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Epidemiology of obesity and influential factors in China: a multicenter cross-sectional study of children and adolescents

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Abstract

Objective To determine the prevalence of and risk factors for overweight and obese among Chinese children and adolescents.

Methods This analytical cross-sectional study included 16,640 children and adolescents aged 6–18 years across four provinces of China in 2016. Physical characteristics and responses to questionnaires were analyzed. Body Mass Index (BMI) and the prevalence of overweight and obesity were calculated.

Results Among children and adolescents, the overall prevalence of overweight and obesity in 2016 in four regions of China was 27.2% and 29.6%, respectively. Among different stages and sexes, the highest prevalence of obesity (15.8%) was observed in adolescent boys. From childhood to adolescence, the obesity rate among boys increased by 0.7% (from 15.1% to 15.8%), while the obesity rate among girls decreased by 0.9% (from 10.8% to 9.9%). Children and adolescents who were overweight or obese had significantly higher systolic blood pressures, larger waist circumferences and larger hip sizes than those with a normal BMI. Logistic regression analyses identified thirteen factors associated with overweight or obesity in children and adolescents.

Conclusions Our results indicate that the prevalence of overweight and obesity is high among children and adolescents, especially among male adolescents in four regions of China. A suitable intervention program should not only help parents understand the serious risk of childhood obesity but also, more importantly, help to encourage a healthy lifestyle among children and adolescents.

Keywords Epidemiology, Obesity, Child, Adolescent

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Introduction

Obesity can affect all aspects of children and adolescents, including but not limited to their psychological health, cardiovascular health, and overall physical health [1, 2]. Complications of obesity include high cholesterol, hyperlipidemia, insulin resistance, increased mechanical stress on joints, obstructive sleep apnea, and many other health and social problems [3–8]. Obesity during childhood can also predispose individuals to many other chronic diseases in the long term, such as earlier onset of type 2 diabetes, hypertension, and cardiovascular diseases [9, 10].

Childhood obesity has become a global public health crisis [11], with the most rapid increased observed in low- and middle-income countries [12]. Given the global emergency posed by excess weight in children, member states of the World Health Organization (WHO) endorsed a goal of "no increase in childhood overweight by 2025" [13]. According to the report from WHO [14] in 2022, more than 390 million kids and teenagers between the ages of 5 and 19 were overweight. From only 8% in 1990 to 20% in 2022, the prevalence of overweight (including obesity) among children and adolescents aged 5–19 has increased significantly. Additionally, the data report from CDC of 2017–2018 NHANES [15] reported that approximately 1 in 6 children and adolescents aged 2 to 19 (16.1%) are overweight, and almost 1 in 5 children and adolescents aged 2 to 19 (19.3%) are obese in the US. Data from the China Health and Nutrition Survey (CHNS) in 2015 showed that the prevalence of overweight/obesity was 26.95% in children and adolescents aged 6–17 years old [16]. Similarly, Zheng et al [17] analyzed data from five major cities (Beijing, Shanghai, Nanjing, Xi'an, and Chengdu) across China in 2015 and 2016, and they found that the prevalence of overweight/obesity in children and adolescents was 29.8%, with 12.7% being obese. According to the 2021 Children's Blue Book and China Children's Development Report [18], the prevalence of overweight and obesity among Chinese children aged 6 to 18 years was 15.5% in 2010, 24.2% in 2019, and increased to 29.4% in 2022.

Due to its public health significance, the increasing trend in childhood overweight and obesity needs to be closely monitored to facilitate the identification of its epidemiological patterns and correlated factors. Estimation of the prevalence and secular trends in pediatric obesity in China is hampered by the paucity of data sets that mirror the demographic, physical measurements, diet patterns, dietary energy intake, cultural and socioeconomic composition of the Chinese population. A complete picture of all risk factors associated with obesity remains elusive. It is unclear whether there may be sub-groups of obese children who, at certain ages, are either particularly susceptible to demographic, diet, socioeconomic, environmental factors or are selectively exposed to such factors [19].

The lack of data that accurately reflect the demographic characteristics, physical measurements, eating patterns, dietary energy intake, cultural characteristics, and socioeconomic characteristics of the Chinese population makes it difficult to estimate the prevalence and long-term trends of pediatric obesity in China. The available cross-sectional data, however imperfect, suggest that there are complex patterns in the etiology of childhood obesity that vary with time, age, sex, and geographical regions [14, 15, 17, 20]. There are many possible reasons for pediatric obesity, such as energy imbalance, unhealthy food preferences, inadequate micronutrient intake, sedentary lifestyle, irregular sleep duration, and low sleep quality. One or more of these factors may have an influence on the tendency toward abnormal body mass index (BMI) percentile values [3, 21, 22]. This study aimed to (1) assess the prevalence of overweight and obesity in children and adolescents in China and (2) identify and quantify the data features associated with overweight or obesity. Our study was the nationwide cohort with a large sample size and a large number of variables, including physical measurements, sociodemographic data, and dietary habits.

Methods

Subjects and data collection

The present study is a descriptive and analytical cross-sectional study that includes 17,024 children aged 6–18 years old with physical examination records and self-report health questionnaires. The surveys were conducted in the HaiNan, GuangDong, HeBei, and LiaoNing provinces of China in 2016. Children and adolescents in these four provinces were collected using a multi-stage, stratified, cluster-sampling design. 12 prefectures were randomly selected from provinces or autonomous regions, followed by 12 districts, 2 county-level cities, and 4 counties randomly selected from prefectures. Level of urbanization was not used during this stage of sampling. Primary schools and secondary schools were randomly chosen from the cities, counties, and districts selected before. All children and adolescents aged 6–18 years old in the selected schools were invited to our study. Before the implementation of the survey, we conducted unified training for pediatricians/child health doctors in the hospitals in each province that were mainly responsible for the survey, used electronic scales of uniform brand and model for physical examinations, and conducted the survey using formatted questionnaires. We performed physical examination on children and interviewed parents of children with health-related questionnaires. A physical examination was performed to asses age, sex, height, weight, hip size, waist circumference, and blood pressure.

Socioeconomic status, food intake, and lifestyle factors were assess by self-report questionnaires during an interview with parents. The questionnaire used herein was developed based on questionnaires from previous similar studies [23–26]. This study has obtained informed consent from all participants and/or their legal guardians.

The study was conducted in accordance with the ethical standards of the responsible committee on human experimentation (institutional or regional) and with the Helsinki Declaration of 1964, as revised in 2000. The Institutional Review Board at HaiNan Women and Children Health care Hospital for Education and Research approved the study (HNWCMC Ethical Approval 2016 [16]).

Data preprocessing and measurements

After collecting the questionnaires, 15 questionnaires were deleted due to incomplete information, e.g., data fields with a high missing data rate (>70%). During data preprocessing, we removed 384 redundant records and converted multiple categorical data values with numeric values using label encoding. The final study population consisted of 16,640 records of children (6–9 years old) and adolescents (10–18 years old) in 2016, including 50 data variables from physical examinations and self-report questionnaires on health history, socioeconomic factors, dietary intake, and lifestyles. The evaluation of eating habits was collected through a food group consumption frequency survey (e.g. milk products, fried food, fruit, etc.). A total of 53.6% of participants were male, and 46.4% were female.

There were 24 numerical and 26 categorical variables in our study. We inspected the numerical data distribution in Supplemental Table 1 (Suppl Table 1) and the categorical data distribution in Supplemental Table 2 (Suppl Table 2). Suppl Table 1 lists distinct counts, means, standard deviations (STDs), and five quartiles, while Supp Table 1 lists the feature factor counts and frequencies.

Before our survey we calibrated our instruments to ensure that it is operating correctly and efficiently. All measurements of height, weight, and blood pressure were objectively taken by our trained research nurses following the manufacturer's instructions. The instruments had been evaluated for reliability and validity. Height and weight were measured using a calibrated Seca® mechanical measuring system 220 and a calibrated column scale 700, both known for their accuracy in clinical settings. Blood pressure was measured with a mercury

Table 1 BMI statistics of children and adolescents in China

Age	Gender	Mean	SD	Minimal	Lower Quartiles	Median	Higher Quartiles	Maximal	Median differences vs. National BMI
6	Boys	16.1	2.5	11.8	14.3	15.4	17.8	26.2	0.1
	Girls	15.0	2.4	11.2	13.4	14.5	15.9	26.5	-0.5
7	Boys	16.6	3.2	11.0	14.3	15.9	18.4	27.2	0.3
	Girls	15.7	2.6	11.1	13.8	15.3	17.2	25.1	0.3
8	Boys	16.9	3.2	11.0	14.7	16.1	18.4	33.2	0.1
	Girls	16.0	2.9	11.2	14.0	15.4	17.3	27.4	0.2
9	Boys	16.9	3.2	11.4	14.7	16.1	18.3	31.6	-0.3
	Girls	16.1	2.7	11.0	14.1	15.5	17.4	27.2	-0.1
10	Boys	17.8	3.6	11.1	15.2	17.3	19.9	34.7	0.0
	Girls	17	3.2	11.0	14.6	16.3	18.6	30.8	0.2
11	Boys	18.2	3.9	11.4	15.4	17.0	17.0	36.6	-0.5
	Girls	17.4	3.6	11.4	14.9	16.6	16.6	38.4	-0.1
12	Boys	19.6	4.8	11.9	16.0	18.1	18.1	39.9	0.1
	Girls	18.6	4.1	11.0	15.7	17.5	17.5	35.7	0.1
13	Boys	20.6	4.7	12.6	16.7	19.5	23.7	35.9	0.8
	Girls	19.4	3.9	12.9	16.6	18.5	21.6	33.7	0.4
14	Boys	21.4	5.2	13.5	17.7	20.2	24.1	39.2	1.0
	Girls	20.9	4.4	13.3	17.5	19.9	23.5	41.9	1.1
15	Boys	22.0	5.0	13.1	18.6	20.8	24.6	42.5	1.1
	Girls	21.5	4.3	13.1	18.6	20.7	23.4	42.6	1.4
16	Boys	22.5	4.6	12.9	19.1	21.3	25.1	41.3	1.2
	Girls	21.7	3.4	15.0	19.4	21.1	23.4	40.4	1.4
17	Boys	22.4	4.3	15.4	19.6	21.3	24.6	38.8	0.8
	Girls	21.9	3.3	15.0	19.8	21.2	23.1	35.9	1.2
18	Boys	23.5	5.5	13.9	19.4	22.0	26.5	42.6	1.2
	Girls	22.0	4.1	15.0	19.4	21.3	23.5	42.8	1.0

The BMI distribution were expressed as mean, standard deviation (SD), minimal, lower quartiles, median, higher quartiles, and maximal BMI (Table 1). The BMI in quartiles were defined according to BMI percentiles (lower quartiles = 25th percentile, median = 50th percentiles, higher quartiles = 75th percentiles)

Table 2 Comparison of physical measurements and systolic blood pressure among normal, overweight, and obesity groups

Groups	Normal	Overweight	Obesity	*P* values
Mean SBP	108 ± 15	115 ± 15	120 ± 15	< 0.001
% High SBP	3.3%	6.3%	12.5%	< 0.001
Mean Waist	60.4 ± 7.9	70.6 ± 8.8	80.9 ± 11.9	< 0.001
Mean Hips	73.1 ± 12.0	83.1 ± 11.4	90.7 ± 13.2	< 0.001
Mean W/H Ratio	0.84 ± 0.08	0.85 ± 0.08	0.90 ± 0.07	> 0.05

SBP, systolic blood pressure. W/H, waist/hips

sphygmomanometer, validated for precise readings according to established standards.

BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2). To determine overweight and obesity, we utilized three parameters: age, sex, and BMI. The overweight and obesity criterion was based on the 2005 China national BMI growth charts and reference dataset [27]. The reference set was used to classify children as normal weight (BMI < 85th BMI-for-age percentile), overweight (BMI 85th-94th (94.9) BMI-for-age percentile), or obese (BMI ≥ 95th BMI-for-age percentile) as previously described [28–32]. Blood pressure was measured with a mercury sphygmomanometer and a stethoscope (Yuwell, #A, JiangSu, China). According to the top of the meniscus, all values were obtained and reported to the closest even digit. Usually, one minute would pass between each of the two measures that were collected. The third measurement was conducted if the first two readings for SBP varied by greater than 10 mmHg. In the statistical studies, the average value of two measurements was applied to each time point.

Statistical analysis

Physical measurements are normally distributed continuous variables. Means with standard deviations and medians with interquartile ranges were used for continuous variables. We used a linear regression model to compare BMI-for-age growth profiles between males and females. Continuous variables were reported as means and standard deviation (SD), and comparisons between normal weight, overweight and obese individuals were performed using Student's t tests. Categorical variables were reported as total numbers and percentages, and chi-square tests were used to compare the prevalence of overweight and obesity between the subgroups.

To analyze the associations of potential risk factors with obesity, the child's BMI-based overweight/obesity status that was entered into the regression model as a response or outcome event was classified as a binary variable with code 0 for "normal" and code 1 for "overweight/obese".

Variable selections were carried out based on combinations of clinical knowledge and previous literature with common stopping rule/selection criteria and stepwise algorithms [33, 34].

First, the base case analysis was performed using univariate analysis. the 50 variables were entered into a univariate analysis, and 35 variables for boys and 31 variables for girls had significant associations with childhood/adolescent overweight or obesity ($p \leq 0.2$) were served as potential risk factors to stay in the candidate set of variables [35]. Those potential risk factors entered a multivariate logistic regression model. Multivariate logistic regression analysis was used to determine whether the significant relationship between the selected candidate variables and overweight/obesity remained. The selected candidate variables are categorical variables and the predictors in the multivariate logistic regression model. Except for the variable of interest (exposure), others were the covariates or confounders adjusted in the model that are theoretically be correlated with both outcome and predictors. The reference group is the category that was not shown in the results which is usually a control group. For example, the frequency of intaking puffed food has 6 levels, ranging as none, one every 2–3 months, 1–2 servings a month, 1–2 servings a week, 4–5 servings a week, more than one serving a day, one serving a day (Suppl Table 2). Figure 5 shows that the OR values with the frequency of puffed snack are daily, 1–2 times Monthly, 4–5 times weekly against the reference control group in which children did not consume any puffed snack. The candidate variables were identified with both-directional stepwise regression analysis to select the optimal variables and obtain their standardized regression coefficients and estimated adjusted odds ratios.

The thirteen most influential factors associated with overweight or obesity in the multivariate analysis were identified. They are parental perception of underweight in their children, Puffed Snack (4–5 times Weekly), Parent did not want their children to lose weight, Intake of Dairy product (1–2 times per week), Puffed Snack (1–2 times Monthly), Mother Weight, Children perception of overweight, Parental perception of overweight in their children, Girl self-perception of underweight, Staple food (rice, wheat, soybean), Monthly Income (>8000 Yuan), Boy self-perception of overweight, Sweet Drink (Daily) (Supple Table 4). An odds ratio larger than 1.0 indicates that a variable is likely to be a risk factor for overweight or obesity; in contrast, an odds ratio smaller than 1.0 indicates that a variable is likely to be a protective factor against overweight or obesity. $p < 0.05$ was considered to indicate statistical significance. All data were analyzed with R (version 4.1.2).

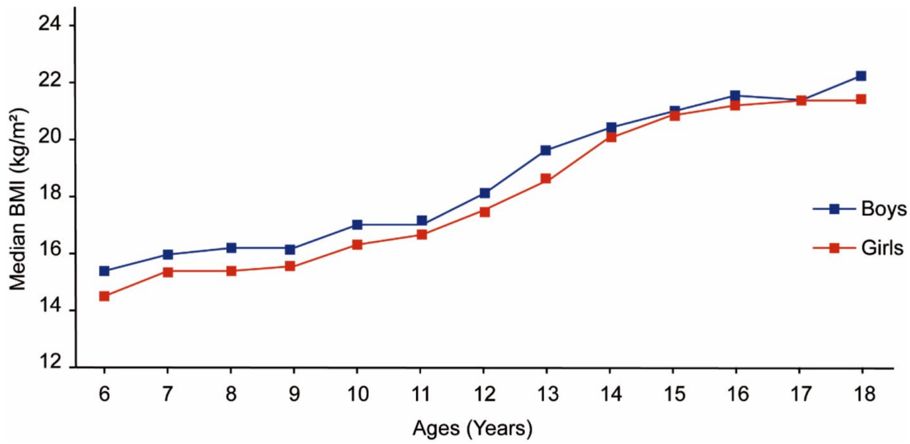

Fig. 1 BMI-for-age growth curves for Chinese boys and girls

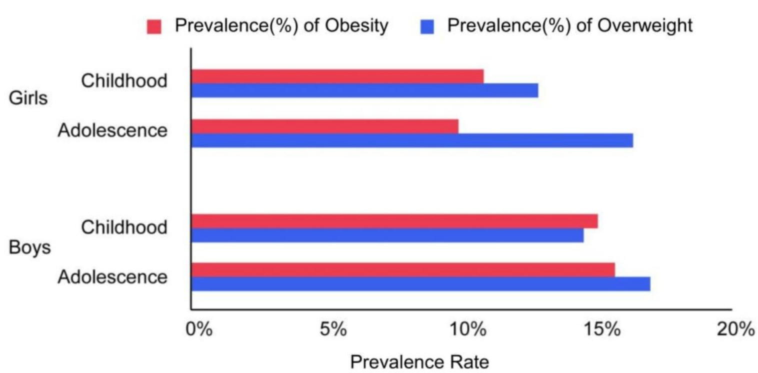

Fig. 2 Comparison of prevalence of overweight and obesity. Paired prevalence at X-axis were plotted as bar graphs, orange color for obesity prevalence and blue for overweight prevalence. Prevalence was compared between boy and girl groups and further compared between childhood and adolescence. Childhood refers a stage from age 6 to 9, adolescents refers a stage from age 10 to age 18

Results

To examine BMI data distribution, we categorized the BMI data values by age and sex and computed the mean and five quantiles of BMI (Table 1).

BMI mean and median values increased proportionally with age. We noticed that the mean and median BMIs in the groups of boys were always slightly larger than those in the corresponding groups of girls. After comparing to the 2005 China national BMI survey study [27], we found that the median BMI values from age 6–13 in our 2016 study were very close and comparable to the corresponding National BMI median values in 2005 with only minimal differences (ranging from −0.5 to 0.8), but from age 14 to 18, the BMI medians in our study were larger than those in the 2005 national survey study in China (0.8−1.4). These results suggested that from 2005 to 2016, BMI values in adolescents aged 14–18 years increased in China.

Figure 1 shows two longitudinal lines of BMI data in China for 7,720 females and 8,920 males. The closed circles represent BMI medians at the Y-axis for corresponding ages; each set of circles connected with a line across ages (years) at the X-axis represents either boy (the blue line) or girl (the orange line) BMI-for-age growth profiles.

The BMI profiles of boys and girls follow a similar pattern, but BMI values for boys were consistently larger than BMI values for girls, especially between ages 6–13. We found a significant difference in BMI between boys and girls using a linear regression model (p-value <0.01), indicating that boys have higher BMI than girls of the same age. BMI increases relatively slowly in childhood by 0.7 for boys and 1.0 for girls from age 6 (boy 15.4 and girl 14.5) to 9 (boy 16.1 and girl 15.5), and then BMI values increase more rapidly in adolescents (age 10–18) by 5 for boys and girls from age 10 (boy 17.0 and girl 16.3) to age 18 (boy 22.0 and girl 21.3) (Fig. 1; Table 1).

The age-gender aggregated counts and prevalence of overweight and obesity are compared in Fig. 2 and Suppl Table 3.

When comparing the overweight or obesity rates between childhood and adolescence regardless of gender differences (Suppl Table 3), the total overweight rate increased by 2.8% from 13.9 to 16.7%; however, the total obesity rates decreased by 0.4% from 13.3 to 12.9%.

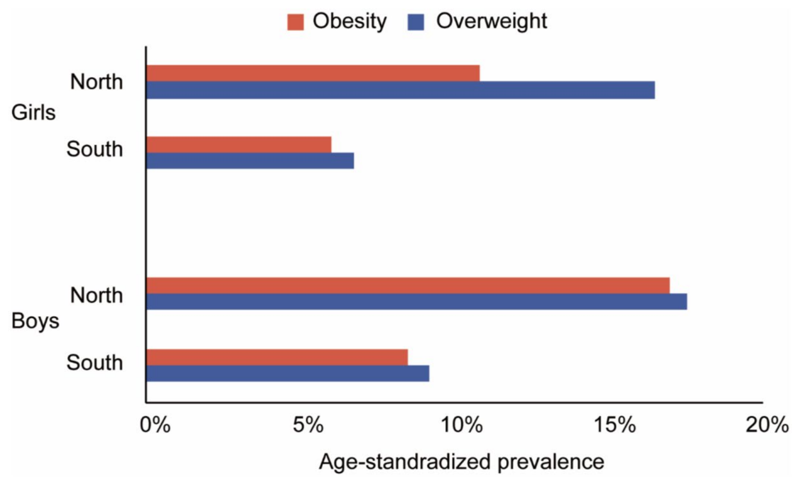

Fig. 3 Comparison of age-standardized prevalence of overweight and obesity between south and north regions in China. Paired overweight and obesity prevalence at X-axis were plotted as bar graphs in two different colors, i.e., orange for obesity prevalence and blue for overweight prevalence. Prevalence was compared between two gender groups (boys and girls) and further compared between south and north regions. All prevalence differences between south and north regions are statistically significant ($p < 0.0001$)

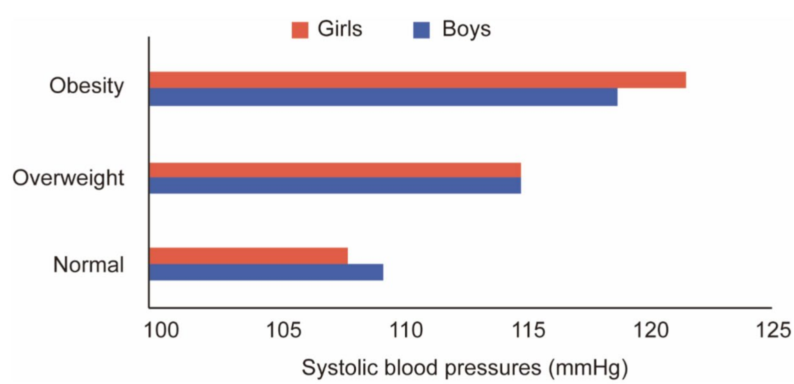

Fig. 4 Comparison of systolic blood pressures in normal, overweight, and obesity groups. The gender-paired systolic blood pressure measurements on the X-axis (mmHg) were plotted as bar graphs including normal, overweight, and obesity groups on the Y-axis. Systolic blood pressure measurements were compared among the three groups and further compared between boys and girls. Statistical tests (Student T tests) from overweight or obesity versus normal group were performed ($p < 0.0001$)

When examining overweight and obese prevalence across age-sex subgroups (Fig. 2), we found that the highest prevalence of both overweight and obesity was in adolescent boys (17.1% and 15.8%, respectively).

We further compared overweight and obesity rates between boys and girls (Fig. 2 and Suppl Table 3). From childhood to adolescence, overweight rates increased by 2.5 and 3.4% in boys and girls, respectively (boys from 14.6 to 17.1% and girls from 13.0 to 16.4%). From childhood to adolescence, the obesity rate among boys increased by 0.7% (from 15.1 to 15.8%), but interestingly, the obesity rate among girls decreased by 0.9% (from 10.8 to 9.9%). The results suggested that obesity was more likely to occur in male adolescents, which is consistent with the findings in Table 1.

To reveal the prevalence difference of overweight and obesity between two different geographical areas (south and north regions) in China, we calculated estimated age-standardized means [36, 37]. We then compared the age-standardized prevalence between southern and northern China (Fig. 3).

In Fig. 3, we found that both boys' and girls' age-standardized prevalence (overweight and obesity) in the two northern provinces were significantly higher than those of boys and girls in the two southern provinces ($p<0.0001$, Fig. 3). The results suggested that overweight and obesity were more common in the two northern provinces in China (HeBei and LiaoNing) than in the two southern provinces (HaiNan and GuangDong).

The mean SBP values were comparable without significant differences between subgroups of boys and girls among the normal, overweight, and obesity groups (Fig. 4). However, we observed that the mean SBP increased significantly ($p<0.001$) by approximately 6 ~ 7

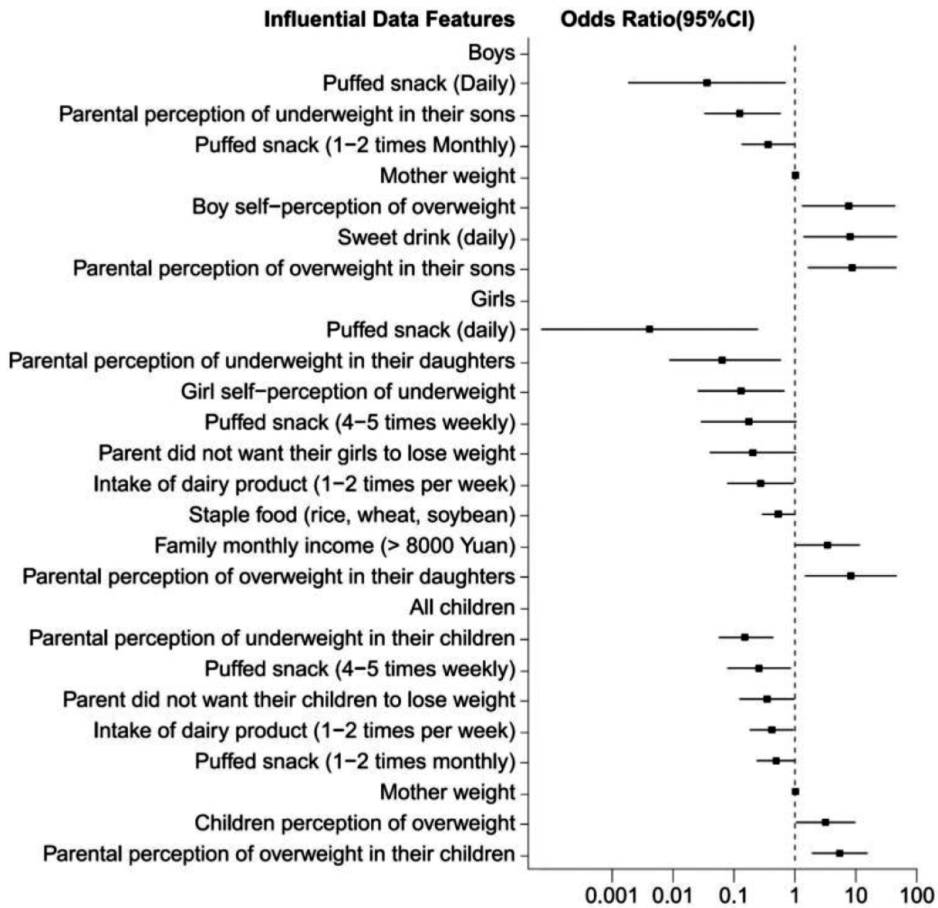

Fig. 5 Ranking of most influential data features for overweight and obesity. The most influential data features identified from all children, boys, and girls' groups were listed on the Y-axis. Within each group, the Odds Ratio (OR) from individual data features were plotted as bar graphs sorted in descending order on the X-axis

mmHg from the normal group (boys: 109 and girls: 108) to the overweight group (boys and girls: 115) and by 4 ~ 7 mmHg from the overweight group to the obese group (boys: 119 and girls: 122) (Fig. 4; Table 2). Thus, children and adolescents with overweight or obesity had significantly higher SBP than normal children and adolescents.

When other physical measurements of the normal group were compared to those groups who were overweight or obese (Table 2), the mean waist circumferences groups of overweight and obese children significantly increased 10 and 20 cm ($p<0.001$), and hip sizes significantly increased 10 and 17 cm ($p<0.001$), respectively. However, the ratio of the waist and hip (W/H) increased only 0.01 and 0.06, respectively.

To determine the correlations among the physical measurements, we computed the estimated Pearson correlation coefficient between SBP and other physical measurements. They are BMI (0.52), weight (0.6), height (0.56), waist (0.46), hips (0.51), and W/H ratio (-0.15). The highest correlation value was 0.6 (between SBP and weight), and the lowest value was −0.15 between SBP and the W/H ratio. Other measures (BMI, height, waist, and hips) had relatively moderate correlations with SBP (correlation coefficient = 0.5).

To evaluate the associations between response/outcome (overweight or obesity) and fifty predictors in the all-children set and two gender subsets (boys and girls), univariate and multivariate logistic regression analyses were performed in sequential order.

The ranking of the most influential data features for overweight or obesity ($P \leq 0.05$) in all children, boys, and girls is listed in Fig. 5 along with a Table showing adjusted odds ratios (ORs) and 95% confidence intervals (CIs) (Suppl Table 3).

The multivariate regression model C-index values were 0.806 for all children, 0.816 for boys and 0.789 for girls, indicating that multivariate logistic regression models fitted their predictors well and that the model performances were much better than random predictions.

The OR values were categorized into three groups (all children, girls, and boys) in Fig. 5. Within each group, the ORs were sorted in descending order.

From the ranking list of the most influential data features (Fig. 5), we noticed that parental perception of overweight in their children was tightly and consistently associated with the corresponding BMI classification in three groups (all children, girls, and boys) with large odds ratios (OR=5.41, 8.25 and 8.70, respectively). More specifically, if a parent perceived their child as overweight, then it was 5.4-fold more likely that their child was overweight when compared to other children who were not considered by their parents to be overweight. The results suggest that there was a strong association between parental perception of the body image of their children and the actual obese status of their children.

The other two common risk factors affecting all children ranking in the 2nd and 3rd positions were children's self-perception of overweight (OR=3.19) and mother's weight (OR=1.02). Interestingly, when examining these two factors in boys' and girls' subsets, we found that both factors had a significant influence only on boys (OR=7.62, ranking position 3 and 1.02, ranking position 4).

In addition to the common variable, boys had two unique features that made them more likely to be overweight or obese and that were not seen in the girl subset. These included daily sweet drink (OR=8.08) and self-perception of overweight among boys (OR=7.62). Girls also had one distinctive risk factor (family monthly income, > ¥8000, OR=3.43). Thus, daily sweet drink could be independent predictors of overweight or obesity for boys, while higher family monthly income (> ¥8000 in 2016) could be an independent predictor of overweight or obesity for girls.

There were six variables that reduced the chances for all children to be overweight or obese (Fig. 5). Puffed snacks and the parent perception of underweight in their children were two protective factors against overweight among boys and girls. Additionally, girls had four additional protective factors against overweight or obese (Fig. 5): self-perception of underweight (OR=0.13), parental opinion (parents did not want their girls to lose weight, OR=0.20), intake of dairy products weekly (OR=0.27) and eating staple foods daily (OR=0.53).

Puffed snacks, made using corn grits, rice, wheat, or other cereals and are frequent flavoring with cheese, oil, chili, onion or garlic powder, were the strongest protective factors (rank: 1) against overweight and obesity among all children in this study. Furthermore, the higher frequency of eating puffed snacks daily was associated with a 10- and 50-fold decreased risk of overweight or obesity in boys (OR=0.036) and girls (OR=0.004), respectively, when compared to the lower frequency of eating puffed snacks monthly for boys (OR=0.36) and weekly for girls (OR=0.17). The results suggested that puffed snack intake was associated with weight loss in children.

Discussion

The prevalence of obesity has increased worldwide in children and adolescents since 1975 [38]. Our results (Fig. 2) demonstrated that the prevalence of overweight/obesity in 2016 was 27.2% and 29.6% for children and adolescents in China, respectively. We compared our study with other cross-sectional surveys [16–18, 39–42] of overweight/obesity in China (Table 3). The results from two recent studies [41, 42] are based on large sample sizes (201,098 and 14,597 participants, respectively), but both studies focused on ages, genders and geographical coverage and lacked clinical correlations and a questionnaire survey; therefore, they did not include comprehensive risk factor analysis. While the studies showed a similar overall prevalence of overweight/obesity (26.95 −32.60%), our study was the nationwide cohort with a large sample size and large number of survey variables, including physical measurements, sociodemographic data, and dietary habits.

A similar prevalence trend of obesity was also found in other developing countries. A recent study in 2021 showed that obesity in adolescents reached an alarming level in Turkey [3]. Approximately 14.3% of children were overweight, and 13.8% of children were obese in Istanbul, Turkey [18], which is comparable to the prevalence of adolescent overweight (16.7%) and obesity (12.9%) in China (Supple Table 3).

This cross-sectional study extends results from previously published studies of pediatric obesity by examining the prevalence of overweight and obesity in children and adolescents by gender, age, and geographical location. In addition, we evaluated the changes in obesity between age gradations (childhood and adolescence) in China with gender stratifications as well as the association between obesity and physical measurements. This study revealed overweight and obesity with disproportionately higher prevalence found in male adolescents. This study further quantified the association between overweight/obesity and possible risk factors.

The discrepant distribution of BMI between regions of different geographic Chinese school children and adolescents is depicted in Fig. 3. Children in the north had a greater frequency of overweight and obesity. The cause of this discrepancy of the north-south variation is probably multifactorial such as genetics and ethnicity, dietary patterns, and climate and lifestyle.

The genetic variations and differences in ethnic backgrounds between Northern and Southern Chinese populations may affect body composition and weight distribution. Another one possible explanation for this discrepancy is the climate. Climate differences between

Table 3 Comparison of epidemiology studies of overweight and obesity in China

Publication	Current study	Song L et al. [4]	Zheng J et al. [5]	Sun M et al. [20]	Yuan YQ et al. [39]	Wan H et al. [40]	Zhang L et al. [41]	Yuan JN et al. [42]
Cross-sectional survey	In four provinces of China in 2016	China Health and Nutrients Survey (CHNS) in 2015	In five mega-cities across China in 2015, 2016 and 2017	In 16 primary schools in Changsha city, China, 2012	In 35 special education schools in China between 2018 and 2019	In seven communities in Shanghai, China, 2018	In 11 provinces of China in 2017–2019	In four provinces of China in 2009 and 2019
Sample records	16,640	1369	3313	2224	1873	4658	201 098	14 597
Number of covariates	50	7	8	18	5	6	Not available	Not available
Age range	6–18 years old	6–17 years old	7–16 years old	9–13 years old	6–18 years old	23–99 years old	8–13 years old	6–15 years old
Prevalence of overweight or obesity	29.60%	26.95%	29.80%	25.30%	32.60%	Not mentioned	18.8%~28.6%(differ from region)	11.9% in 2009 and 12.4% in 2019
Correlation with physical measurements	Systolic blood pressures, waist circumference, and hip size	Not available	Not available	Not available	Not available	Not available	Not available	Not available
Obese associated variables	13	Body perception	Eating-out behaviors	Picky eating habits	Intellectual disabilities	cardiovascular and cerebrovascular disease (CVD), diabetic kidney disease (DKD) and diabetic retinopathy (DR)	Not available	Not available

Northern and Southern China can influence physical activity levels and energy expenditure. Colder climates in the north may lead to a more sedentary lifestyle indoors, while warmer climates in the south might encourage more outdoor activities. Because of this, people in northern regions may engage in less physical activity and store more fat in order to withstand the bitter cold of the winter. A change in diet is an additional explanation. A prior study found a positive correlation between childhood obesity and China's traditional northern dietary pattern [43]. Northern Chinese cuisine tends to include more wheat-based foods (like noodles and dumplings) and richer dishes, potentially leading to higher calorie intake compared to the generally lighter and rice-based diet of Southern China. This association may be partially attributed to the traditional northern diet's high carbohydrate intake and low levels of micronutrients. The results of this study showed clearly that obesity is particularly prevalent in north China.

Sex was found to be significantly associated with obesity in previously published studies. Based on 2,224 students in grades 4 to 6 from 16 primary schools in Changsha, China, the prevalence rates of overweight and obesity in school-age children were 17.0% and 8.3%, respectively. Boys had higher rates of overweight and obesity than girls (19.9% vs. 13.6% and 12.9% vs. 3.0%, respectively, $p<0.05$) [20]. The global age-standardized prevalence of obesity increased from 0.7% (0.4–1.2) in 1975 to 5.6% (4.8–6.5) in 2016 for girls and from 0.9% (0.5–1.3) in 1975 to 7.8% (6.7–9.1) in 2016 for boys [38]. According to a systematic review evaluating the prevalence of overweight and obesity in adolescents worldwide, boys showed a higher prevalence of overweight in almost half of the countries and a higher prevalence of obesity in almost all countries [44]. The reason for the differences in the prevalence of overweight and obesity between genders has been related to geopolitical and cultural conditions [45].

In accordance with these reports, we found that gender differences in prevalence were obvious and consistent. From childhood to adolescence, the rate of obesity in boys increased by 0.7% (from 15.1 to 15.8%), but interestingly, the rate of obesity in girls decreased by 0.9% (from 10.8 to 9.9%) (Supple Table 3). Therefore, boys had a statistically higher obesity prevalence than girls in China. The gender-relevant obesity analysis found that adolescent boys were more predisposed to obesity than childhood boys and childhood girls (Fig. 2). Boys had three distinct risk factors for overweight/obesity compared to girls, whereas girls had four distinct risk factors against overweight or obesity (Fig. 5).There are several factors that contribute to Chinese girls at adolescence generally being thinner or less overweight, for example, there may be cultural preferences and norms that encourage healthier eating habits and portion control among Chinese girls. For example, they are in general emphasize more fresh vegetables, fruits, and lean proteins, which can contribute to lower calorie intake and healthier weight management boys.

The result of the Pearson correlation analysis between SBP and other physical measurements suggests that factors such as weight, BMI, height, waist circumference, and hip size were all positively and moderately associated with SBP. However, the association between the W/H ratio and SBP was much weaker than those between the other five measurements and SBP, which is consistent with other reports [46].

In addition to the common risk factors in the literature [32, 47], our study also showed that socioeconomic variables such as geographical area (Fig. 3), maternal weight, consumption of sweet drinks, and higher family monthly income (Fig. 5) were significant risk factors for developing obesity and overweight in boys and girls.

Among these common risk factors affecting all children (Fig. 5), maternal obesity stands out as a significant public health problem [48]. Pregnancy itself is a trigger for obesity, with the prevalence of obesity during pregnancy being 30% and 40% for women with adequate and excessive gestational weight gain respectively [49].

In China, the consumption of sweet drinks is prevalent among children and adolescents. According to a 2022 report by Liu XT et al. [50], 87.6% of adolescents in China consume sugary drinks, with a consumption level of 205.4 ml/day per person.

We also noticed that a higher prevalence of obesity was observed in children with higher family income in China (Fig. 5). This contrasts with the prevalence pattern of obesity in developed countries, in which the prevalence of childhood obesity was highly associated with children in low-income families ($p<0.001$) or families living in the most deprived areas [51]. Our results support the findings from other studies worldwide [52–54], which reported that children from lower income families in industrialized countries and higher income families in developing countries (including China) were more likely to be overweight or obese than their counterparts. The higher income families in China that just went through a rapid economic growth in past two decades are defined only by the income number; however, these more affluent families with high socioeconomic status (SES) in China may still share the same unhealthy lifestyle with the low-SES families in industrialized countries. For example, both types of families have easy access to high-calorie and often fast food. The high-SES families in industrialized countries often have a healthy lifestyle, including healthy eating and proper physical activity. Their school programs help empower their children to develop lifelong healthy habits and maintain healthy body weight [52]. Thus, the high-SES families in developed countries show a reversal in the positive association between SES and overweight/obesity, which has not yet occurred for children in developing countries such as China [55].

We have identified six variables that reduced the chances for all children to be overweight or obese (Fig. 5) although their effects and mechanism remain unclear. Among them, consuming puffed snacks warrants further study. Puffed food incorporates air into products, resulting in a reduction in caloric density, indirectly decreasing energy consumed [56]. An animal study showed that dietary intake of puffed coarse cereals could decrease body weight gain and fat accumulation, improve blood glucose tolerance and serum lipid levels, reduce systemic inflammation, and downregulate the expression of hepatic lipogenic genes [57]. When overweight adolescents consumed isoenergetic amounts of 25 g/d puffed wheat for 4 weeks, the results showed a reduction in BMI and waist circumference [58].

However, many cross-sectional studies on puffed snack consumption in school-age children have suggested that puffed snack consumption was associated with a higher risk of overweight/obesity in school-age children [20].

Puffed snacks can be either healthy or unhealthy depending on the ingredients of puffed snacks. It is essential to further analyze the intake and sources of total energy and free sugar in children's puffed snacks to distinguish unhealthy puffed snacks from healthy snacks. For example, Cheese Cookies have approximately 142 calories and 3.59 g total fat per serving size (1 ounce), while popcorn has fewer calories and less total fat (approximately 110 calories and 1.29 g total fat per serving) (https://www.fatsecret.cn).

Puffed snacks are very popular snack foods with a high market concentration rate in China. For example, the leading brand is Oishi sweet corn puffs snack in the Chinese market, which is a puffed corn-based snack food that contains iron and some amount of dietary fiber. This could potentially be a snack option for weight loss.

There are some limitations of the current study that may constrain the interpretation of our data and could be addressed in future research. First, this cross-sectional study involves looking at data from a population at one specific point in time. These data were limited to children living in the four provinces in northern and southern China and thus may not be fully representative of other populations or regions in China. Future research might require more comprehensive coverage of other provinces, including a longitudinal follow-up. Second, the variables were predefined and did not include all possible obesity-related factors. Third, we limited our obesity risk correlation assessment to systolic blood pressure because many metabolic test results were not uniformly available in most subjects. Finally, these descriptive research results are limited to infer possible correlations rather than cause-and-effect relationships. The results should be interpreted with caution. However, we can use these preliminary data to support further research and experimentation. This study allows us to gather preliminary data to support further translational research and experimentation. For example, we can design cohort studies of potential risk factors for overweight or obesity to identify any potential causal relationships. Moreover, basic experiments on animals or cells can be conducted to study the molecular mechanism of obesity.

Conclusion

The findings have revealed that the prevalence of overweight and obesity (27.2% and 29.6%, respectively) is high among children and adolescents. We have emphasized the complex correlations among thirteen risk factors associated with overweight and obesity in children and adolescents. It is important to interpret these results with caution. Nonetheless, they provide useful evidence for future obesity prevention efforts, particularly by focusing on adolescent boys and promoting healthy food choices.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12887-024-04970-1.

Supplementary Material 1

Author contributions

XW, FLC and HY contributed to conceptualization, data curation, formal analysis, funding acquisition, and writing of the original draft. LHA and XXY contributed to conceptualization, data curation, project administration, writing of the original draft, and reviewing and editing. DN, YJP and GZH contributed to investigation, methodology, project administration, and resources. YYJ, YBL, YLT and LQ contributed to resources, software, supervision, validation, and visualization. All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work. LHA and XXY are the co-first authors. XW, FLC and HY contributed equally to the work and are co-corresponding authors.

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Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study has obtained informed consent from all participants and/or their legal guardians. The Institutional Review Board at HaiNan Women and Children Healthcare Hospital for Education and Research approved the study (HNWCMC Ethical Approval 2016 [16]).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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