**Original Article**

# The Association of Overweight and Obesity with Blood Pressure among Chinese Children and Adolescents*

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**Abstract**

**Objective** To examine the association between obesity and high blood pressure (BP) in Chinese children and adolescents.

**Methods** Body mass index (BMI) and blood pressure measurements of 197 191 children aged 7-17 years were obtained from a Chinese national survey in 2010. Obesity and high BP were defined according to the reference values for Chinese children. Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) of different BMI categories for high BP, as well as the population attributable risk percent (PAR%), were also calculated.

**Results** The prevalence of high BP was 16.1% for boys and 12.9% for girls in 2010. Overweight and obese children had a significantly higher prevalence of high BP than non-overweight children in both boys and girls in each age group. ORs (95% CI) for high BP were 4.1 (3.9, 4.4) in obese boys and 4.0 (3.7, 4.3) in obese girls. The overall PAR% for high BP due to overweight and obesity was 14.4%.

**Conclusion** Overweight and obese children have a significantly higher risk of high BP than non-overweight children. Eliminating overweight and obesity could reduce 14.4% of high BP cases.

**Key words:** Children; Adolescents; High blood pressure; Obesity

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## INTRODUCTION

High blood pressure (BP) is a long-term public health problem worldwide, and a major risk factor for cardiovascular disease, which substantially contributes to premature mortality and accounts for 7 million deaths each year[1-2].

Pathophysiological and epidemiological findings indicate that the presence of essential high BP at a young age is a strong predictor of essential hypertension later in life[2-3]. A recent study that analyzed data from the US National Health and Nutrition Examination Survey (NHANES) from 1988-1994 and 1999-2000 estimated that 50% of children aged 10 years with a blood pressure (BP) level greater than the 95th percentile developed hypertension at 20 years old[4]. Several studies have shown that the prevalence of high BP in children and adolescents has increased over time. Din-Dzietham et al. reported that the increase in BP among children and adolescents was largely due to the

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increase in obesity based on data from the NHANES 1988 and 1999[5]. Because of the close association between BP, overweight, and obesity, some researchers forecast that the rapid increase in obesity may contribute to an increase in the prevalence of high BP in children and adolescents[6-10].

China is experiencing a huge increase in obesity[11-12]. The prevalence of obesity increased from 0.13% and 0.12% in 1985, to 1.4% and 0.9% in 1995, and to 5.1% and 2.7% in 2005, for males and females among Chinese children and adolescents aged 7-18 years[12]. Obesity is considered a major risk factor for the development of high BP in Chinese children[10,13-14]. However, a recent report of the Bogalusa Heart Study indicated that the level of BP did not increase despite an increase in obesity[15]. Therefore, it is important to assess the effect of obesity on BP, and to clarify to what extent the current prevalence of high BP can be accounted for by the presence of overweight and obesity among Chinese children and adolescents.

In the current study, we assessed the association between obesity and overweight with high BP using recent 2010 data from the Chinese National Survey on Students' Constitution and Health (CNSSCH) of a large nationally representative sample. We also quantified the potential effect of theoretically eliminating overweight and obesity on high BP among Chinese children and adolescents.

## SUBJECTS AND METHODS

### *Participants*

The CNSSCH is a nationally representative cross-sectional survey of students in China conducted approximately every 5 years. The 2010 CNSSCH included 197 430 Han nationality participants aged 7-17 years, who were selected by stratified multistage sampling among 30 provinces, using the same procedures as the 2005 CNSSCH, which has been described in detail in previous publications[11-12]. In this survey, primary and secondary Han nationality students aged 7-17 years were selected from 30 of 31 mainland provinces. Tibet was surveyed but not included in the present study because only Tibetans were selected in Tibet, where the Han nationality was the minority[11]. According to the residential location, we recruited the same number of subjects from urban and rural areas in each province. All subjects had a thorough medical examination before measurements were taken, and those with overt disease or physical/mental deformities were excluded.

The study was conducted according to the declaration of Helsinki and approved by the Ministry of Education, General Administration of Sport, The Ministry of Health, State Ethnic Affairs Commission, The Ministry of Science and Technology, and The Ministry of Finance. Consent for the study was obtained by the parents and the students.

We excluded 239 participants because of missing data or extreme height, weight, and BP values (>6 standard deviations from the mean[10]). A total of 197 191 participants (98 606 boys and 98 585 girls) were included in our analyses.

### *Anthropometric Measurements*

Height and weight were measured according to standardized procedures in all survey sites. Students were asked to have light clothes, be barefoot, and stand straight. Before measurements, students were told to defecate and avoid drinking, but no fasting was required. Height was measured using a wall-mounted stadiometer to the nearest 0.1 cm and weight was measured with a standardized scale to the nearest 0.1 kg. Height and weight were measured twice and the mean value was recorded. A third measurement was taken if the difference between two measures was higher than the allowed value (0.5 cm for height and 0.1 kg for weight), and then the mean value of the two closest measures was recorded. Additionally, the stadiometer and scale were calibrated before use, and all measurements were conducted by a team of field technicians. All technicians were required to pass a training course for anthropometric measurements.

### *BP Measurements*

According to the recommendation of the National High Blood Pressure Education Program Working Group (NHBPEP) in Children and Adolescents[16], BP readings by an auscultation method with a standardized clinical sphygmomanometer were recorded in this survey. A stethoscope was placed over the brachial artery pulse, proximal and medial to the cubital fossa, and below the bottom edge of the cuff. Appropriate cuff bladders with different sizes were used to cover at least 40% of the arm circumference at a point midway between the olecranon and the acromion. BP measurements were taken 5 min after resting. Systolic BP (SBP) was defined as the onset of "tapping" Korotkoff sounds (K1) and diastolic BP

(DBP) as the fifth Korotkoff sound (K5). A mean of three BP measurements at a single visit was used for each child. BP was measured three times and the mean value was recorded.

***Definition of BMI Categories***

Body mass index (BMI) was calculated as weight (kg)/height$^2$ (m$^2$). Participants were defined as overweight and obese if the observed BMI values were higher than the corresponding cut-offs for Chinese children in the "BMI Classification Reference for Screening Overweight and Obesity in Chinese School-age Children and Adolescents" published by the Working Group on Obesity in China (WGOC)[17]. The cut-off values of this reference were sex- and age-specific, as described previously[11-12]. Children and adolescents with a BMI below the cut-off point for overweight were defined as non-overweight.

***Evaluation of High BP***

High BP was defined as SBP, DBP, or both exceeding the 95th percentiles of the "Recommended Blood Pressure Cut-offs for Chinese Children". The cut-off values vary by sex and age[18].

***Statistical Analyses***

All data analyses were performed by SPSS statistics 13.0 (SPSS Inc., Chicago, IL, USA). Participants were divided into four age groups, including 7-9, 10-12, 13-15, and 16-17 years. Descriptive statistics for height, weight, BMI, SBP, and DBP were calculated by sex and age group, and displayed as the mean and standard deviation (SD). The prevalence of high BP, overweight, and obesity was calculated for each age and sex group, and the differences between age groups were compared using general linear models. To estimate the relationship between high BP and BMI, we calculated the prevalence of high BP, and the level of SBP and DBP for sex, age and BMI groups. Logistic regression was conducted to calculate the odds ratios (ORs) and their 95% confidence intervals (CIs) of different BMI categories for high BP after adjusting for province, urban or rural, age, and height. To quantify the proportion of high BP that could theoretically be prevented if all overweight and obese cases were eliminated from the study population, we calculated the population attributable risk percent (PAR%) and the 95% CIs based on asymptotic approximations, as described by Greenland and Drescher[19].

## RESULTS

***Characteristics of Subjects***

In 197 191 children and adolescents, including 98 606 boys and 98 585 girls, weight, height, BMI, SBP, and DBP increased along with increasing age groups in both sexes (Table 1). Mean SBP and DBP increased by 16.1 mmHg and 8.9 mmHg in boys, and 9.4 mmHg and 6.5 mmHg in girls from 7-9 years to 16-17 years, respectively.

***Prevalence of High BP, Overweight, and Obesity***

The prevalence of high BP was 16.1% for boys and 12.9% for girls. The prevalence of high BP was elevated with increasing age in both sexes ($P$<0.001). The prevalence of overweight was 12.1% for boys and 7.4% for girls, and the prevalence of obesity was 6.9% for boys and 3.5% for girls, which decreased with increasing age ($P$<0.001).

***Prevalence of High BP among Different BMI Categories***

Overweight and obese children and adolescents showed a significantly higher prevalence of high BP in boys and girls in each age group (Table 2, $P$<0.001) than non-overweight children and adolescents. After adjusting for province, urban or rural, age, and height, overweight and obesity remained significantly associated with BP in boys and girls of all age groups ($P$<0.001). The adjusted ORs for high BP were 2.2 (95% CI: 2.0, 2.3) and 2.0 (95% CI: 1.9, 2.2) for overweight boys and girls, respectively. The adjusted ORs were 4.1 (95% CI: 3.9, 4.4) and 4.0 (95% CI: 3.7, 4.3) for obese boys and girls, respectively, compared with corresponding non-overweight children.

***Relationship between BP and BMI Percentiles***

The prevalence of high BP increased in parallel with BMI percentiles in all age groups of boys and girls ($P$<0.001), especially when BMI was higher than the 75th percentile (Figure 1). Additionally, SBP and DBP increased along with increasing BMI percentiles, especially when the BMI percentile was higher than the 75th percentile (Figure 2).

***Effect of Overweight and Obesity on High BP***

As shown in Table 3, the PAR% of overweight and obesity on high BP was higher in boys than these in girls, which was 14.4% (95% CI: 13.9, 15.0) in total. Boys had a higher PAR% than girls in all four age groups,

**Table 1.** Weight, Height, BMI, and Blood Pressure in Chinese Children and Adolescents, 2010

| Characteristic | Boys (Age, Year) | | | | Girls (Age, Year) | | | |
|---|---|---|---|---|---|---|---|---|
| | 7-9 | 10-12 | 13-15 | 16-17 | 7-9 | 10-12 | 13-15 | 16-17 |
| Number | 26 878 | 26 910 | 26 879 | 17 939 | 26 881 | 26 928 | 26 879 | 17 897 |
| Weight, kg | 28.6 (6.9) | 39.7 (10.8) | 53.5 (12.0) | 60.1 (10.6) | 26.7 (5.9) | 38.1 (9.1) | 48.3 (8.3) | 51.4 (7.3) |
| Height, cm | 130.7 (7.5) | 146.5 (9.2) | 164.6 (8.7) | 171.0 (6.4) | 129.5 (7.7) | 146.9 (8.7) | 157.4 (6.0) | 159.1 (5.7) |
| BMI, kg/m$^2$ | 16.6 (2.7) | 18.2 (3.4) | 19.6 (3.4) | 20.5 (3.1) | 15.8 (2.3) | 17.5 (2.8) | 19.4 (2.8) | 20.3 (2.5) |
| SBP, mmHg | 97.6 (11.2) | 103.1 (11.3) | 109.7 (11.6) | 113.7 (11.3) | 96.2 (11.0) | 101.9 (10.9) | 104.7 (10.5) | 105.6 (10.6) |
| DBP, mmHg | 60.8 (9.9) | 64.2 (9.4) | 67.0 (9.5) | 69.7 (9.2) | 60.2 (9.6) | 64.2 (9.2) | 65.8 (8.8) | 66.7 (8.5) |

***Note.*** Mean (Standard Deviation); BMI, Body Mass Index; DBP, Diastolic Blood Pressure; SBP, Systolic Blood Pressure.

**Table 2.** Prevalence and Adjusted ORs of High BP in Different BMI Categories among Chinese Children and Adolescents

| Gender | Characteristic | Age, Years | | | | | | | | | | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 7-9 | | | 10-12 | | | 13-15 | | | 16-17 | | | | | |
| | | Non-OW | OW | OB | Non-OW | OW | OB | Non-OW | OW | OB | Non-OW | OW | OB | Non-OW | OW | OB |
| Boys | Number | 21 129 | 3099 | 2650 | 20 749 | 3971 | 2190 | 22 484 | 3081 | 1314 | 15 505 | 1808 | 626 | 79 867 | 11 959 | 6780 |
| | High BP, *n* (%) | 1626 (7.7) | 477 (15.4) | 610 (23.0) | 2029 (9.8) | 805 (20.3) | 776 (35.4) | 3491 (15.5) | 890 (28.9) | 604 (46.0) | 3577 (23.1) | 669 (37.0) | 348 (55.6) | 10 723 (13.4) | 2841 (23.8) | 2338 (34.5) |
| | OR (95% CI)[a] | 1.0[b] | 2.0 (1.8, 2.3) | 3.2** (2.8, 3.6) | 1.0[b] | 2.3 (2.1, 2.5) | 4.5** (4.1, 5.1) | 1.0[b] | 2.2 (2.0, 2.4) | 4.5** (4.0, 5.1) | 1.0[b] | 2.0 (1.8, 2.3) | 4.2** (3.6, 5.0) | 1.0[b] | 2.2** (2.1, 2.3) | 4.1 (3.9, 4.4) |
| Girls | Number | 23 266 | 2108 | 1507 | 24 014 | 1833 | 1081 | 24 214 | 2006 | 659 | 16 360 | 1305 | 232 | 87 854 | 7252 | 3479 |
| | High BP, *n* (%) | 1906 (8.2) | 336 (15.9) | 370 (24.6) | 2611 (10.9) | 381 (20.8) | 379 (35.1) | 3108 (12.8) | 461 (23.0) | 260 (39.5) | 2486 (15.2) | 321 (24.6) | 107 (46.1) | 10 111 (11.5) | 1499 (20.7) | 1116 (32.1) |
| | OR (95% CI)[a] | 1.0[b] | 2.0 (1.7, 2.2) | 3.0** (2.6, 3.4) | 1.0[b] | 2.1 (1.8, 2.4) | 4.0** (3.5, 4.6) | 1.0[b] | 2.1 (1.8, 2.3) | 4.6** (3.8, 5.4) | 1.0[b] | 1.8 (1.6, 2.1) | 5.1** (3.9, 6.7) | 1.0[b] | 2.0** (1.9, 2.2) | 4.0 (3.7, 4.3) |

***Note.*** BMI, Body Mass Index; BP, Blood Pressure; OR, Odds Ratio; Non-OW, Non-overweight; OW, overweight; OB, Obesity. [a]OR for all groups were adjusted for province, urban or rural, age and height. [b]Reference of calculating adjusted ORs. **$P$ value <0.001.

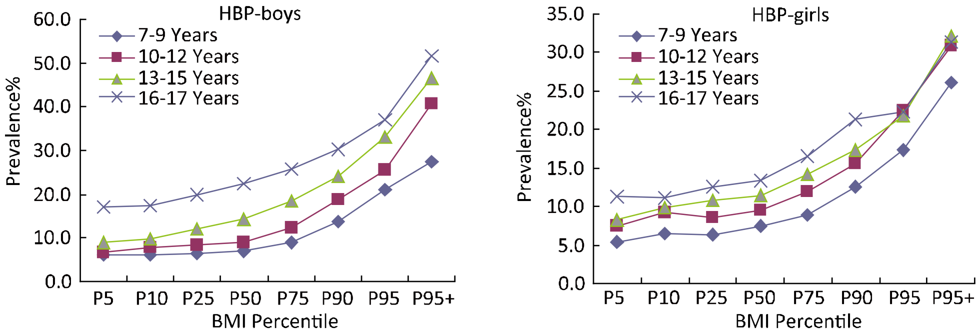


**Figure 1.** Change in Prevalence of High BP according to BMI Percentile by Age Group. BMI, body mass index; BP, blood pressure.

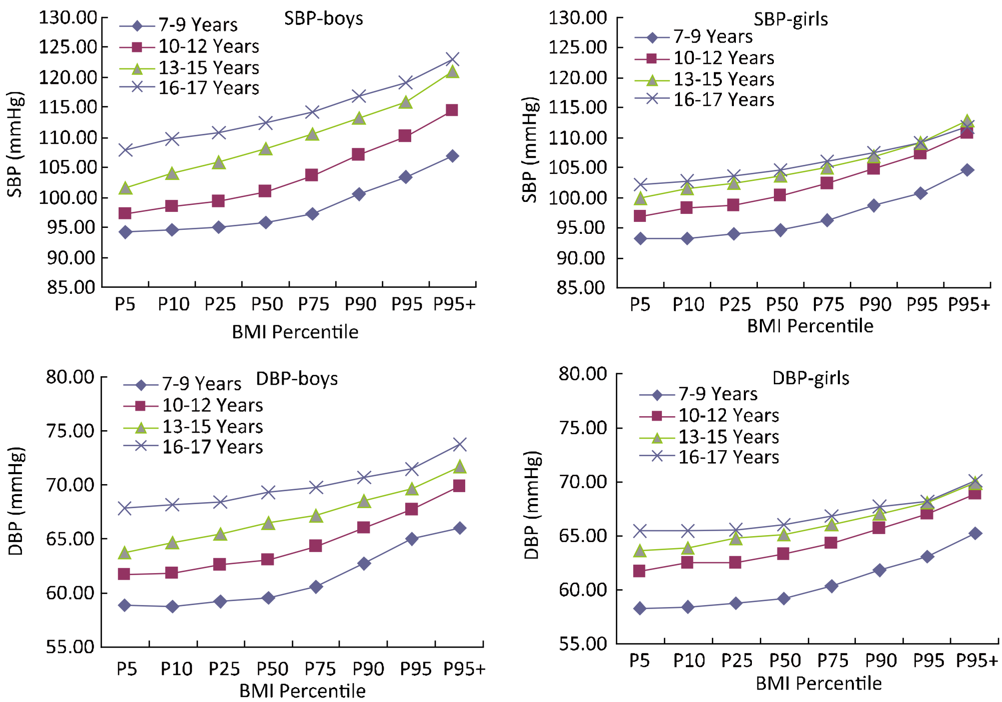


**Figure 2.** Change in Mean SBP and DBP according to BMI Percentile by Age Group. BMI, body mass index; DBP, diastolic blood pressure; SBP, systolic blood pressure.

**Table 3.** Population Attributable Risk (PAR) and 95% Confidence Interval (95% CI) of Overweight and Obesity in High BP

| Gender | BMI Categories | Age (year) | | | | Total |
|---|---|---|---|---|---|---|
| | | 7-9 | 10-12 | 13-15 | 16-17 | |
| Boys | Overweight | 8.8 (7.3, 10.3) | 11.5 (10.1, 13.0) | 8.3 (7.2, 9.3) | 5.5 (4.6, 6.4) | 7.8 (7.2, 8.4) |
| | Obesity | 15.0 (13.4, 16.5) | 15.6 (14.3, 16.8) | 8.0 (7.3, 8.7) | 4.4 (3.9, 5.0) | 9.0 (8.5, 9.5) |
| | Both[a] | 23.8 (21.6, 25.9) | 27.1 (25.2, 29.0) | 16.3 (15.0, 17.6) | 9.9 (8.8, 11.0) | 16.8 (16.0, 17.5) |
| Girls | Overweight | 6.3 (5.0, 7.5) | 5.3 (4.4, 6.4) | 5.3 (4.3, 6.3) | 4.2 (3.1, 5.3) | 5.2 (4.7, 5.8) |
| | Obesity | 9.4 (8.2, 10.7) | 7.8 (6.8, 8.7) | 4.6 (3.9, 5.2) | 2.5 (2.0, 3.0) | 5.6 (5.2, 6.1) |
| | Both[a] | 15.7 (13.9, 17.5) | 13.2 (11.8, 14.5) | 9.9 (8.7, 11.1) | 6.7 (5.5, 7.9) | 10.8 (10.2, 11.5) |

***Note.*** PAR% (95% CI) for overweight and obesity to high BP in boys and girls; [a]Both of overweight and obesity.

and higher proportions of PAR% were found at 7-12 years compared with 13-17 years in boys and girls, with the highest proportion of 27.1% (95% CI: 25.2, 29.0%) in boys aged 10-12 years.

## DISCUSSION

We examined the national prevalence of high BP using the recent largest sample of Chinese children and adolescents aged 7-17 years. Overweight and obese were significantly associated with an increased risk of high BP after adjusting for geographical region, age, and height in both sexes. We also found that the PAR estimate of overweight and obesity in high BP was 14.4% in total, indicating that theoretically eliminating overweight and obesity could reduce 14.4% of high BP cases among Chinese children and adolescents.

The prevalence of high BP obtained in our study was similar to the results of the China Health and Nutrition Survey (CHNSs) in 2004[18], but was lower than that of a study in Shangdong City[20], which used the same reference as the present study. This difference may be explained by the small sample size in the CHNSs (1111 children aged 6-17 years), and different obesity rates (our study: 6.9% for boys and 3.5% for girls; Shangdong City: 10.6% for boys and 5.7% for girls[13]). A study of Japanese children aged 9-10 years and 12-13 years showed higher mean SBP values and lower mean DBP values in Japanese children than in Chinese children[21]. Another study conducted in Tunisia, a developing country in the southern and eastern Mediterranean, showed a mean SBP in adolescents aged 15-17 years that was higher than that in our study. Mean DBP was similar, while the prevalence of hypertension (≥95th percentile recommended by the National High Blood Pressure Education Program [NHBPEP] Working Group [2004] and JNC-7[16,22]) was 4.3% in boys and 5.1% in girls[23]. Additionally, the NHANES 1999-2000 reported a higher mean SBP for age and sex and a similar mean DBP to the present study[24].

Some studies have reported a positive association between BP and obesity or BMI in children and adolescents[2,6-9,25-26], but few data are available from large-scale studies of Chinese students[10]. Cao et al. reported that BP levels increased in parallel with BMI in Chinese children and adolescents in Changsha city[14]. We found that BP and the prevalence of high BP increased with increasing BMI percentiles in all age groups. A recent study analyzing data from eight studies involving 47 196 children indicated that, after adjustment for age, sex, and race, the ORs of obese children (BMI ≥90th percentile) for hypertension (BP ≥95th percentile for height and weight) were 2.4 to 3.7 for SBP and 1.7 to 2.9 for DBP[8]. Another study of 2385 Japanese students aged 9-13 years reported increased ORs for high BP in children with a BMI ≥95th percentile (~6.3 for boys and 7.8 to 13.3 for girls)[21]. Similar phenomena have been reported in Mexican adolescents aged 12-15 years, where a higher risk for hypertension (using the criteria of NHBPEP [2004]) among the overweight (odds ratio=3.6) and obese (odds ratio=14.2) (using the reference cut-offs for BMI from the CDC growth charts) was found[7]. Our findings are consistent with those findings of previous studies, which indicated blood pressure, as well as prevalence of high BP, increased with increasing BMI.

We reported the PAR for contemporary Chinese children and adolescents, and showed that the intervention of obesity prevention would be more efficient for boys and younger children than for girls and older children. From a public health perspective, 14.4% of high BP could be potentially reduced if overweight and obesity were eliminated from the study population, with the highest proportion of PAR less than 30% in sex and age groups. Our findings suggest that preventing overweight and obesity in Chinese children and adolescents is not as efficient as we originally thought for controlling high BP. Because the majority of high BP children are neither overweight nor obese, other factors, including dietary factors (excessive sodium and dietary fat intake, and lower potassium intake), family history of hypertension, socioeconomic status, and birth weight should be further studied to evaluate the effect of each risk factor on the prevalence of high BP among Chinese children and adolescents[27-32].

There are several strengths of the present study. The data were derived from a nationally representative survey with a large sample size (197 191). We were able to analyze the association between BP and BMI in various sex- and age-specific subgroups. Furthermore, we quantified the effect of obesity and overweight on the prevalence of high BP, which helped determine the effect of weight control on prevention of high BP. One limitation of this study is that BP was measured at a single visit. Previous studies have suggested that every population should use their own standards to define BP levels in children[33]. High BP was defined by Chinese criteria in the present study. Therefore, results of this study might not be comparable with other findings. Another limitation is that the non-overweight group was not classified into normal weight and wasting because the cut-off values of wasting are still being developed in China. Further studies should be conducted for four BMI categories when wasting can be defined. Additionally, the present study was based on a cross-sectional survey. A future longitudinal survey will better clarify the relationship between BP and obesity.

In conclusion, overweight and obese children have a significantly higher risk of high BP. Eliminating overweight and obesity could potentially reduce 14.4% of high BP cases, which suggests that other factors, besides obesity, could also play an important role for high BP from a public health perspective. Further research is required to quantify the effect of reducing other risk factors of high BP among Chinese children and adolescents.

## COMPETING INTERESTS

The authors declare that they have no competing interests.

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