Original Article

Secular Changes on the Distribution of Body Mass Index among Chinese Children and Adolescents, 1985-2010*

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Abstract

Objective To analyze the change in Body Mass Index (BMI) distribution among Chinese children and adolescents for the development of more effective intervention for childhood obesity.

Methods Data on the national students' constitution and health survey between 1985 and 2010 was used for this study. Subjects were students aged 7-18 randomly selected from 30 provinces in China. BMI for-age curves were developed by LMS method, and the trend of BMI distribution was determined by comparing the upper BMI percentiles and analyzing the skew shift of distribution between 1985 and 2010.

Results An overall positive swift trend of BMI between 1985 and 2010 was observed among the Chinese school-age children and adolescents. The average median of the BMI increased from 16.8 and 17.0 kg/m^2 to 18.2 and 17.9 kg/m^2 in 25 years, with increments 0.56 and 0.36 kg/m^2 per decade for males and females, respectively. The more obvious increments were found at the high BMI. The total increments of BMI in this period were 4.03 and 2.20 kg/m^2 at the 85th, 6.14 and 3.57 kg/m^2 at the 95th, and 6.99 and 4.27 kg/m^2 at the 97th percentiles, for males and females, respectively.

Conclusion Obvious increments were observed at high BMI of the Chinese children and adolescents. More effective interventions should be taken for control and prevention of obesity and its health consequence for these subgroups. It is necessary to establish a risk-complex system consisting of the identification of BMI scope, the screen of the disease risk factors and the assessment of excessive adiposity.

Key words: Body mass index; Obesity; Chinese School-age children; Secular growth changes

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INTRODUCTION

Overweight and obesity are often defined based on body mass index (BMI, kg/m^2), while almost all these individuals are sited at the upper BMI percentiles, such as the 85th, 95th, 97th, and 99th percentiles, etc. (high BMI)[1]. Although body mass index doesn't measure body fatness directly, it appears that the association between BMI and adiposity in children is significantly closed at the high BMI levels[2]. Previous studies showed that children and adolescents who have high levels of BMI are more likely to have severe psychological and health problems than their peers; the higher the BMI, the more likely to have excess adiposity, multiple metabolic risk factors, and

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a high risk at adult obesity[3-4]. Other studies showed that high BMI in children may also have immediate consequences, such as elevated lipid concentrations, insulin, and blood pressure[5]. Some longitudinal studies indicated that high BMI in childhood is associated with vascular fatty streaks, raised lesions in left ventricular masses, and premature mortality in adulthood[6]. It is for these reasons, the rising of high BMI, reflecting the increasing risk on the prevalence of childhood obesity, has become a global public health concern especially in developed countries[7].

Studies on the secular trend of BMI in recent decades have proved two pronounced close-associated features proclaiming the progress of upward epidemic obesity. First, the significant differences were mainly found in the upper tail of the BMI distribution, with constant or only slightly increased values in the lower quartiles. Ogden et al, using the U.S. nationally representative samples over a 30 year period (1965-1994), found marked increases in the proportion of children in the high BMI over time[8]. Ekblom et al., through comparing the BMI percentiles between 1987 and 2001 in Sweden, found that the 10th percentile of BMI only slightly changed in most of the age groups; the median (P50) was moderately elevated with differences ranging from -1.6 to 5.7%; whereas the BMI at the 90th percentile swiftly increased with differences ranging from 7.4% to 12.3%. It is apparent that the difference in the whole BMI distribution was mainly due to a change in the prevalence of the upper percentiles. Accompanying with the elevated median BMI among adolescents, the prevalence of overweight and obesity combined category increased more than 2.5 folds in 10 to 16 year old adolescents[9]. Second, accompanying with the increasing proportion in the upper percentiles, the distribution skewed to right over time. Flegal and Troiano designed a qualitative graphical method (by showing the shape of the line formed by M±d plots) to summarize the change. The y-axis in the histogram displays the value of the difference between corresponding percentiles which can be interpreted by the direction and distance (BMI units) of the shift[10]. Ogden et al. used this method to present a complete picture of the trend and demonstrated that the distribution of BMI between the NHANES II (1976-1980) and NHANES 1999-2004, both among the adults (20-74 y) and children and teenagers (6-19 y), had significantly shifted to the right. Similar to those described above, the differences of BMI at the lower end were fairly constant, while those at the upper ends were progressively greater and let the distribution became therefore more skewed[11].

There are two trends, namely the secular changes of physical growth[12-13] and the swift increase of childhood overweight/obesity[14] coexistent in China in recent decades. However, what's the correlation between the two and whether the former has impact (positive or negative) on the latter haven't been well documented yet[15]. Because childhood obesity has become a major public health concern, it is an urgent task to monitor the change of BMI (especially high BMI) among populations over time and to identify the different patterns among different subgroups[16]. In addition, many preventive and control affords (i.e., if more aggressive therapy are warranted for an excessive heavy child) should be supported by evidence from high BMI[17]. Therefore, the purpose of the present study was to analyze the change in Body Mass Index (BMI) distribution among Chinese children and adolescents for the development of more effective intervention for childhood obesity in China.

METHODS

Data Sources and Sampling

Data come from the 1985, 1995, 2000, 2005, and 2010 rounds of the Chinese National Survey on Students' Constitution and Health (CNSSCH)[18-23]. This survey is conducted with 5-year interval jointly by the Chinese Ministry of Education, the Chinese Ministry of Health, the Chinese Ministry of Science and Technology, the State Ethnic Affairs Commission and the State Sports General Administration of China. It is a multi-province survey with the largest national representative samples of school-age children and has been widely used to evaluate the health status of the school children at the national and provincial levels. The subjects are primary and secondary school students aged 7-18 that were randomly selected from 30 provinces excluding Tibet, the only one in which Han Chinese do not constitute an ethnic majority. Each province was considered as independent subpopulation and the local institutions of school health recruited the province-wide samples by means of a 3-stage clustering process. In each provinces, the subjects were grouped by gender and location (urban or rural), and each of the four groups consisted of equal numbers of individuals from three

SES classes (upper, middle, and lower). The five indices constituting the criteria for defining the three classes were made province-specific in 1985: the regional gross domestic product, the total yearly income per capita, the average food consumption per capita, the natural growth rate of the population, and the regional social-welfare index[18]. During the second sampling step, three urban and three rural residential areas were selected. And then, several primary and secondary schools were randomly selected from a list compiled by local Educational Bureauex. A list of students from grades 1-12 was compiled, and a random selection of two or three classes (depending on their size) was made from each grade level.

Ethical approval was obtained from Peking University Medical Research Ethics Committee, and informed consent was obtained verbally. The students were informed that their privacy would be respected. To ensure the validity of comparisons among samples, the subjects in each group were selected at random at various time periods. Because all the subjects in the 1991 round were drawn only from the upper class, these data were excluded from the study[19]. In addition, over the course of the entire series of round from 1985-2010, not only were the subjects drawn from the same set of urban and rural areas, but 86.6% and 78.9%, respectively, of those schools remained in the sample. All the subjects were Han (along with 92.7% of the population nationwide) and had lived for at least one year in the local area. A total of 359 946 subjects were selected (294-306 in each sex-age subgroup) in 1985, 204 977 were selected in 1995, 216 654 were selected in 2000, 234 421 were selected in 2005 (155-169 in each subgroup), and 297 062 were selected in 2010 (162-181 in each subgroup). During the BMI comparison for change, a special subgroup (from coastal developed metropolis) was selected in the most advanced urban areas which contained nine cities: Beijing, Shanghai, Tianjin, Shijiazhuang, Shenyang, Dalian, Jinan, Qingdao, and Nanjing. The other subjects selected from the urban and rural areas then consisted the ‘overall urban’ (including the ‘coastal’ subgroup) and the ‘overall rural’ subgroups, in order to respectively reflect the urban and rural areas in china.

Physical Measurement

A thorough medical examination was performed before measurement, and the data of the subjects suffering from evident diseases or physical/mental deformities were excluded. Height (cm) and weight (kg) were measured by trained personnel. All measurements were performed in the morning according to a standard procedure and by means of the uniformly recommended apparatus[24]. No blood samples were collected during the survey. Height and weight were measured with subjects dressed in light clothing (shorts and socks, but without shoes). Height was recorded in centimeters to one decimal place, while weight was recorded in kilograms to one decimal place. Rigid quality control measures were enforced in the field. After completing the daily measurements, 3% of the subjects were invited to be measured again. If more than 5% of the measurements exceeded the normal

Table 1. Sample Sizes in Each Age Groups in Different Cycles between 1985 and 2010

Age (years)	1985	1995	2000	2005	2010
7-	34 203	16 381	18 057	19 376	24 480
8-	34 240	16 388	18 103	19 333	25 038
9-	34 235	17 386	18 031	19 402	24 872
10-	24 237	17 509	18 290	19 642	25 290
11-	24 240	17 416	17 995	19 582	24 785
12-	24 328	17 342	18 056	19 254	24 702
13-	24 230	17 310	17 936	19 426	24 811
14-	24 236	17 332	17 986	19 288	24 878
15-	34 229	17 334	18 009	19 752	24 888
16-	34 230	17 201	18 019	19 550	24 787
17-	34 185	17 262	17 893	19 509	24 604
18-	33 443	17 114	18 279	20 307	23 927
Total	359 946	204 977	216 654	234 421	297 062

variation, the whole examination in that day should have to be performed once again in another day. Subjects whose measurements had disparities exceeding the limiting scores were considered invalid. The coefficients of variations among provinces ranged from 1.5% to 2.1% in 1985, 1.5% to 2.1% in 1995, 1.7% to 2.2% in 2000, 1.6% to 2.0% in 2005, as well as 1.7% to 2.1% in 2010[23].

Descriptive Statistics

Body mass index (BMI, kg/m^2) is calculated as weight in kilograms divided by height in meters squared. Overweight and obesity were defined by the Chinese WGOC criteria; BMI of 24 and 28 are cutoffs for overweight and obesity, respectively, for both males and females 18 years of age[25]. BMI percentile curves were constructed by using Cole's LMS method. Based on the calculation of L (power in the Box-Cox transformation), M (median) and S (coefficient of variation), the sex-specific smooth curves are formulated and the percentile values for each age were obtained[26]. Several statistical parameters of the frequency analysis, such as the mean, median, range, and skewness index were calculated in order to describe the change of BMI distribution between 1985 and 2010. Pair-wised χ^2 tests were used to ascertain the statistical significance (P<0.01 or P<0.001) of differences between corresponding groups. All the analyses are carried out by using SPSS 16.0.

RESULTS

Positive Secular Changes of BMI during 1985-2010

Age-specific BMI percentile curves were established for males and females by using LMS method (Figure 1), while the 3rd, 5th, 10th, 15th, 25th, 50th, 75th, 85th, 90th, 95th, and 97th percentile values for several represent ages (i.e., the 7-, 10-, 12-, 15-, and 18- year old) in 1985, 2000, and 2010 were displayed in Tables 2 and 3. A remarkable increase trend covering all the age groups was found at different BMI percentiles. The average median (P50) of the BMI increased from 16.8 and 17.0 kg/m^2 in 1985 to 18.2 and 17.9 kg/m^2 in 2010, with average increments 0.56 kg/m^2 and 0.36 kg/m^2 per decade, which was more significant in males than in females, and more swifter in the latter period (2000-2010) than in the former (1985-2000). However, more obvious increments were found at the high BMI. For males, the average increments per decade in 25 years were 0.13 kg/m^2 at P85, 0.21 kg/m^2 at P95, and 0.24 kg/m^2 at P97; for females, these per-decade increments were 0.08 kg/m^2 at P85, 0.12 kg/m^2 at P95 and 0.14 kg/m^2, respectively.

The Unbalanced Increments of BMI Values at Different Percentiles

Puberty is not only the period in which most significant increase trend existed, but also the most obvious unbalanced increments of BMI values in various percentiles occurred (Figures 2 and 3). In the lower percentiles, only 0.56 and 0.39 kg/m^2 for the 5th, 1.04 and 0.74 kg/m^2 for the 25th were found, for males and females respectively, from 1985 to 2010. In the moderate percentiles, the increments evidently rose to 1.63 and 2.86 kg/m^2 in males, and 1.06 and 1.63 kg/m^2 in females, for the 50th and 75th percentiles, respectively. In contrast, the increments of BMI during the same 25 years were high as 4.03 and 2.20 kg/m^2 for the 85th, 6.14 and 3.57 kg/m^2 for the 95th, and even as high as 6.99 and 4.27 kg/m^2 for the 97th percentiles, for males and females, respectively.

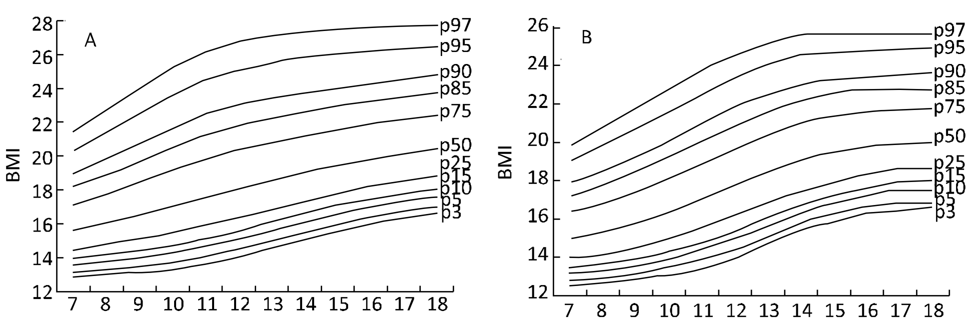

Figure 1. Smoothed percentile curves of body mass index for Chinese (A) males and (B) females children aged 7 to 18.

Table 2. Changes in the Percentile Values of Body Mass Index in Chinese Boys Aged 7-18 Years during 1985-2010 (kg/m^2)

Age (years)	P3	P5	P10	P15	P25	P50	P75	P85	P90	P95	P97
	In 1985										
7-	12.9	13.1	13.4	13.6	13.9	14.5	15.2	15.5	15.8	16.3	16.7
10-	13.3	13.5	13.9	14.1	14.5	15.2	16.0	16.4	16.8	17.4	18.0
12-	13.8	14.0	14.4	14.7	15.1	15.9	16.8	17.4	17.8	18.5	19.2
15-	15.5	15.8	16.3	16.7	17.2	18.3	19.4	20.0	20.5	21.2	21.7
18-	16.8	17.2	17.8	18.2	18.7	19.7	20.8	21.4	21.9	22.5	23.0
	In 2000										
7-	12.9	13.2	13.5	13.8	14.2	15.0	16.1	17.0	17.7	19.3	20.6
10-	13.4	13.7	14.1	14.4	14.9	16.0	17.8	19.3	20.4	22.2	23.4
12-	13.8	14.2	14.7	15.0	15.6	16.9	18.8	20.3	21.4	23.3	24.8
15-	15.6	15.9	16.4	16.8	17.5	18.8	20.5	21.9	23.1	25.0	26.5
18-	16.7	17.1	17.7	18.2	18.8	20.1	21.9	23.2	24.0	25.8	27.1
	In 2010										
7-	12.9	13.1	13.6	13.9	14.5	15.6	17.2	18.2	19.0	20.3	21.4
10-	13.3	13.7	14.3	14.7	15.5	17.1	19.2	20.6	21.7	23.7	25.2
12-	14.0	14.4	15.1	15.6	16.3	18.1	20.3	21.9	23.0	25.1	26.8
15-	15.6	15.9	16.6	17.0	17.8	19.4	21.5	22.9	24.0	26.0	27.5
18-	16.7	17.01	17.6	18.1	18.8	20.4	22.4	23.7	24.7	26.4	27.7

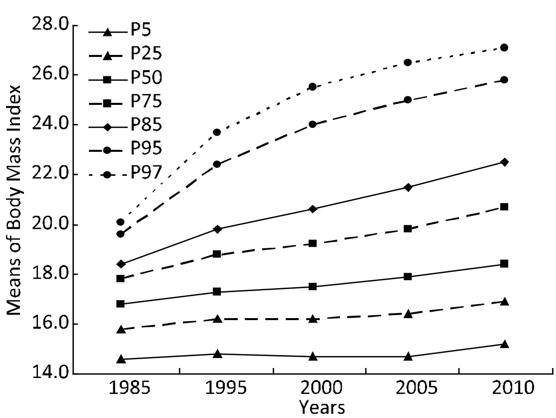

Figure 2. Secular changes of different BMI percentiles in 13-year old boys during 1985-2010.

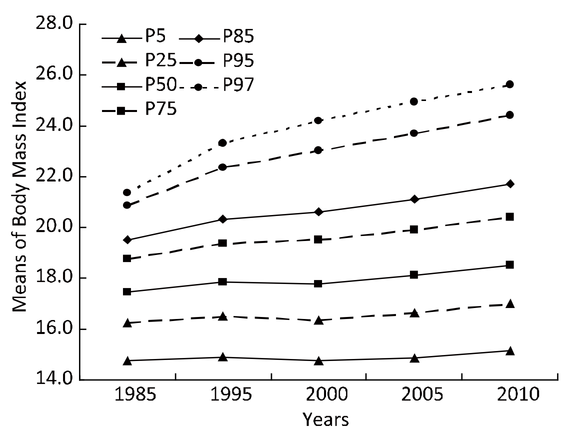

Figure 3. Secular changes of different BMI percentiles in 13-year old girls during 1985-2010.

The Disparities on the BMI Changes among Different SES Regions

There were large disparities at the upper tail of the BMI distribution among three SES regions (Table 4). In each of the sex-age groups, both the 85th and 95th BMI values in the 'coastal' group were higher than that of the 'overall urban' group and significant higher than that of the 'overall rural' group, and the largest disparities existed in early puberty. The values of the 13-year 'coastal' boys, for example, were 1.8 and 3.3 kg/m^2 higher at the 85th, and 1.8 and

Table 3. Changes in the Percentile Values of Body Mass Index in Chinese Girls Aged 7-18 during 1985-2010 (kg/m^2)

Age (years)	P3	P5	P10	P15	P25	P50	P75	P85	P90	P95	P97
	In 1985										
7-	12.5	12.7	13.1	13.4	13.6	14.2	14.9	15.3	15.6	16.1	16.4
10-	13.0	13.2	13.6	13.8	14.2	14.9	15.8	16.3	16.7	17.4	17.9
12-	13.6	13.9	14.3	14.6	15.1	16.1	17.3	18.0	18.5	19.4	20.0
15-	15.8	16.1	16.7	17.1	17.8	19.0	20.4	21.2	21.7	22.5	23.1
18-	16.8	17.1	17.7	18.1	18.8	20.2	21.6	22.3	22.8	23.6	24.1
	In 2000										
7-	12.6	12.8	13.2	13.5	13.9	14.6	15.6	16.4	17.0	18.3	19.1
10-	13.0	13.3	13.7	14.0	14.5	15.6	17.1	18.2	19.0	20.6	21.7
12-	13.7	14.0	14.6	15.0	15.6	17.0	18.7	19.8	20.7	22.2	23.5
15-	15.7	16.1	16.7	17.4	17.8	19.3	20.9	21.9	22.7	24.2	25.2
18-	16.7	17.1	17.7	18.2	18.8	20.2	21.8	22.8	23.4	24.7	25.6
	In 2010										
7-	12.6	12.8	13.2	13.5	14.0	15.0	16.3	17.2	17.9	19.0	19.9
10-	13.1	13.4	13.9	14.3	15.0	16.3	18.1	19.2	20.1	21.6	22.8
12-	14.0	14.4	15.0	15.3	16.2	17.7	19.6	20.9	21.8	23.4	24.6
15-	15.8	16.2	16.9	17.4	18.0	19.6	21.4	22.5	23.4	24.8	25.8
18-	16.8	17.1	17.7	18.2	18.7	20.1	21.8	22.8	23.6	24.9	25.8

Table 4. Comparison of the 85th and 95th Percentile Values between Different SES Groups (2010) and the WHO Reference

Age (years)	P85				P95			
	Coastal	Urban	Rural	WHO-2006	Coastal	Urban	Rural	WHO-2006
	Males							
7-	19.9	19.1	18.4*	17.3	22.4	21.9	20.2*	18.5
8-	20.9	19.9*	19.2**	17.7	23.1	22.6	21.4*	19.1
9-	21.7	21.2	20.1**	18.3	24.3	23.9	22.1**	19.8
10-	22.8	21.9	21.0**	18.9	25.6	24.7	23.3**	20.7
11-	23.9	22.7*	21.4**	19.6	26.7	25.7*	24.0**	21.6
12-	24.9	23.1**	21.5**	20.5	27.8	26.4*	24.7**	22.6
13-	25.1	23.3**	21.8**	21.4	28.5	26.7*	24.7**	23.7
14-	25.2	23.7*	22.2**	22.4	28.4	27.5	25.1**	24.7
15-	25.3	24.0*	22.4**	23.2	29.5	27.7*	25.3**	25.7
16-	25.2	23.9*	22.8**	24.0	28.5	27.4*	25.4**	26.5
17-	25.6	24.4*	22.9**	24.7	29.1	27.9*	25.6**	27.2
18-	25.5	24.3*	23.1**	25.3	29.0	27.8*	25.4**	27.8
	Females							
7-	18.5	17.7	16.8**	17.6	21.0	19.8*	19.1**	19.1
8-	19.1	18.3	17.3**	18.1	21.3	20.6	19.5**	19.8
9-	19.9	19.1	18.0**	18.8	22.5	21.5	20.3**	20.7
10-	20.5	19.8	18.9**	19.5	22.9	22.4	21.4*	21.6
11-	21.5	20.8	19.7*	20.4	24.5	23.3*	22.1**	22.7
12-	22.6	21.4*	20.6**	21.4	26.0	24.1**	23.1**	23.9
13-	23.0	22.1	21.2**	22.4	25.7	25.0	23.8**	25.0
14-	23.5	22.5	21.7**	23.3	26.3	25.1*	24.0**	25.9
15-	23.3	22.7	22.2*	24.0	26.3	25.5	24.4**	26.7
16-	23.7	23.0	22.5*	24.5	26.7	25.4*	24.5**	27.2
17-	23.2	22.9	22.6	24.8	26.1	25.1*	24.6*	27.5
18-	23.7	22.8	22.7	25.0	26.9	25.3**	24.6**	27.7

Note. The significance of difference using the pair-wised χ^2 tests between (left) 'overall urban' and 'coastal' groups and between (right) 'overall rural' and 'coastal' groups. $^{*}P<0.01$; $^{**}P<0.001$.

3.8 kg/m^2 higher at the 95th percentiles than that of the ‘overall urban’ and ‘overall rural’ groups, respectively. For 12-year girls, the values of the ‘coastal’ were 1.2 and 2.0 kg/m^2 higher at P85, and 1.9 and 2.9 kg/m^2 higher at P95 than that of the two latter groups. The 85th and 95th of the WHO-2006 screening criterion[27] listed here can be used to witness the results of the increases at the upper percentiles among the ‘coastal’ and ‘urban’ groups in recent 25 years. In 2010, male’s corresponding percentile values among the two had exceeded or approached that of the WHO-2006. The magnitude of the change in girls was much weak, among which only those from the ‘coastal’ group reached the same level, and there were still gaps between the ‘rural’ group and the WHO reference. However, all these changes proclaim the swift spreading of overweight and obesity.

The Skew Shift of BMI Distribution Over Time

Figure 4 displays the changes in frequency of the BMI distribution between 1985 and 2010. The male’s histogram in 1985 was characterized by a near-normal distribution, but changed remarkably in 2010, with the range from 10-30 to 10-39 kg/m^2, and the skewness increased from 0.561 to 0.849. A same phenomenon was found in females, with the enlargements of range (from 10-29 to 10-37 kg/m^2) and the increase of skewness (from 0.490 to 0.617). Further studies proved that this trend occurred in all the sex-age groups (especially those in the adolescence) which not only manifested by the marked disparities on the difference between means and medians, but also by the enlargement of skew indices (Table 5). This feature is thought to be a direct factor influencing the increasing epidemic of childhood overweight/obesity in China in recent years.

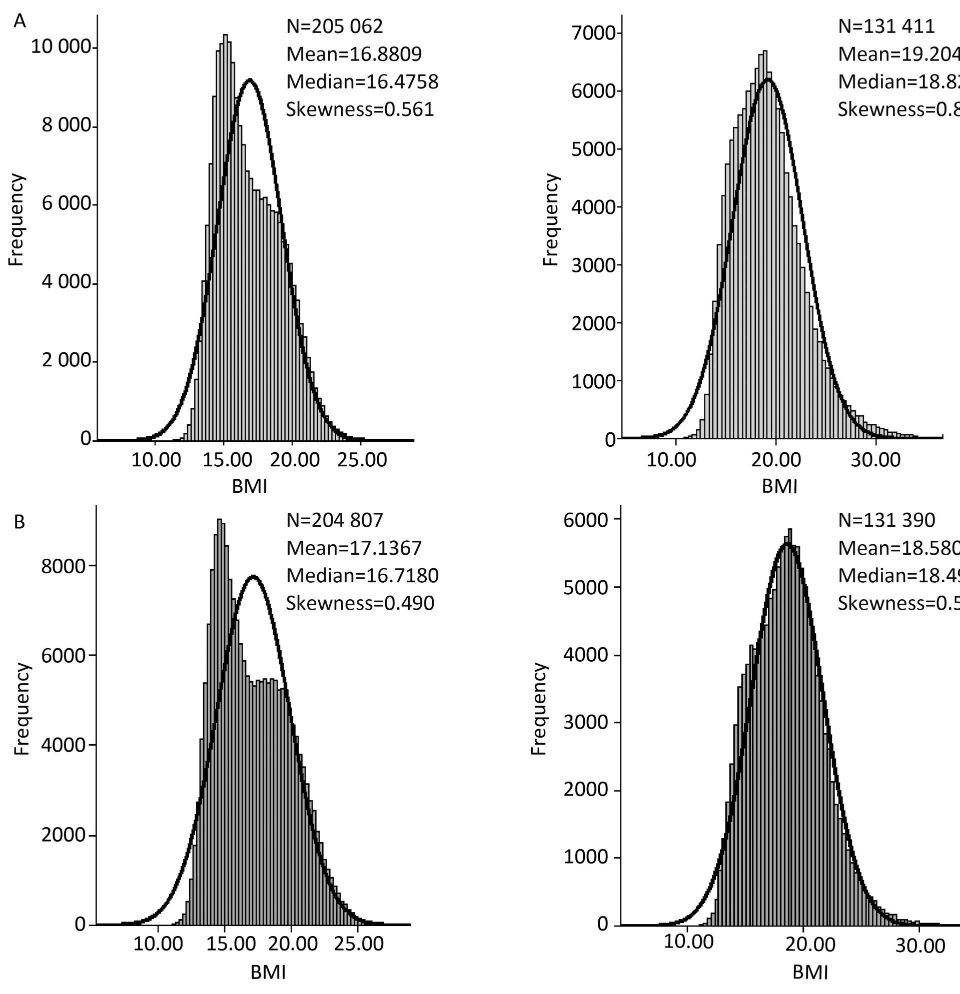

Figure 4. Changes of the frequency histograms in (A) males and (B) females aged 7-18 years from 1985 to 2010.

Table 5. The Comparison of Frequency Parameters on BMI Distribution between 1985 and 2010

Age (years)	Males					Females				
	No.	Mean	Median	Mean-median	Skewness	No.	Mean	Median	Mean-median	Skewness
	In 1985									
7-9	51 338	14.79	14.69	0.10	1.422	51 340	14.50	14.41	0.09	1.099
10-12	51 358	15.68	15.53	0.15	1.174	51 357	15.67	15.47	0.20	0.972
13-15	51 055	17.63	17.51	0.12	0.373	51 346	18.38	18.26	0.12	0.394
16-18	51 055	19.44	19.39	0.05	0.373	50 803	20.02	19.93	0.09	0.292
	In 2010									
7-9	26 833	16.56	15.85	0.71	1.389	26 923	15.77	15.29	0.48	1.408
10-12	26 949	18.24	17.43	0.81	1.182	26 955	17.46	16.95	0.51	1.095
13-15	26 882	20.63	20.03	0.60	1.288	26 921	19.44	19.06	0.38	1.049
16-18	26 882	20.63	20.03	0.60	1.288	26 833	20.31	19.98	0.32	1.003

DISCUSSION

Similar to the stature and other physical growth indices[12], a positive secular trend of BMI has occurred among the Chinese school-age children and adolescents in recent 25 years. Of special note was the dissimilar pattern in China and the developed countries. Although greater increments occurred at the upper percentiles, there were also significant positive changes in the lower and moderate percentiles (Figures 2-3) characterized by China, a country under transition and also contributed to formulate the upward of BMI distribution. This trend has benefit effects on children's physical constitution and health. China was once a poor country and about 50% Chinese children in the early 1950s were suffered from malnutrition (stunting and wasting). Although the nutrition status had been gradually improved since then, the prevalence of protein energy malnutrition still remained at 35% among the rural school children in 1985[28]. The period of 1985-2010 was by far the most astonished period for nutrition improvement in China. In the first 15 years between 1985 and 2000, the medians of BMI in Chinese children increased 0.57 and 0.44 kg/m^2 in children aged 7-9 years, 0.9 and 0.75 kg/m^2 in children aged 10-12 years, and 0.63 and 0.3 kg/m^2 in children aged 13-15 years, for males and females, respectively[29]. From 2001 to 2010, these medians further increased 0.59 and 0.44 kg/m^2 in children aged 7-9 years, 1.0 and 0.73 kg/m^2 in children aged 10-12 years, and 0.89 and 0.50 kg/m^2 in children aged 13-15 years, for males and females, respectively. Based upon this trend, the prevalence of malnutrition among children aged 7-15 year in the 'overall rural' area swiftly decreased from 40.1% and 34.8% in the 1985, 28.6% and 24.6% in the 1995, 26.3% and 23.0% in the 2000, and 22.8% and 19.2% in the 2005, for males and females, respectively[30]. Meanwhile, the incidences of common pediatric diseases (i.e., the iron-deficiency anemia) also swiftly decreased, and the physical fitness of both the urban and rural children significantly improved[31]. Undoubtedly, these achievements were resulted largely from the catch-up changes from the excessive lower body weight and BMI 25 years ago.

The negative impact of this trend, a direct factor contributing to the epidemic of childhood overweight/obesity, should not be neglected. This trend is characterized by the following traits: a) the long-term persistence of increasing in children of all the school ages and covered all the BMI percentiles; b) a remarkable accelerating tendency since 2000; c) the increase occurred mainly at the upper BMI percentiles; d) more significant increments of high BMI occurred in the more advanced socioeconomic regions; e) the increasing trend was coexisted with the skew shift of BMI distribution. As of the fact that this trend progressively continues, the combination of the factors clearly predict more risk at obesity-related harmful health effects to Chinese children.

In comparison with the 85th and 95th percentiles of WHO-2006, the changes in the two urban groups between 1985 and 2010 are astonished (Table 4). In 1985, the 85th and 95th of the BMI-for-age curves of the males in the 'coastal' group were slightly lower than that of the WHO at early school ages, and lagged behind since the early puberty, resulting in a Sino-WHO gaps at 18-year-old increased 0.6 kg/m^2 for the P85 and 2.0 kg/m^2 for the P95, respectively. For females, an evident lower and level-off tendency increased with ages, resulting in Sino-WHO gaps at 18-year 2.4 kg/m^2 for the P85 and 3.7 kg/m^2 for the P95, respectively. In 2010, however, both the 85th and 95th percentiles in the age curves of this group significantly exceeded that of the WHO. Similarly, the BMI levels of the 'overall urban' group were quite low in 1985; many of its subpopulations were even excluded from the candidate reference team because of their very low BMI levels to be used for comparison. However, great changes occurred since then, and male's 85th and 95th percentiles in this group had already caught up that of the WHO-2006 in 2010. For the 13-year boys, e.g., the values are 1.9 kg/m^2 higher for 85th and 3.0 kg/m^2 higher for 95th than the corresponding percentiles of the WHO criterion. Moreover, because of the positive skew tendency, all the other subpopulations (including the backwoods developing rural areas) will have the large possibility of gradually joining the rank of epidemic of childhood overweight/obesity.

In order to better prevent and control obesity and its risk factors, one way is to focus on the high BMI to identify the overall health outcome rather than the metabolic syndrome along in overweight/obesity individuals. The American scholars divided the BMI scope of the US CDC-2000 criterion into four classes: ≤P85, >P85 ~ <P95 (overweight), >P95 ~ <P97 (obesity), and ≥P97 (obesity and excessive heavy); and combined with the assessment of individual's excess adiposity and the prediction of the obesity status in adulthood[32]. Thus, the BMI scope, the excessive adiposity and the adulthood obesity are combined into a risk-complex of obesity; the higher the BMI the higher possibility of disease risk the individual would have. The threshold of the disease risk they preferred specially emphasis on the clustering of more than two disease risk factors, which is more rigorous than the NCEP standard[33] and focus on the cardiovascular diseases: triglycerides, fasting insulin, low-density lipoprotein cholesterol (LDL), high-density lipoprotein cholesterol (HDL), systolic blood pressure (SBP), and diastolic blood pressure (DBP), based on the Bogalusa longitudinal study. Freedman et al. used this standard in analyzing the US national representative data and summarized that of children with a BMI≥P95 of the US CDC-2000 criterion, 65% had excess adiposity, 39% had at least two risk factors, and 65% had an adult BMI of >35 kg/m^2, whereas of those with a BMI≥P99, 94% had excess adiposity, 59% had at least two risk factors, and 88% had an adult BMI of >35 kg/m^2[34]. In order to further complete the risk-complex of obesity, there are some other tasks: a) to strengthen the assessment of the excess adiposity which can directly reflect the association between overweight/obesity and body fatness rather than body weight; b) to further study among the target groups with different SES background, in order to ensure not only the feasibility and sensitivity of the thresholds but make them coincidence with the hereditary traits of the Chinese population.

This study gives a complete picture on the co-supplement function of the two features of the secular trend of BMI, the greater increase in the upper percentiles and the shift of distribution to the right as shown above. Our analyses showed that the most important feature in the frequent change of the BMI distribution between 1985 and 2010 was the enlargements of the disparity of the mean-median differences. This feature strongly suggests that the median rather than the mean can accurately represent the average BMI level of a population[35]. Besides, the changes both in shape (shorter and wider curve in the axis) and in distance (8-9 BMI units) in the histogram (Figure 4) were not only resulted from the obvious increase of the proportion in the upper percentiles, but largely due to the enlargement of the individual variation among the children. On the other hand, the skew shift has not only been widely reported to predict the whole BMI distribution in a country/area over time, but also existed between different groups. Kalies et al., using the changes in the upper percentile values rather than the lower, proved that the overall distribution of BMI became more skewed in Bavaria, German in the period of 1982 till 1997, and showed that the distribution in their non-German group (Mediterranean emigrant children with high epidemic of obesity) was obviously characterized by the right shift with median values 0.3-0.5 kg/m^2 higher than that of the control group (German ethnic), whereas the prevalence of overweight/obesity in the former was 1.9-2.4 folds higher for boys and 1.5-1.9 folds higher for girls, respectively, than in the latter[36].

The asymmetry of the percentiles is an important characteristic of the BMI distribution[37]. Rose and Day, drawn from their survey on the cross-sectional data from 52 subgroup populations in the International Inter-salt Study, found that the distribution of many health-related indicators (i.e., blood pressure, alcohol intake, sodium intake, etc.) appeared to move up and down as a whole so that the population mean can predict the number of deviant individuals. However, if these indicators are based on the BMI distribution, the prediction can underestimate the prospect results caused by the asymmetry[38]. There are three special notes we should pay attention to. The first is to do preceding works to identify the magnitude of the asymmetry before analysis is conducted, and raise rectifying measures (i.e., to use the median plus the range of variation rather than to use the mean). It's also better to use the high BMI to replace the average of distribution of BMI, because in most of the time the marked increase related to the high BMI indicates that the observed differences over time were not caused by a shift in the mean but by the shift in the upper tail of the distribution. In Ogden et al.'s report on the U.S. national data in 2009-2010, the prevalence of childhood obesity was not changed since 2007 to 2008, but there was a significant increase in high BMI among the male adolescents aged 12 to 19. For this reason, they suggested to combine the surveillance data of the high BMI and the prevalence from the survey together, in order to obtain more accurate epidemic information[39]. Secondly, we should clearly remember that BMI gain appeared to be a characteristic feature of the entire population studied and does not seem to be a separate problem of the obese children[40]. The fact that those reports only focused on the change of prevalence but without analyzing the changes of the background was the main factor of underestimating the looming public health issues[41]. Therefore, the reasons for the increasing epidemic of overweight/obesity in an area or in a population should be sought not only by comparing obese and non-obese individuals but rather by seeking to understand which factors are causing the increases in the population as a whole. Thirdly, the interventions may also need to focus on the population rather than solely on the heaviest individuals. Moreover, the difference of the health-related indicators such as serum cholesterol, whatever within a given population or between populations, are reflected principally in genetic variability with some effects of behaviors modified by the determinants including not just the physical environment but also social, cultural and psychological factors affecting daily activity, leisure, time allocation, physical activities, as well as food patterns and availability. It's certain that the trends in BMI pattern described above suggest the combination of both profound environmental determinants and a population with a high degree of susceptibility[42].

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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