



# Changes in the age-specific body mass index distribution among urban children between 2002 and 2018 in Changsha, China

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**Background:** It had been reported that the increase in the prevalence of childhood overweight and obesity in several developed countries over the decade was largely a consequence of changes in the upper end of the body mass index (BMI) distribution. We speculated that the change in BMI distribution among Chinese children is different from that in developed countries. Therefore, we investigated the changes in the BMI distribution among urban children in Changsha, China.

**Methods:** A secondary data analysis of the 2002 and 2018 Annual Survey on Students' Constitution and Health from Yuhua District, Changsha City, China was performed. The BMI distribution of children aged 6–15 years (n=72,061) was examined by calculating the BMI value at 5th, 50th, 85th, and 95th percentiles. Differences in the BMI value at the 5th, 50th, 85th, and 95th percentiles between 2002 and 2018 according to age and sex were calculated.

**Results:** From 2002 to 2018, the standardized rate of underweight decreased from 6.9% to 3.4%, whereas that of obesity increased from 6.1% to 13.8%. The BMI of the population increased over the 16-year period. The greatest change between the years was seen in the 85th percentile, and moderate changes were seen in the 5th and 50th BMI percentiles. Also, the greatest changes in the BMI percentiles were evident at age 12–14 years.

**Conclusions:** The whole spectrum of BMI distribution among school-aged children shifted over the 16-year study period, although the increases were more marked in the upper than lower percentiles. Health professionals and health policymakers should develop strategies and interventions aimed at preventing adverse health effects caused by this change.

**Keywords:** Children; body mass index (BMI); distribution; obesity; overweight

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## Introduction

Together with socioeconomic development and transformation of lifestyle, the childhood obesity epidemic in different part of this world has changed over time (1-4). Although the childhood obesity rate has plateaued in some developed countries, it is increasing in rapidly developing countries, such as China (5,6). The prevalence of overweight and obesity among school-aged children in China has increased from 5.3% in 1995 to 20.5% in 2014 (7).

Understanding how the BMI distribution changes over time can allow identification of subpopulations susceptible to overweight and obesity, enabling the development of tailored interventions (8,9). Studies had investigated the changes in the shape and location of BMI distributions over the last decades in several developed countries, and found the most pronounced elevations in BMI have occurred in the upper part of the BMI spectrum (>75th percentiles), whereas little or no changes have occurred below the 50th percentile (10-14). These studies concluded that the increases in the mean BMI and prevalence of overweight and obesity in children have resulted mainly from the pronounced change in the upper end of the BMI spectrum, suggesting that the factors leading to BMI changes were changed in only a subgroup of the school-aged population (10-12).

However, we speculated that the pattern of change in the BMI distribution in China is different from that in developed countries, because the increased obesity prevalence in China is accompanied by reduced rates of stunting and thinness (7,15); therefore, the entire spectrum of BMI distribution may have shifted. The aim of this study was to investigate the changes in the BMI distribution of Chinese children overtime and identify the age at which the BMI distribution is most sensitive to change.

We chose the Yuhua District of Changsha City as the study site. Changsha is a second-tier city located in central south China. The lifestyle in Changsha has changed dramatically over the past two decades as a result of rapid socioeconomic development. Yuhua District is one of six districts of Changsha City, and it covers 292 square kilometers. The gross domestic product of Yuhua District increased from ¥2,425 million in 2002 to ¥188,816 million in 2018. We investigated the prevalence of underweight, overweight, and obesity among children aged 6–15 years in Yuhua District in 2002 and 2018. The distribution of BMI was examined as the BMI values at 5th, 50th, 85th, and 95th percentiles. And the changes of BMI percentiles over time were calculated according to age and sex.

We present the following article in accordance with the STROBE reporting checklist (available at <http://dx.doi.org/10.21037/tp-20-305>).

## Methods

### *Study setting and participants*

This study was a secondary data analysis of the 2002 and 2018 Annual Survey on Students' Constitution and Health from Yuhua District, Changsha City, China. The survey was sponsored by the Education Bureau of Changsha City. The participants were primary or middle school students. A random cluster sampling method was used to select schools from Yuhua District. All students at the selected schools underwent standard physical examinations. Children aged less than 6 years or more than 15 years from the dataset were excluded from the analysis. In China, school-aged children must complete nine years of compulsory education in primary (6 years) and middle (3 years) school, starting primary school at 6 to 7 years of age. Therefore, surveys in primary and middle schools take into account the majority (>98%) of children 6–15 years of age in the study region.

The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study protocol was reviewed and approved by the Medical Ethics Committee of the Hunan Children's Hospital (HCHLL-2019-41). The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Informed consent was waived because this was a retrospective study, and the authors had no access to information that could identify individual participants during and after data collection.

### *Measurements and variables*

Age (years), sex, height, and weight were collected from the Annual Survey on Students' Constitution and Health dataset. Height and weight were measured by a team of health professionals, following the Handbook of National Student Constitution and Health Survey. BMI was calculated as weight in kilograms divided by the square of height in meters. The weight status of children was defined according to BMI percentile based on growth charts for Chinese children and adolescents aged 0–18 years (16). The growth charts provide age and sex-specific BMI cutoff values for underweight (BMI <5th percentile), healthy

**Table 1** Sample size of the study population according to sex and survey year, Yuhua District, Changsha, China

Sex and age (years)	Survey year	
	2002	2018
All participants		
6–15	26,644	45,417
6–10	14,345	25,310
11–15	12,299	20,107
Males		
6–15	14,127	24,214
6–10	7,570	13,289
11–15	6,557	10,925
Females		
6–15	12,517	21,203
6–10	6,775	12,021
11–15	5,742	9,182

weight (BMI 5th–<85th percentile), overweight (BMI 85th–<95th percentile), and obese (BMI  $\geq$ 95th percentile) (16,17).

### Statistical analysis

Crude rates and 95% confidence intervals (CIs) for each weight status were calculated by sex and survey year. Standardized rates for each weight status were estimated using the sum of the 2002 and 2018 populations as the standard population and were adjusted by age and sex. All hypothesis tests were two tailed with the type 1 error rate fixed at 5%. Percentiles (5th, 50th, 85th, and 95th) were used to examine the distribution of BMI. The differences on the BMI value at 5th, 50th, 85th, and 95th percentiles between 2002 and 2018 were calculated according to age and sex, and the difference in percent were also calculated. Missing data were not imputed. Statistical analysis was conducted using SAS version 9.3 software (SAS Institute, Cary, NC, USA).

### Sensitivity analysis

Because yearly data from 2002 to 2018 were not available, we used data from two years (2002 and 2018). To assess the effect of the study year (selection bias) on the results, sensitivity analyses were conducted using data from the

2003 and 2017 Annual Survey on Students' Constitution and Health. As data for children aged 6 and 15 years were not available in the 2003 dataset, the sensitivity analyses were performed in children aged 7–14 years. The standardized rates of the weight status; the age and sex-specific prevalence of underweight, overweight and obesity; and the BMI at 5th, 50th, 85th, and 95th percentile by age and sex in 2003 and 2017 were calculated.

## Results

The sample sizes of the two surveys are shown in *Table 1*. In 2002 and 2018, 26,644 and 45,417 children 6–15 years of age, respectively, participated in the health survey. All participants had complete records for age, sex, height, and weight; therefore, no participants were excluded because of missing data.

The distributions of weight status according to sex and survey year are presented in *Table 2*. The standardized rate of underweight decreased from 6.9% in 2002 to 3.4% in 2018, and that of overweight increased from 7.3% in 2002 to 12.4% in 2018. The prevalence of obesity increased from 6.1% in 2002 to 13.8% in 2018.

*Figure 1* shows the prevalence of underweight, overweight, and obesity according to age, sex, and survey year. In 2002, the prevalence of underweight increased markedly after age 10 years in both sexes, peaked at age 13 years, and decreased thereafter. The prevalence of underweight in 2018 reached a plateau at aged 6–11 years, and then decreased to <3.5% in both sexes.

The prevalence of overweight and obesity (BMI  $\geq$ 85th) were generally lower in 2002 than in 2018 (*Figure 1*). The prevalence of overweight and obesity decreased from ages 6 to 15 years in 2002, but increased from ages 6 to 10 years and decreased with age thereafter in 2018. The obesity prevalence followed a similar pattern.

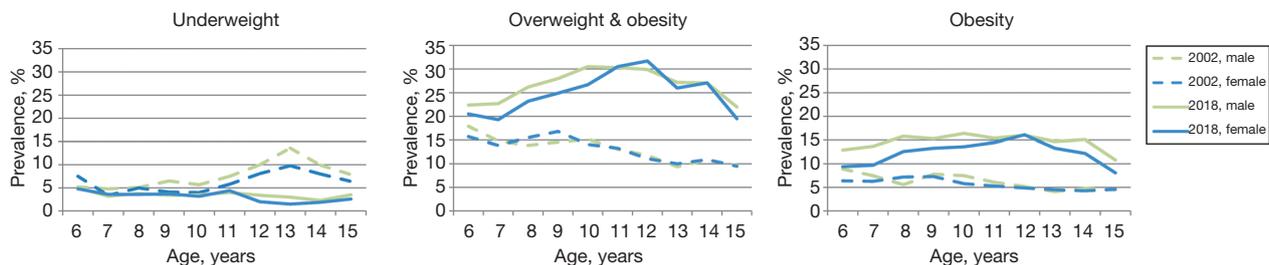
*Figure 2* shows the BMI values at 5th, 50th, 85th, and 95th percentile according to age, sex, and survey year. The BMI distributions were more skewed to the right in 2018 than in 2002. From 2002 to 2018, increases in the values of BMI at all percentiles were observed for both sexes. The differences between two survey years were greater at 85th and 95th than at the 5th and 50th percentiles. Marked differences in BMI value occurred at a younger age in the 50th percentile compared with the 5th percentile.

*Table 3* shows the differences in values, as well as differences in percent at the 5th, 50th, 85th, and 95th BMI percentile between 2002 and 2018 according to sex. The 5th

**Table 2** Distribution of weight status according to sex and survey year among children 6–15 years

Weight status and sex	Crude rates, % (95% CI)		Standardized rates <sup>a</sup> , % (95% CI)	
	2002	2018	2002	2018
<b>Underweight</b>				
Both sexes	6.8 (6.5, 7.1)	3.4 (3.2, 3.5)	6.9 (6.6, 7.2)	3.4 (3.2, 3.5)
Male	7.5 (7.0, 7.9)	3.5 (3.3, 3.7)	7.5 (7.1, 8.0)	3.5 (3.3, 3.7)
Female	6.0 (5.6, 6.4)	3.2 (3.0, 3.4)	6.1 (5.7, 6.5)	3.2 (3.0, 3.4)
<b>Healthy weight</b>				
Both sexes	79.9 (79.4, 80.4)	70.5 (70.1, 70.9)	79.8 (79.3, 80.2)	70.4 (70, 70.8)
Male	79.2 (78.6, 79.9)	69.6 (69.0, 70.1)	79.1 (78.4, 79.8)	69.5 (68.9, 70.1)
Female	80.6 (79.9, 81.3)	71.5 (70.9, 72.1)	80.5 (79.8, 81.2)	71.5 (70.9, 72.1)
<b>Overweight</b>				
Both sexes	7.3 (7.0, 7.6)	12.3 (12.0, 12.6)	7.3 (7, 7.6)	12.4 (12.1, 12.7)
Male	7.0 (6.6, 7.4)	12.0 (11.6, 12.4)	7 (6.6, 7.5)	12.1 (11.7, 12.5)
Female	7.6 (7.1, 8.0)	12.6 (12.2, 13.1)	7.6 (7.2, 8.1)	12.7 (12.2, 13.1)
<b>Obesity</b>				
Both sexes	6.1 (5.8, 6.3)	13.8 (13.5, 14.2)	6.1 (5.8, 6.4)	13.8 (13.5, 14.2)
Male	6.3 (5.9, 6.7)	14.9 (14.5, 15.4)	6.3 (5.9, 6.7)	14.9 (14.5, 15.4)
Female	5.8 (5.4, 6.2)	12.6 (12.2, 13.1)	5.8 (5.4, 6.2)	12.6 (12.2, 13.1)

<sup>a</sup>, rates were adjusted by age and sex, using the sum of both population as the standard population. CI, confidence interval.



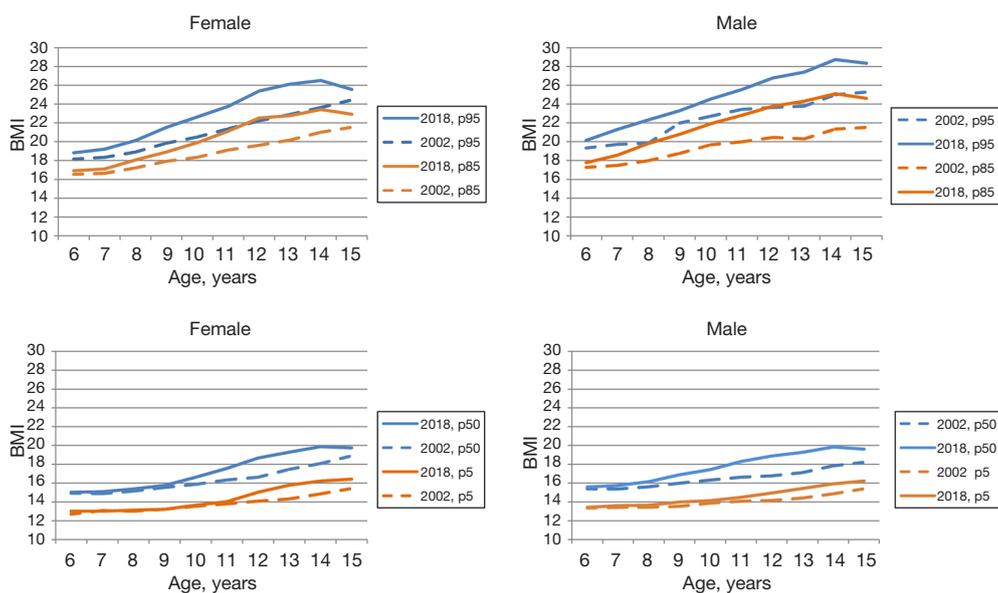
**Figure 1** Age and sex-specific prevalence of underweight, overweight, and obesity among children in 2002 and 2018, Yuhua District, Changsha, China.

BMI percentile was moderately elevated from 2002 to 2018 in most ages, with most growths less than 10%. In males, the BMI at 50th percentile increased by >10% after 11 years of age. For female, the growth of BMI at 50th percentile increased until the age of 12 years (+12.27%), and slowed down thereafter. The greatest change in BMI from 2002 to 2018 was in the 85th percentile, with differences in percent ranging from 2.8% to 19.7% among male, and from 2.2% to 14.8% among female. Substantial increases in BMI were

also observed at the 95th percentiles, with growth in percent ranging from 4.2% to 15.2% among male, and from 3.6% to 14.2% among female. Overall, the greatest change in the value of BMI percentiles occurred at age 12–14 years.

**Sensitivity analysis**

Sensitivity analyses were conducted using data from the 2003 and 2017 Annual Survey on Students’ Constitution



**Figure 2** Distribution of BMI at 5th, 50th, 85th, and 95th percentile according to age and sex among children in 2002 and 2018, Yuhua District, Changsha, China. p5, 5th percentile; p50, 50th percentile; p85, 85th percentile; p95, 95th percentile. BMI, body mass index.

and Health. The standardized rate of underweight decreased from 6.2% in 2003 to 3.8% in 2017, while the prevalence of overweight increased from 8.6% in 2003 to 11.7% in 2017, and the prevalence of obesity increased from 8.1% in 2003 to 13.1% in 2017 (Table S1). The distributions of the age and sex-specific prevalence of underweight, overweight and obesity in 2003 and 2017 are presented in Figure S1. The BMI at 5th, 50th, 85th, and 95th percentile according to age and sex in 2003 and 2017 are shown in Figure S2. The differences in the age and sex-specific prevalence of three weight statuses and in the BMI percentiles between 2003 and 2017 were similar to those differences between 2002 and 2018, but in a relatively more gradual and gentle manner.

## Discussion

The prevalence of underweight decreased from 6.8% in 2002 to 3.4% in 2018 among children 11–15 years of age, and that obesity increased from 6.1% to 13.8%. The BMI of the entire population increased over the 16-year study period in both sexes, and the greatest change was seen in the 85th percentile, with moderate changes seen in the 5th and 50th percentiles. As for the age specific changes of BMI distribution, the greatest changes occurred at the 12–14 years of age.

Our findings of increased prevalence of overweight and

obesity, as well as the decreased prevalence of underweight over the 16-year period are consistent with other studies in Chinese populations (15,18–21). Because of regional disparities in socioeconomic development in China, the epidemic of overweight and obesity started to emerge in all parts of China with different speed (20). Without immediate interventions, it could be foreseen that the increasing trends in the prevalence of overweight and obesity in China would be sustained in the years to come.

Comparing the age specific BMI distributions over time can pinpoint the ages at which BMI is sensitive to change, allowing identification of the susceptible age groups to launch interventions. In this study, the changes of BMI in percentiles increased with age in both sexes. Similar patterns had been observed in the 95th percentile among children in the United States, 1988–1994 through 2013–2014 (13). Whether this is because the BMI of older children are more sensitive to lifestyle changes or a result of a cumulative effect of lifestyle changes on weight status is unclear. However, our data suggest the need for interventions to prior to 12 years of age.

Studies in several developed countries showed that the increases in mean BMI and prevalence of obesity were caused by an increase of BMI among children who were in the upper BMI percentiles (10–14). For example, Kurokawa *et al.* analyzed the trends of BMI distribution in Japanese

**Table 3** Changes in BMI percentiles from 2002 to 2018 according to sex and age, Yuhua District, Changsha, China

Sex	Age	5th percentile		50th percentile		85th percentile		95th percentile	
		Difference <sup>a</sup>	%						
Male	6	0.07	0.52	0.19	1.23	0.49	2.84	0.82	4.24
	7	0.19	1.42	0.37	2.41	1.09	6.24	1.59	8.07
	8	0.21	1.56	0.54	3.46	1.83	10.18	2.48	12.50
	9	0.46	3.40	0.90	5.63	2.03	10.83	1.31	5.96
	10	0.25	1.80	1.11	6.80	2.24	11.39	1.82	8.01
	11	0.42	2.99	1.67	10.04	2.83	14.16	2.11	9.00
	12	0.80	5.65	2.11	12.58	3.33	16.28	3.14	13.28
	13	1.02	7.08	2.15	12.56	4.00	19.70	3.62	15.22
	14	1.06	7.13	2.00	11.21	3.76	17.62	3.73	14.92
	15	0.83	5.39	1.40	7.69	3.10	14.41	3.06	12.10
Female	6	0.31	2.44	0.10	0.67	0.37	2.24	0.66	3.64
	7	-0.07	-0.50	0.20	1.34	0.45	2.70	0.87	4.75
	8	0.11	0.85	0.23	1.52	0.85	4.94	1.22	6.46
	9	0	0	0.21	1.35	0.99	5.53	1.68	8.47
	10	0.11	0.81	0.76	4.79	1.56	8.51	2.14	10.44
	11	0.24	1.74	1.23	7.53	2.00	10.47	2.39	11.18
	12	0.95	6.75	2.04	12.27	2.90	14.78	3.17	14.27
	13	1.47	10.3	1.82	10.42	2.60	12.89	3.23	14.11
	14	1.37	9.23	1.80	9.96	2.42	11.52	2.88	12.19
	15	0.99	6.42	0.85	4.50	1.38	6.41	1.12	4.58

<sup>a</sup>, unit: kg/m<sup>2</sup>. BMI, body mass index.

children from 1989 to 2003, and found little or no change in the 10th and 25th percentiles. However, the increases in the 75th and 90th percentiles were more marked than that in the 50th percentile among primary school children (11). The authors speculated that a subgroup of the population (in the upper percentiles of BMI) is more susceptible to factors that increase the risk of overweight and obesity (11). However, we found a shift in the BMI distribution in the entire population, although the increases in the upper percentiles were more marked than those in the lower percentiles. Unlike in developed countries, the BMI shift in this study indicated that the factors that contributing to the increased BMI influenced the entire population. This finding emphasizes the need for studies on the short- and long-term effect of increasing BMI on population health.

The rapid socioeconomic development in China over the

past two decades has led to a dramatic change in lifestyle, resulting in an obesity epidemic (22,23). This change is now affecting the health of the younger generation (7,22). The increase in BMI among children of all ages and in all BMI percentiles was unsurprising and indicates the need for actions to prevent adverse consequences. The health consequence of the shift in BMI distribution should be investigated, and interventions are needed to slow the increasing obesity prevalence and prevent related adverse health effects.

This study had several limitations. First, BMI was used to evaluate overweight and obesity. Although BMI is an imperfect measure of body fat and adiposity (24,25), it is the most feasible and widely used measurement in public health surveillance (1,7,17,26,27). The weight status of children and teenagers is defined according to BMI percentiles for

age and sex. As shown in this study, the BMI distribution is changing, meaning that BMI percentile values are not fixed. To make the distribution of weight status comparable between 2002 and 2018, fixed cutoff points to define weight status are needed (26). Therefore, we used the cutoffs from the growth charts delivered in 2009 (16), which are still in use in China in 2020. Second, as a retrospective study, we analyzed available data only and thus could not evaluate factors associated with the BMI change. Also, as a cross-sectional study, we could not analyze the BMI trajectory. Predicting age-specific trends in BMI shifting and developing targeted interventions will require identification of the associated factors and their effect sizes. Therefore, a further longitudinal study is needed. Third, this study used cross-sectional data from 2002 and 2018, and not the yearly data in between; therefore, we could not investigate the pattern and changing trend in BMI over the 16-year period. To predict future changes in BMI and evaluate the effectiveness of interventions, annual changes in BMI distribution need to be monitored. Fourth, this study was conducted in a single district in China, limiting the generalization of the findings. Further studies are needed to investigate whether other regions in China and other developing countries are undergoing similar transitions in BMI distribution, and what kind of interventions are needed to prevent adverse health consequences.

## Conclusions

The whole spectrum of BMI distribution among school-aged children in Yuhua District was shifted over the 16-year study period in both sexes. The increases in BMI were moderate at the 5th and 50th percentiles, and was greatest at 85th percentile. Further studies should investigate the short- and long-term effects of increasing BMI on population health, and interventions to prevent the adverse health effects of increased BMI are needed.

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## Footnote

*Reporting Checklist:* The authors have completed the STROBE reporting checklist. Available at <http://dx.doi.org/10.21037/tp-20-305>

*Data Sharing Statement:* Available at <http://dx.doi.org/10.21037/tp-20-305>

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*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study protocol was reviewed and approved by the Medical Ethics Committee of the Hunan Children's Hospital (HCHLL-2019-41). The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The requirement for written informed consent was waived by the Medical Ethics Committee of the Hunan Children's Hospital.

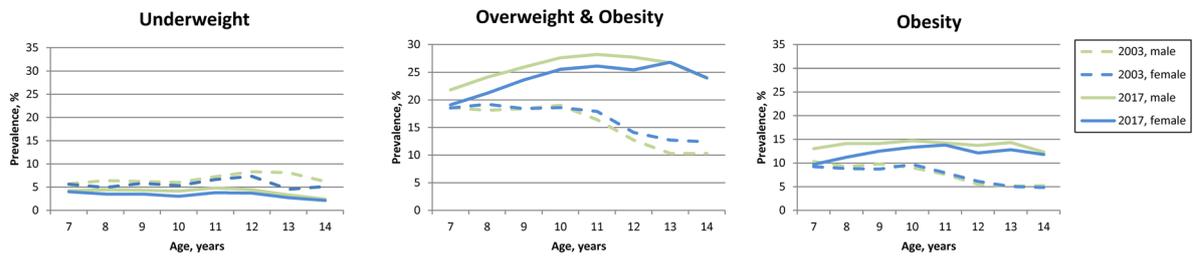
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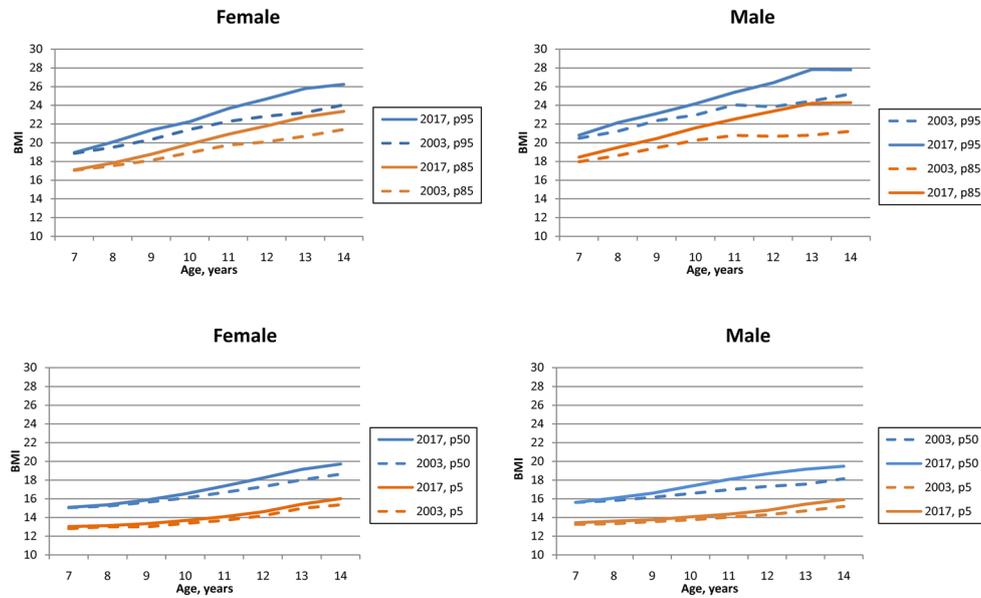
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**Figure S1** Age and sex-specific prevalence of underweight, overweight, and obesity among children in 2003 and 2017, Yuhua District, Changsha, China.



**Figure S2** Distribution of BMI at 5th, 50th, 85th, and 95th percentile by age and sex among children from Yuhua District, Changsha, China in 2003 and 2017. p5, 5th percentile; p50, 50th percentile; p85, 85th percentile; p95, 95th percentile. BMI, body mass index.

**Table S1** Standardized rates of underweight, healthy weight, overweight, and obesity in 2003 and 2017 among children 7–14 years, Yuhua District, Changsha, China

Weight status and sex	Standardized rates <sup>a</sup> , % (95% CI)	
	2003	2017
<b>Underweight</b>		
Both sexes	6.2 (6.0, 6.4)	3.8 (3.7, 3.9)
Male	6.6 (6.4, 6.9)	4.1 (3.9, 4.3)
Female	5.6 (5.4, 5.9)	3.4 (3.2, 3.6)
<b>Healthy weight</b>		
Both sexes	77.1 (76.7, 77.4)	71.5 (71.1, 71.8)
Male	77.0 (76.5, 77.5)	70.2 (69.7, 70.6)
Female	77.2 (76.7, 77.7)	73.0 (72.5, 73.4)
<b>Overweight</b>		
Both sexes	8.6 (8.4, 8.9)	11.7 (11.5, 11.9)
Male	8.2 (7.9, 8.5)	11.8 (11.5, 12.1)
Female	9.2 (8.8, 9.5)	11.6 (11.2, 11.9)
<b>Obesity</b>		
Both sexes	8.1 (7.9, 8.3)	13.1 (12.8, 13.3)
Male	8.2 (7.9, 8.5)	13.9 (13.6, 14.2)
Female	8.0 (7.7, 8.3)	12.1 (11.7, 12.4)

<sup>a</sup>, rates were adjusted by age and sex, using the sum of both population as the standard population. CI, confidence interval.