GH, Tan TX, Cheah CS. Preschool-age Chinese children's weight status: WHO classification, parent ratings, child/family characteristics. *J Pediatr Nurs* 2017;33:63–69. doi: 10.1016/j.pedn.2016.11.005.
21. Chen S, Binns CW, Zhang Y. The importance of definition in diagnosing obesity: a review of studies of children in China. *Asia Pac J Public Health* 2012;24:248–262. doi: 10.1177/1010539512441617.
22. Zhang YQ, Li H, Wu HH, Zong XN, Zhu ZH, Pan Y, et al. The 5th national survey on the physical growth and development of children in the nine cities of China: Anthropometric measurements of Chinese children under 7 years in 2015. *Am J Phys Anthropol* 2017;163:497–509. doi: 10.1002/ajpa.23224.
23. Zong XN, Li H. Construction of a new growth references for China based on urban Chinese children: comparison with the WHO growth standards. *PLoS One* 2013;8:e59569. doi: 10.1371/journal.pone.0059569.
24. Information CfHSA. An Analysis Report of National Health Services Survey in China. <http://www.nhfpc.gov.cn/mohwsbwstjxxzx/s8211/list.shtml>, 2013.
25. de Onis M. Update on the implementation of the WHO child growth standards. *World Rev Nutr Diet* 2013;106:75–82. doi: 10.1159/000342550.
26. Ziegler EE. Growth of breast-fed and formula-fed infants. *Nestle Nutr Workshop Ser Pediatr Program* 2006;58:51–59. discussion 59–63. doi: 10.1159/000095010.
27. de Beer M, Vrijkotte TG, Fall CH, van Eijsden M, Osmond C, Gemke RJ. Associations of infant feeding and timing of linear growth and relative weight gain during early life with childhood body composition. *Int J Obes (Lond)* 2015;39:586–592. doi: 10.1038/ijo.2014.200.
28. de Onis M, Onyango AW, Borghi E, Garza C, Yang H. WHO Multicentre Growth Reference Study Group. 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;9:942–947. doi: 10.1017/PHN20062005.
29. Huang X, Chang J, Feng W, Xu Y, Xu T, Tang H, et al. Development of a new growth standard for breastfed Chinese infants: what is the difference from the WHO growth standards? *PLoS One* 2016;11:e0167816. doi: 10.1371/journal.pone.0167816.
30. Yang Z, Duan Y, Ma G, Yang X, Yin S. Comparison of the China growth charts with the WHO growth standards in assessing malnutrition of children. *BMJ Open* 2015;5:e006107. doi: 10.1136/bmjopen-2014-006107.
31. Zong X, Li H, Zhang Y, Wu H. Weight-for-length/height growth curves for children and adolescents in China in comparison with body mass index in prevalence estimates of malnutrition. *Ann Hum Biol* 2017;44:214–222. doi: 10.1080/03014460.2016.1232750.
32. Zong XN, Li H. Secular trends in prevalence and risk factors of obesity in infants and preschool children in 9 Chinese cities, 1986–2006. *PLoS One* 2012;7:e46942. doi: 10.1371/journal.pone.0046942.
33. Grummer-Strawn LM, Reinold C, Krebs NF. Use of World Health Organization and CDC growth charts for children aged 0–59 months in the United States. *MMWR Recomm Rep* 2010;59:1–15.
34. Mei Z, Ogden CL, Flegal KM, Grummer-Strawn LM. Comparison of the prevalence of shortness, underweight, and overweight among US children aged 0 to 59 months by using the CDC 2000 and the WHO 2006 growth charts. *J Pediatr* 2008;153:622–628. doi: 10.1016/j.jpeds.2008.05.048.
35. Liu P, Xu L, Wang Y, Zhang Y, Du Y, Sun Y, et al. Association between perinatal outcomes and maternal pre-pregnancy body mass index. *Obes Rev* 2016;17:1091–1102. doi: 10.1111/obr.12455.
36. Yu Z, Han S, Zhu J, Sun X, Ji C, Guo X. Pre-pregnancy body mass index in relation to infant birth weight and offspring overweight/obesity: a systematic review and meta-analysis. *PLoS One* 2013;8:e61627. doi: 10.1371/journal.pone.0061627.

How to cite this article: Wang JL, Ma JQ, Xu MY, Li F, Ren F, Guo YF, Sheng XY. Comparison of the effects of different growth standards on infants in Urban Shanghai: a cluster-randomized controlled trial. *Chin Med J* 2019;132:4–10. doi: 10.1097/CM9.0000000000000004