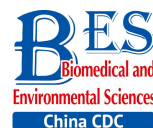


Original Article



The Influence of Secular Trends in Body Height and Weight on the Prevalence of Overweight and Obesity among Chinese Children and Adolescents*

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Abstract

Objective To explore the influence of secular trends in body height and weight on the prevalence of overweight and obesity among Chinese children and adolescents.

Methods The data were obtained from five cross-sectional Chinese National Surveys on Students' Constitution and Health. Overweight/obesity was defined as BMI-for-age Z-score of per the World Health Organization (WHO) reference values. Body height and weight for each sex and age were standardized to those reported in 1985 (standardized height: SHY; standardized weight: SWY) and for each sex and year at age 7 (standardized height: SHA; standardized weight: SWA) using the Z-score method.

Results The prevalence of overweight/obesity in Chinese children was 20.2% among boys and 10.7% among girls in 2010 and increased continuously from 1985 to 2010. Among boys and girls of normal weight, SHY and SHA were significantly greater than SWY and SWA, respectively ($P < 0.001$). Among boys and girls with overweight/obesity, SHY was significantly lower than SWY ($P < 0.001$), and showed an obvious decreasing trend after age 12. SHA was lower than SWA among overweight boys aged 7-8 years and girls aged 7-9 years. SHY/SHW and SHA/SWA among normal-weight groups were greater than among overweight and obese groups ($P < 0.001$).

Conclusion The continuous increase in the prevalence of overweight/obesity among Chinese children may be related to a rapid increase in body weight before age 9 and lack of secular increase in body height after age 12.

Key words: Obesity; Children; Secular trends; Body height; Body weight

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INTRODUCTION

Obesity/overweight is associated with a number of health risks, including cardiovascular diseases, type 2 diabetes

mellitus, respiratory and skeletal muscle problems, and psychological problems^[1-4] and has become an important global health challenge. Over the past few decades, the prevalence of overweight and obesity among children and adolescents has been increasing

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in both developed and developing countries. Hossain reported that there were at least 155 million overweight or obese children all over the world^[5]. In European countries, the number of children with obesity in the 2000s was 10 times higher than in the 1970s^[6]. In the United States, 16.9% of children and adolescents aged 2-19 years were obese^[7]. Ji and Ma reported that the prevalence of childhood overweight/obesity increased from 1.62% and 0.93% in 1985 to 7.8% and 16.0% in 2005, and to 10.6% and 18.5% in 2010, among girls and boys, respectively^[8-9].

It is well known that body mass index (BMI, weight in kilograms divided by the square of height in meters) is one of the most highly recommended and widely used tools for defining childhood overweight and obesity^[10-11]. The prominent secular trends in child body height and weight have been shown since the 1980s, especially in developed countries such as European countries and the United States^[12-17]. In Chinese children, increasing secular trends in body height and weight in the second half of the 20th century has been well documented^[18-20]. However, it remains unknown whether the increase in the prevalence of child overweight/obesity over the years is caused by a too fast secular increase in body weight or the lack of a secular increase in body height among Chinese children and adolescents.

The purposes of the study are to explore the influence of secular trends in body height and weight on the prevalence of childhood overweight or obesity.

METHODS

Study Population and Data Sources

The study used data from the Chinese National Surveys on Students' Constitution and Health (CNSSCH) from 1985, 1995, 2000, 2005, and 2010. The CNSSCH was jointly launched by the Ministry of Education, the National Health and Family Planning Commission, the Ministry of Science and Technology, the State of National Affairs, and the State Sports General Administration in China in 1985 and has been conducted every 5 years since 1995^[19,21-24]. The participants in the CNSSCH were selected by stratified cluster random sampling from 30 of 31 provinces in China. The detailed sampling procedure has been published elsewhere^[21-24]. In the present study, the participants only included children and adolescents aged 7-18 years of the Han nationality.

The sample sizes were 409,946 (205,100 boys and 204,846 girls) in 1985, 204,894 (103,084 boys and 101,810 girls) in 1995, 207,397 (103,804 boys and 103,593 girls) in 2000, 232,138 (116,676 boys and 115,462 girls) in 2005, and 215,280 (107,651 boys and 107,629 girls) in 2010. The project was approved by the Medical Research Ethics Committee of Peking University Health Science Center (IRB00001052-13082).

Measures

Body height and weight measurements were obtained from the five CNSSCH surveys. The same types of instruments were used to measure body height (cm) and weight (kg) as per standard procedures over the five CNSSCH surveys^[19,21-24]. The participants were required to wear only light clothes and to stand straight, barefoot, and at ease when being measured. Body weight was measured to the nearest 0.1 kg using level scales. Body height was measured to the nearest 0.1 cm with metal column height measuring stands. Both instruments were routinely calibrated before daily use to reduce daily biases. The measurements were conducted by professional technicians who passed a training course for anthropometric measurements. Overweight was defined as BMI-for-age Z-score at or above +1 standard deviation (SD), but lower than +2 SD; obesity was defined as BMI-for-age Z-score at or above +2 SD; and normal weight was defined as BMI-for-age Z-score at or above -2 SD, but lower than +1 SD, according to the WHO reference for children aged 5-19 years^[25-26].

Statistical Analysis

Data were analyzed using IBM SPSS data statistics 20.0 software. The prevalence rates of overweight and obesity in different survey years were calculated for each sex and age group (7-18 years). The secular trends in child body height and weight over survey years (from 1985 to 2010) and ages (from 7 to 18) were demonstrated using standardized body height and weight to reveal the changes in prevalence of childhood overweight/obesity. Body height and weight were standardized by two approaches: one by data in the 1985 survey year and the other by data at age 7. Standardized body height (SHY) and weight (SWY) based on data from 1985 were calculated using the Z-score method^[27] (Formula 1).

$$x'_{y} = \frac{x - \bar{x}_{1985}}{s}$$

(1)

In formula (1), x' , was standardized body height or weight; x was the value of body height or weight for each gender and age in 1995, 2000, 2005, and 2010; \bar{x}_{1985} was the mean of body height or weight for each gender and age in 1985; and s was the SD of body height or weight for each gender and age in 1995, 2000, 2005, and 2010. Standardized body height (SHA) and weight (SWA) based on data at age 7 were calculated using a separate Z-score method^[36] (Formula 2).

$$x'_a = \frac{x - \bar{x}_{7\text{-year-old}}}{s}$$

(2)

In formula (2), x'_a was the standardized body height or weight; x was the value of body height or weight for each gender and survey year in children aged 8-18 years; $\bar{x}_{7\text{-year-old}}$ was the mean of body height or weight for each gender and survey year in children aged 7 years; and s was the SD of body height or weight for each gender and survey year in children aged 8-18 years. A paired t -test was used to test the differences between SHY and SWY, and between SHA and SWA among boys and girls with normal weight, overweight, and obesity. The Kruskal-Wallis H test and Mann-Whitney U test were used to test for differences in SHY/SWY and SHA/SWA among normal weight, overweight, and obesity. The level of significance was set at $\alpha = 0.05$ except for the Mann-Whitney U test ($\alpha = 0.017$), and all testes were two-sided.

RESULTS

The Prevalence of Child Overweight and Obesity at Different Years and Ages

As shown in Table 1, the prevalence of overweight and obesity increased continuously among both boys and girls from 1985 to 2010, and was higher in boys than in girls. The prevalence of overweight and obesity was 13.3% and 6.9% among

boys and 8.9% and 1.8% among girls in 2010. Figure 1 shows the changing tendencies in the prevalence of overweight and obesity in different age groups. The prevalence of overweight generally increased from age 7 to age 11 among boys and from age 7 to age 12 among girls and started to decrease after age 11 or 12 in 2000, 2005, and 2010. The prevalence of obesity among boys and girls were relatively high from ages 7 to 10 and decreased rapidly after age 10.

The Influence of the Secular Trends in Body Height and Weight Standardized to 1985 Data on the Prevalence of Overweight and Obesity

The SHY and SWY based on body height and weight for each gender and age in 1985 were used to show the secular trends in body height and weight over the survey years. As shown in Table 2, the SHY was significantly greater than the SWY among normal-weight boys and girls over the four survey years from 1995 to 2010 (all $P < 0.001$). Among boys and girls with overweight and obesity, the SHY was significantly lower than the SWY over the 5 survey years (all $P < 0.001$). The differences in SHY/SWY among boys and girls with normal weight, overweight, and obesity were significant over the 5 survey years (all $P < 0.001$); the SHY/SWY ratios of normal-weight groups were the highest, and those of obese groups were the lowest. Figure 2 shows the trends of SHY and SWY from age 7 to age 18. Among normal-weight boys and girls, the tendency of SHY from age 7 to age 18 was generally consistent with that of SWY. There were increases in both trends between age 7 and 13 among boys and between age 7 and 12 among girls, followed by decreases after age 13 among boys and after age 12 among girls. The SHY trends reached peaks at age 8 among overweight/obese boys and obese girls and at age 10 among overweight girls. There were slight decreases in the SHY trends before age 12 and

Table 1. The Prevalence of Overweight and Obesity among Chinese Boys and Girls During 1985-2010

Years	Boys			Girls		
	N	Overweight (%)	Obesity (%)	N	Overweight (%)	Obesity (%)
1985	205,100	1.0	0.1	204,846	1.0	0.1
1995	103,084	4.8	1.5	101,810	3.5	0.5
2000	103,804	8.4	3.4	103,593	5.5	1.0
2005	116,676	10.9	5.2	115,462	7.1	1.5
2010	107,651	13.3	6.9	107,629	8.9	1.8

significant decreases after age 12 among both boys and girls with overweight and obesity. In contrast, the SWY generally showed increasing trends after age 11 among both boys and girls with overweight and obesity, though the increasing SWY trend for girls with overweight was less apparent.

The Influence of Growth Trends in Body Height and Weight Standardized by Data at Age 7 on Increases in Overweight and Obesity Prevalence Rates

Based on the body height and weight at age 7 for each gender and survey year, body height and weight from age 8 to age 18 were standardized to show

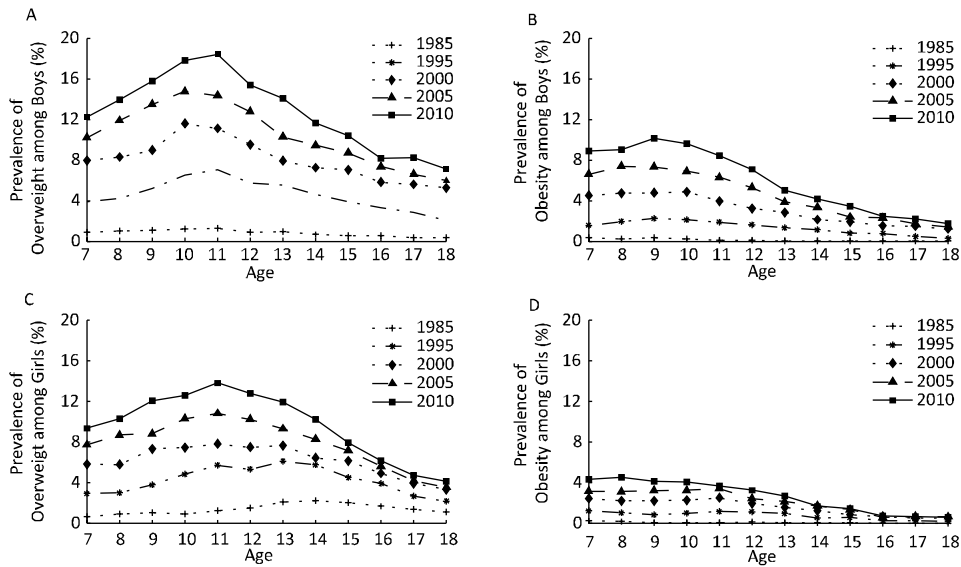


Figure 1. The prevalence of overweight and obesity among Chinese children and adolescents during 1985-2010. (A) Prevalence of overweight in boys; (B) Prevalence of obesity in boys; (C) Prevalence of overweight in girls; (D) Prevalence of obesity in girls.

Table 2. Comparison between SHY and SWY among Chinese Boys and Girls with Normal Weight, Overweight, and Obesity During 1985-2010

Year	Normal Weight			Overweight			Obesity		
	SHY	SWY	SHY/SWY	SHY	SWY	SHY/SWY	SHY	SWY	SHY/SWY
Boys									
1985	0.01±0.99**	0.07±0.91	0.92 (1.24) ^c	0.79±1.10**	2.88±1.08	0.29 (0.38)	1.11±1.28**	4.90±1.64	0.25 (0.27)
1995	0.43±0.98**	0.35±0.76	1.14 (1.52) ^c	1.11±1.00**	2.39±0.78	0.49 (0.41)	1.37±1.32**	4.00±1.25	0.38 (0.26)
2000	0.53±0.96**	0.38±0.68	1.30 (1.72) ^c	1.10±0.96**	2.00±0.66	0.57 (0.49)	1.42±1.17**	3.43±1.22	0.44 (0.31)
2005	0.66±0.97**	0.44±0.63	1.37 (1.72) ^c	1.25±0.92**	1.97±0.61	0.65 (0.47)	1.62±1.00**	3.28±1.00	0.51 (0.31)
2010	0.82±0.98**	0.52±0.61	1.46 (1.70) ^c	1.34±0.95**	1.92±0.60	0.72 (0.51)	1.77±0.96**	3.19±0.90	0.57 (0.32)
Girls									
1985	0.00±0.99**	0.08±0.90	0.83 (1.45) ^c	0.33±1.09**	2.45±0.93	0.14 (0.58)	0.75±1.34**	4.59±1.62	0.18 (0.31)
1995	0.37±0.99**	0.31±0.80	0.98 (1.65) ^c	0.84±1.10**	2.36±0.80	0.38 (0.52)	1.19±1.46**	4.19±1.39	0.32 (0.29)
2000	0.46±0.99**	0.34±0.76	1.08 (1.77) ^c	0.92±1.04**	2.13±0.70	0.46 (0.53)	1.23±1.35**	3.76±1.43	0.38 (0.32)
2005	0.56±0.99**	0.40±0.72	1.12 (1.75) ^c	1.04±1.04**	2.12±0.68	0.52 (0.52)	1.46±1.16**	3.71±1.19	0.43 (0.31)
2010	0.69±1.01**	0.47±0.71	1.19 (1.74) ^c	1.18±1.02**	2.13±0.65	0.58 (0.51)	1.65±1.02**	3.58±0.99	0.48 (0.30)

Note. ** $P < 0.001$, the differences between SHY and SWY were compared using a paired t -test; ^c $P < 0.001$, the differences by pairwise comparison in SHY/SWY among normal weight, overweight, and obesity were analyzed by using the Kruskal-Wallis H test and Mann-Whitney U test; SHY and SWY are the abbreviations of standardized body height and weight based on data in 1985; mean \pm SD was used to describe SHY and SWY; median (quartile range) was used to describe SHY/SWY.

the growth trends in body height and weight over different ages. Table 3 shows that the SHA were significantly greater than the SWA among both normal-weight boys and girls over 5 survey years from 1985 to 2010 (all $P < 0.001$) and were significantly greater than the SWA among both overweight boys and girls over four survey years from 1995 to 2010 (all $P < 0.001$); however, they were significantly less than the SWA among both obese boys and girls over 5 survey years from 1985 to 2010 (all $P < 0.001$). The differences in SHA/SWA among boys and girls with normal weight, overweight, and obesity were significant over the 5 survey years (all $P < 0.001$), and the SHA/SWA of normal-weight groups were the highest, whereas those of obese groups were the lowest. Figure 3 shows that the SHA was greater than the SWA among both normal-weight boys and girls aged 7-18 years. The SHA was lower than the SWA among overweight boys aged 7-8 years and overweight girls aged 7-9 years; however, it was greater than the SWA among overweight boys aged 9-18 years and overweight girls aged 10-18 years. The SHA was lower than the SWA among obese boys aged 7-13 years and girls aged 7-18 years; however, it was

greater than the SWA among obese boys aged 14-18.

DISCUSSION

The present study suggests that the prevalence of overweight and obesity among Chinese children and adolescents aged 7-18 years has been increasing continuously from 1985 to 2010. The prevalence rates of overweight and obesity reached 13.3% and 6.9% among boys and 8.9% and 1.8% among girls in 2010. The prevalence of overweight/obesity among Chinese children and adolescents is lower than that in developed countries, but has been increasing rapidly as documented in the present study. Socio-economic, lifestyle, dietary, and behavioral factors may play important roles in the rapid increase in overweight and obesity in China^[24,28]. In addition, a lack of physical activity and the increasing occurrence of sedentary behaviors may also have contributed to the increasing prevalence of overweight and obesity^[29]. Most studies only reported the overall prevalence of overweight and obesity in different age groups over the world^[9,28-31] but did not investigate the prevalence trends in overweight and obesity in different age groups. To

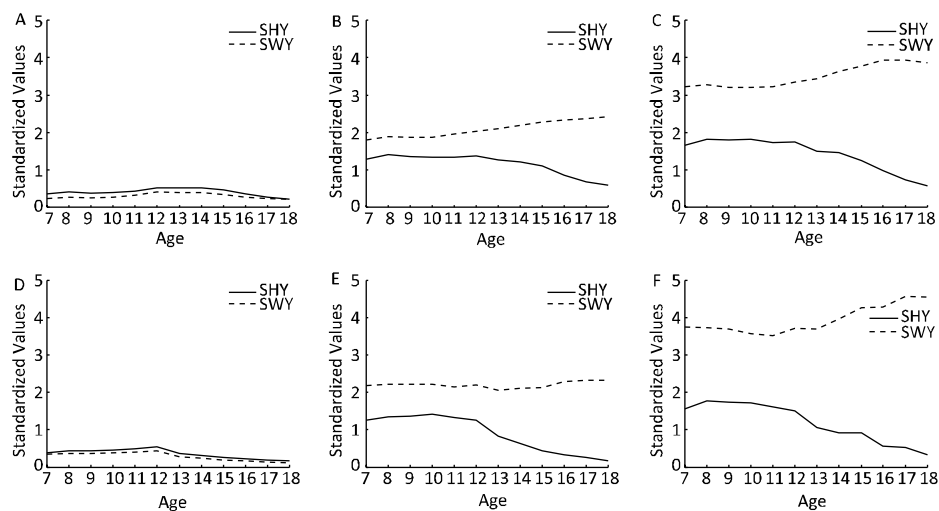


Figure 2. The secular trends of SHY and SWY over different ages among Chinese boys and girls during 1985-2010. SHY and SWY are the abbreviations of standardized body height and weight based on data in 1985. (A) Tendencies of SHY and SWY over different ages among boys with normal weight; (B) Tendencies of SHY and SWY over different ages among boys with overweight; (C) Tendencies of SHY and SWY over different ages among boys with obesity; (D) Tendencies of SHY and SWY over different ages among girls with normal weight; (E) Tendencies of SHY and SWY over different ages among girls with overweight; (F) Tendencies of SHY and SWY over different ages among girls with obesity.

our knowledge, the present study is the first report on the secular trends of overweight and obesity prevalence over different age ranges (7-18 years) based on a large sample size. Our results showed the increased trends in the prevalence of overweight among boys aged 7-11 years and girls aged 7-12 years and the decreasing trends from age 11 or 12 to age 18; the prevalence of obesity among boys and girls remained relatively high at age 7-10 and

decreased rapidly after age 10. Except for the influences of diet and physical activity, the prevalence trends of overweight/obesity in different age groups may also be affected by characteristics of child growth and development. In general, a testicular volume greater than 4 ml indicates puberty onset in boys. Lou et al.^[32] reported that the average age at which testicular volume becomes greater than 4 mL is 9.98 years in Chinese boys, suggesting that

Table 3. Comparison between SHA and SWA among Chinese Boys and Girls with Normal Weight, Overweight, and Obesity during 1985-2010

Year	Normal Weight			Overweight			Obesity		
	SHA	SWA	SHA/SWA	SHA	SWA	SHA/SWA	SHA	SWA	SHA/SWA
Boys									
1985	4.04±2.90**	2.95±2.13	1.37 (0.38) ^c	3.94±2.36**	5.15±1.98	0.75 (0.30)	3.07±2.26**	6.34±2.16	0.47 (0.30)
1995	4.06±2.86**	2.34±1.75	1.73 (0.55) ^c	4.15±2.34**	4.03±1.72	1.03 (0.27)	3.79±2.16**	5.28±1.80	0.74 (0.30)
2000	3.99±2.82**	1.87±1.46	2.11 (0.78) ^c	4.02±2.41**	3.22±1.51	1.22 (0.33)	3.70±2.33**	4.33±1.83	0.86 (0.37)
2005	3.95±2.77**	1.73±1.38	2.22 (0.86) ^c	3.84±2.37**	2.93±1.46	1.30 (0.34)	3.57±2.14**	3.93±1.59	0.91 (0.36)
2010	3.98±2.77**	1.67±1.37	2.29 (0.92) ^c	3.75±2.35**	2.73±1.42	1.37 (0.35)	3.49±2.13**	3.67±1.52	0.96 (0.38)
Girls									
1985	4.31±2.80**	3.15±2.05	1.37 (0.43) ^c	5.18±2.17**	5.86±1.65	0.91 (0.22)	3.53±2.59**	6.56±2.16	0.52 (0.43)
1995	4.19±2.60**	2.66±1.78	1.59 (0.57) ^c	4.61±2.11**	4.60±1.63	1.01 (0.26)	3.92±2.42**	5.75±2.01	0.71 (0.36)
2000	4.11±2.56**	2.29±1.61	1.78 (0.68) ^c	4.21±2.21**	3.82±1.59	1.10 (0.29)	3.72±2.33**	4.96±2.09	0.79 (0.36)
2005	4.06±2.50**	2.21±1.55	1.82 (0.71) ^c	4.02±2.17**	3.55±1.56	1.13 (0.30)	3.75±2.14**	4.74±1.87	0.81 (0.33)
2010	3.99±2.45**	2.14±1.53	1.84 (0.74) ^c	3.88±2.12**	3.37±1.52	1.15 (0.33)	3.54±2.07**	4.34±1.73	0.82 (0.34)

Note. ** $P < 0.001$, the differences between SHA and SWA were compared using a paired t -test; ^c $P < 0.001$; the differences by pairwise comparison of SHA/SWA among normal weight, overweight, and obesity were analyzed by using the Kruskal-Wallis H test and Mann-Whitney U test; SHA and SWA are the abbreviations for standardized body height and weight based on data at age 7, respectively; mean \pm SD was used to describe SHA and SWA; median (quartile range) was used to describe SHA/SWA.

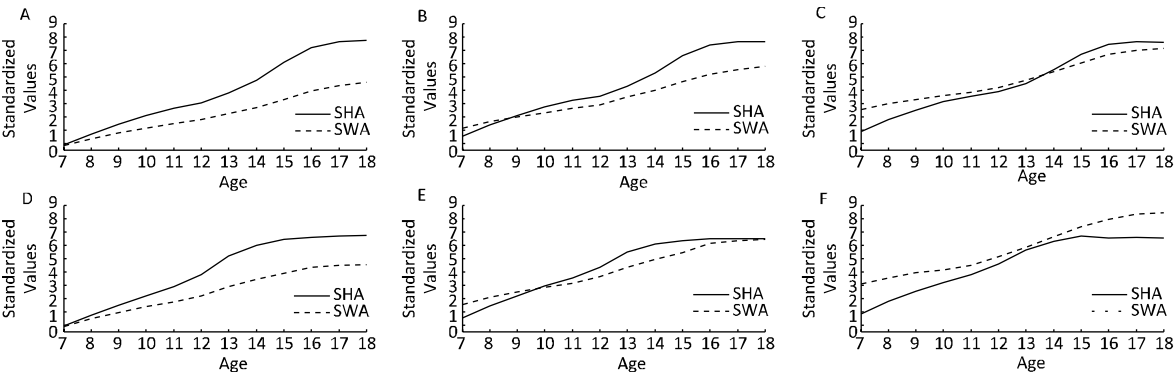


Figure 3. The growth trends of SHA and SWA over different ages among Chinese boys and girls during 1985-2010. SHA and SWA are the abbreviations of the standardized body height and weight based on data at age 7. (A) Tendencies of SHA and SWA over different ages among boys with normal weight; (B) Tendencies of SHA and SWA over different ages among boys with overweight; (C) Tendencies of SHA and SWA over different ages among boys with obesity; (D) Tendencies of SHA and SWA over different ages among girls with normal weight; (E) Tendencies of SHA and SWA over different ages among girls with overweight; (F) Tendencies of SHA and SWA over different ages among girls with obesity.

puberty in boys starts approximately at the age of 10. After puberty onset, the levels of male hormones and growth hormones increase significantly to promote the development of bone and muscle but inhibit the increase in body fat. These changes may help to explain the decreasing trend in the prevalence of overweight among boys from age 11 to age 18. Another study showed that the average age at menarche of Chinese girls is 12.76 years^[33]. During puberty, girls' estrogen levels increase significantly to promote the accumulation of body fat, which may be the reason for the highest prevalence of overweight among girls at age 12. In addition, the prevalence tendencies in overweight and obesity across age groups were generally consistent with changes in body fat percentage (BFP). Ma et al.^[34] found that the BFP of normal-weight children increased from age 7 to age 13 and then decreased slightly.

In the current study, the body height and weight for each gender and age in 1985 were used as the standards to calculate Z-scores to show secular trends of body height and weight over the survey years (SHY and SWY). The body height and weight at age 7 for each gender and survey year were used as the standards to calculate Z-scores to show growth trends in body height and weight across ages (SHA and SWA). The original body height and weight were transformed into the standardized value without units, the mean and standard deviation of which became 0 and 1. The Z-score has been the most commonly used method to set up the evaluation standard of growth and development, such as WHO references for over weight/obesity and growth retardation^[25-26] and the US CDC growth chart^[10]. Fu et al. have developed an objective measure to evaluate actual body shape based on the Z-score method^[27]. The Z-score method is effective to eliminate the influence of different units of body height and weight when comparing growth or secular tendencies between body height and weight.

Our results showed that the SHY was significantly greater than the SWY, and their tendencies from age 7 to 18 were generally consistent among normal-weight boys and girls over 5 survey years, which showed the secular increase in body height to be higher than that of body weight, and their tendencies, were consistent in normal-weight children. Since at least the mid-19th century, a secular increase in body height and weight has been shown in the world^[16]. Loesch et al.^[13] reported increased values of body height and weight of 1.2 cm/decade and 1.3 kg/decade, respectively, in

males and 0.2 cm/decade and 2.1 kg/decade, respectively, in females from 1970 to 1992. The body height and weight of 19-year-old German conscripts increased by 6.5 cm and 9.9 kg from 1956 to 2010^[35]. Ji et al. reported that body height and BMI among Chinese children and adolescents aged 7-18 years increased by 2.5 cm/decade and 0.8 kg/m² per decade in males and 2.0 cm/decade and 0.6 kg/m² per decade in females from 1985 to 2005. From the above studies, the comparison between secular tendencies in body height and weight was not shown due to differences in the units. To our knowledge, the present study has been the first to report that the secular increase in body height was higher than that of body weight among children and adolescents with normal weight.

On the contrary, the SHY was significantly lower than the SWY among boys and girls with overweight or obesity, and the SHY/SWY among normal-weight groups was greater than in the overweight or obesity groups over 5 survey years, which showed that the secular increase in body height was lower than that of body weight among boys and girls with overweight or obesity. Several studies have shown a secular increase in body weight, which was an important reason that the prevalence of overweight/obesity has continued to increase. However, the present result showed that the SHY significantly decreased among overweight or obese children after age 12, which showed a lack of secular increase in body weight after age 12. This may be because the accumulation of body fat in children with overweight or obesity promotes earlier menarche or first spermatorrhea. The cohort study also showed that the earlier initiation and faster progression through puberty was associated with an increased risk of obesity^[36]. Earlier puberty resulted in an earlier growth spurt and lower body height growth during late puberty; thus, the secular increase in body height was higher during early puberty, then decreased dramatically during middle and late puberty development (after age 12). Lobstein et al. reported the key message that the continuing problem of growth retardation and stunting coincides with, and might contribute in part to, the rising prevalence of obesity in many low- and middle-income countries^[37].

We also found that the SHA was significantly greater than the SWA among boys and girls with normal weight between ages 7 and 18. However, the SHA was lower than the SWA among overweight boys aged 7-8 years and overweight girls aged 7-9 years, obese boys aged 7-13 years, and obese girls

aged 7-18 years. In addition, SHA/SWA among normal-weight groups was greater than that of overweight or obese groups over 5 survey years. From the above results, we know that the increase in body height among normal-weight boys and girls should be higher than that of body weight over age 7-18; however, it was lower than that of body weight during early puberty development (before age 9) among boys and girls with overweight and obesity. The rapid increase in body weight before age 9 may be due to the influence of a poor diet and physical inactivity. Except for the secular increase in body weight, the continuous increase in the prevalence of overweight and obesity over the survey years may be related to the rapid increase in body weight during early puberty development (before age 9) and the lack of a secular increase in body height during middle and late puberty development (after age 12).

Although the present study was based on the largest surveys ever conducted in China, it has cross-sectional properties. The prevalence of overweight and obesity and growth tendencies of body height and weight over different ages were based on different groups of participants, and this limits the generalizability of our study findings. Future prospective cohort studies that follow the same participants from childhood through late puberty may help to confirm our study findings.

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