

BMJ Open Association of high birth weight with overweight and obesity in Chinese students aged 6–18 years: a national, cross-sectional study in China

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ABSTRACT

Background The prevalence of childhood overweight and obesity in China has drastically increased 57 times over the past 30 years, and to control birth weight is an effective way to reduce the risk of overweight and obesity across the life course.

Objective This paper aimed to evaluate the association of high birth weight (HBW) with overweight and obesity in Chinese students aged 6–18 years.

Methods All students with HBW (n=4981) aged 6–18 years were selected from a cross-sectional survey from seven provinces of China, and 4981 other students with normal birth weight (NBW) were randomly sampled with matched gender, age and province. Anthropometric parameters were measured and characteristics were collected by questionnaires. Multiple logistic regression was used to estimate the OR of overweight and obesity with HBW, unadjusted and adjusted for confounding factors.

Results Participants with HBW revealed higher body mass index in childhood. The prevalence of overweight and obesity was significantly higher in the HBW group than in the NBW group (overweight 15.3% vs 13.1%, $p<0.05$; obesity 16.9% vs 10.6%, $p<0.05$), and the results were similar for overweight in all age groups except age 6–7, age 14–15 and age 16–18. Additionally, HBW was positively associated with overweight (OR=1.230; 95% CI 1.056 to 1.432) and obesity (OR=1.611; 95% CI 1.368 to 1.897) after adjustment for covariates.

Conclusions HBW leads to an increased risk of overweight and obesity in childhood; thus, measures to control birth weight, such as controlling gestational weight gain, should be taken from the earliest beginning of life.

Trial registration number NCT02343588; Post-results.

INTRODUCTION

Overweight and obesity in childhood have become a critical health issue with the continuous increase in prevalence worldwide,¹ especially in China.^{2–3} The prevalence of obesity in Chinese students aged 7–18 years has increased from 0.13% in 1985 to 7.26% in 2014,⁴ while the prevalence of overweight increased from 6.3% in 1991 to 17.1% in

Strengths and limitations of this study

- This study used a national multicentred sample covering all-age children and adolescents in school.
- The 1:1 matching of gender, age and province between high birthweight group and normal birthweight group was used to enhance the study.
- Some maternal data, such as maternal age of pregnancy and gestational weight gain, were not collected in the survey, which may influence the results.
- 70.9% of birth weight was reported based on the health clinic card or birth certificate, with the other 29.1% recalled by their parents twice during 6 months, which may have recall bias.

2011.⁵ Overweight and obesity are considered high-risk factors for cardiovascular and metabolic complications,^{6–8} and students with overweight and obesity are more likely to suffer physical and psychosocial problems in adulthood.^{9–11} Previous studies have shown that an improvement in physical activity (PA) or dietary intake could produce stronger effects than those without it, while the number of health behaviours was inversely related to the intervention effects for obesity,^{12–13} and the difficulty in preventing obesity is that obesity is the result of many factors, including genetics, unhealthy lifestyle, family environment as well as heavy marketing of unhealthy food products.^{13–14}

The Developmental Origins of Health and Disease hypothesis postulates that adverse influence on intrauterine life can lead to permanent readjustments in physiology and metabolism, which further cause increased risk of diseases in later life. Thus, focusing on the early developmental phase of life offers a new way to understanding the mechanism of overweight and obesity.¹⁵ In childhood and puberty, the association between birth weight and obesity has been continually observed in

cross-sectional,^{16 17} longitudinal¹⁸ and cohort¹⁹ studies. Most studies have found that high birth weight (HBW) was related to elevated risk of obesity in children or adolescents,^{16–19} and healthy lifestyle intervention before and during pregnancy could be effective in reducing the risk of HBW, which meant a balanced diet with low glycaemic load, light-intensity to moderate-intensity PA, and moderate weight gain during pregnancy.^{20 21} However, very few studies have focused on Chinese school-age children, nor have they accounted for regional differences and provincial disparities; thus, a multicentred study is needed to clarify the associations.

Using baseline survey data from seven provinces in China, the present study aimed to evaluate the association of HBW with overweight and obesity among school children aged 6–18 years, and also to investigate the strength of association between HBW and body mass index (BMI) z-score.

METHODS

Sample and participants

Sampling was based on a cross-sectional baseline survey from seven provinces in China (Liaoning, Tianjin, Ningxia, Shanghai, Chongqing, Hunan and Guangdong) prior to the commencement of a national multicentred intervention trial, and these provinces covered all seven geographical areas of China. The protocol of the cluster, randomised controlled trial was previously published.²²

Using the common criteria of HBW,^{16 18 19} all students aged 6–18 years with birth weight over 4.0 kg ($n=4981$) were selected from a baseline survey of 65 347 students, and 4981 other students with normal birth weight (NBW, $2.5 \text{ kg} \leq \text{birth weight} < 4.0 \text{ kg}$) were randomly sampled with matched age, gender and province. Finally, 9962 students, including 4981 students in the HBW group and 4981 students in the NBW group, were enrolled in the present study and were further divided into six subgroups, shown in table 1 and table 2: NBW normal weight group ($n=3800$), NBW overweight group ($n=653$), NBW obesity group ($n=528$), HBW normal weight group ($n=3380$), HBW overweight group ($n=760$) and HBW obesity group ($n=841$), while overweight and obesity were defined using the cut-off references developed by the Working Group on Obesity in China.²³

Birthweight data

Birth weight data were collected using a standard parent questionnaire. Parents were required to record their children's birth weight based on the birth certificate or health clinic record. If they did not have it, parents were asked to recall the birth weight based on their own measurements. About 70.9% of parents record the information of their children's birth weight based on the health clinic card or birth certificate, and the proportions in the HBW group and the NBW group were 73.4% (3655/4981) and 68.4% (3406/4981), respectively. To ensure the reliability of birthweight data, parents were asked to repeat the same

process of questionnaire survey 6 months later. The error in birthweight values between the baseline and 6 months later was lower than 10%, and participants with an error over 10% were eliminated in this study.

BMI and blood pressure

Height and weight were measured by trained project members and experienced research nurses and doctors according to standardised procedure. To record these measurements, students were asked to stand straight in light clothing and without shoes. A portable stadiometer and a lever-type weight scale were validated and then used to measure height and weight, twice respectively. The mean value for both height and weight measurements was calculated using the duplicate measures. Height was measured to the nearest 0.1 cm and weight was measured to the nearest 0.1 kg. In rechecking 5% of the students, the error was less than 3%, or if higher all students were remeasured according to the protocol. BMI was calculated as body weight divided by height (m) squared (kg/m^2).

Blood pressure was measured using a standardised mercury sphygmomanometer (model XJ11D) recommended by the National High Blood Pressure Education Program (NHBPEP) Working Group in children and adolescents. The cuff size was selected according to the NHBPEP Working Group and placed approximately 2 cm above the crease of the elbow. The first reading was taken after students had sat at ease for at least 5 min, with the students asked to keep quiet through the whole measurement. Systolic blood pressure (SBP) was determined by onset of the first Korotkoff sound and diastolic blood pressure (DBP) was defined by the fifth Korotkoff sound. This was performed twice, with the average recorded and used in this study. Elevated blood pressure in children and adolescents was defined as SBP or DBP or both higher than the corresponding cut-offs. The cut-offs were age-specific, gender-specific and height percentile-specific as recommended by the NHBPEP Working Group in 2004.²⁴

Questionnaires

The research team developed self-reported questionnaires for children and parents to collect information on obesity-related factors. Child-reported questionnaires were filled in by students in the classroom, with interpretation performed by trained research staff, with the exception of children at third grade or under primary school, who completed the questionnaires at home with guardians' assistance. Parent-reported questionnaires were all finished by students' guardians.

Child-reported questionnaires contained diet intake (fruit, vegetable and sugar-sweetened beverage), moderate PA, vigorous PA and sedentary time of students. For diet intake, students were asked how many days they eat fruits and vegetables or drink sugar-sweetened beverages, and how many servings or cups of these for each day in the past 7 days. The average intake was calculated: (days

Table 1 Characteristics of study subjects with normal weight against overweight

Baseline characteristics	NBW normal group (3800)	NBW overweight group (653)	HBW normal group (3380)	HBW overweight group (760)	P value
Male, n (%)	2190 (57.6)	441 (67.5)	1906 (56.4)	505 (66.4)	<0.001
Age (year), mean±SD	11.16±0.05	10.76±0.13	11.29±0.06	10.83±0.12	<0.001
Urban area, n (%)	2146 (56.5)	388 (59.4)	2144 (63.4)	501 (65.9)	<0.001
Single child, n (%)	2488 (65.5)	479 (73.4)	1966 (58.2)	524 (68.9)	<0.001
Birth information					
Birth weight (kg), mean±SD	3.22±0.35	3.25±0.36	4.21±0.29	4.21±0.26	<0.001
Caesarean birth, n (%)	1330 (37.4)	269 (43.7)	1424 (43.4)	420 (56.3)	<0.001
Single birth, n (%)	3488 (97.0)	604 (98.1)	3242 (97.9)	739 (98.9)	0.001
Breast feeding, n (%)	3098 (86.0)	536 (86.3)	2887 (86.9)	636 (85.1)	0.552
Anthropometry, mean±SD					
Height (cm)	146.08±17.36	147.24±16.49	148.44±17.30	149.16±16.92	<0.001
Weight (kg)	38.18±13.00	48.30±16.23	40.11±13.13	49.80±16.69	<0.001
WC (cm)	61.64±8.09	72.51±9.49	62.70±7.83	72.65±9.39	<0.001
Systolic pressure (mm Hg)	103.88±11.51	108.08±12.121	103.98±11.36	107.22±12.17	<0.001
Diastolic pressure (mm Hg)	65.71±8.29	67.93±8.99	65.78±8.28	67.04±8.55	<0.001
Body mass index (kg/m ²)	17.26±2.39	21.47±2.74	17.61±2.32	21.58±2.71	<0.001
Diet and physical activity, mean±SD					
Fruit (serving/day)	1.20±1.03	1.25±0.96	1.27±1.08	1.20±0.95	0.050
Vegetable (serving/day)	1.77±1.40	1.79±1.42	1.78±1.43	1.78±1.43	0.976
Sugar-sweetened beverage (cup/day)	0.42±0.75	0.49±0.92	0.45±0.80	0.46±0.86	0.167
Moderate PA (hour/day)	0.49±0.81	0.46±0.72	0.52±0.82	0.50±0.89	0.196
Vigorous PA (hour/day)	0.47±0.78	0.46±0.65	0.47±0.74	0.49±0.82	0.850
Sedentary time (hour/day)	5.73±3.76	5.75±3.58	5.87±3.73	5.72±3.76	0.442
Socioeconomic status, n (%)					
Paternal education level					<0.001
None/Primary	313 (8.2)	55 (8.9)	313 (9.5)	61 (8.2)	
Secondary	2407 (67.3)	374 (60.6)	2207 (67.0)	461 (62.4)	
College and above	876 (24.5)	189 (30.5)	776 (23.5)	217 (29.4)	
Maternal education level					
None/Primary	369 (10.4)	57 (9.3)	407 (12.4)	73 (9.9)	<0.001
Secondary	2417 (67.9)	392 (63.5)	2181 (66.3)	467 (63.3)	
College and above	772 (21.7)	168 (27.2)	702 (21.3)	198 (26.8)	
Family history, n (%)					
Paternal hypertension	144 (4.1)	27 (4.5)	128 (4.0)	37 (5.1)	0.558
Maternal hypertension	66 (1.9)	17 (2.8)	95 (3.0)	25 (3.5)	0.014
Paternal diabetes	41 (1.2)	11 (1.9)	39 (1.2)	14 (2.0)	0.251
Maternal diabetes	17 (0.5)	4 (0.7)	31 (1.0)	11 (1.6)	0.017
Paternal obesity	176 (5.3)	49 (8.5)	159 (5.1)	59 (8.6)	<0.001
Maternal obesity	108 (3.2)	19 (3.3)	128 (4.1)	42 (6.1)	0.003

HBW, high birth weight; NBW, normal birth weight; PA, physical activity; WC, waist circumference.

× servings/cups for each day)/7. One serving of fruits or vegetables was defined as the size of an adult's fist, while one cup of sugar-sweetened beverage was defined as almost 250 mL. Data on moderate and vigorous PA (MVPA) were collected by asking how many days students do moderate or vigorous PA and how many hours for each day over the past 7 days. The average PA followed the calculation of (days × hours for each day)/7. Moderate PA included light activities (eg, walking), while vigorous PA included

high-load activities on musculoskeletal tissues of the body (eg, sports and games).²⁵ For sedentary time, consisting of doing homework, watching television and using a computer, students were asked how many days and how many hours were spent on the three separate activities over the past 7 days. Following the calculation of (days × hours for each day)/7 for each activity, the average sedentary time was the sum of homework, television and computer time.

Table 2 Characteristics of study subjects with normal weight against obesity

Baseline characteristics	NBW normal group (3800)	NBW obesity group (528)	HBW normal group (3380)	HBW obesity group (841)	P value
Male, n (%)	2190 (57.6)	383 (72.5)	1906 (56.4)	603 (71.7)	<0.001
Age (year), mean±SD	11.16±0.05	10.14±0.13	11.29±0.06	10.23±0.11	<0.001
Urban area, n (%)	2146 (56.5)	315 (59.7)	2144 (63.4)	564 (67.1)	<0.001
Single child, n (%)	2488 (65.5)	410 (77.7)	1966 (58.2)	605 (71.9)	<0.001
Birth information					
Birth weight (kg), mean±SD	3.22±0.35	3.31±0.35	4.21±0.29	4.24±0.32	<0.001
Caesarean birth, n (%)	1330 (37.4)	256 (50.2)	1424 (43.4)	534 (64.3)	<0.001
Single birth, n (%)	3488 (97.0)	502 (97.1)	3242 (97.9)	811 (98.2)	0.511
Breast feeding, n (%)	3098 (86.0)	413 (79.7)	2887 (86.9)	721 (86.7)	0.017
Anthropometry, mean±SD					
Height (cm)	146.08±17.36	146.62±15.50	148.44±17.30	148.69±15.87	<0.001
Weight (kg)	38.18±13.00	55.83±19.37	40.11±13.13	58.75±20.96	<0.001
WC (cm)	61.64±8.09	80.27±11.25	62.70±7.83	81.67±11.63	<0.001
Systolic pressure (mm Hg)	103.88±11.51	111.92±13.43	103.98±11.36	111.24±13.10	<0.001
Diastolic pressure (mm Hg)	65.71±8.29	70.43±9.59	65.78±8.28	70.15±8.78	<0.001
Body mass index (kg/m ²)	17.26±2.39	25.09±3.94	17.61±2.32	25.62±4.26	<0.001
Diet and physical activity, mean±SD					
Fruit (serving/day)	1.20±1.03	1.32±1.03	1.27±1.08	1.36±1.09	<0.001
Vegetable (serving/day)	1.77±1.40	1.90±1.57	1.78±1.43	1.95±1.49	0.003
Sugar-sweetened beverage (cup/day)	0.42±0.75	0.37±0.59	0.45±0.80	0.40±0.61	0.041
Moderate PA (hour/day)	0.49±0.81	0.51±0.82	0.52±0.82	0.50±0.69	0.375
Vigorous PA (hour/day)	0.47±0.78	0.48±0.45	0.47±0.74	0.47±0.67	0.967
Sedentary time (hour/day)	5.73±3.76	5.87±3.75	5.87±3.73	5.74±3.56	0.431
Socioeconomic status, n (%)					
Paternal education level					<0.001
None/Primary	313 (8.2)	29 (5.7)	313 (9.5)	35 (4.3)	
Secondary	2407 (67.3)	319 (62.5)	2207 (67.0)	504 (61.5)	
College and above	876 (24.5)	162 (31.8)	776 (23.5)	281 (34.2)	
Maternal education level					
None/Primary	369 (10.4)	31 (6.1)	407 (12.4)	60 (7.3)	<0.001
Secondary	2417 (67.9)	346 (67.9)	2181 (66.3)	529 (64.0)	
College and above	772 (21.7)	168 (26.0)	702 (21.3)	198 (28.7)	
Family history, n (%)					
Paternal hypertension	144 (4.1)	29 (5.8)	128 (4.0)	49 (6.0)	0.002
Maternal hypertension	66 (1.9)	12 (2.4)	95 (3.0)	31 (3.8)	0.067
Paternal diabetes	41 (1.2)	9 (1.8)	39 (1.2)	16 (2.1)	0.032
Maternal diabetes	17 (0.5)	6 (1.2)	31 (1.0)	20 (2.6)	<0.001
Paternal obesity	176 (5.3)	59 (12.4)	159 (5.1)	88 (11.5)	<0.001
Maternal obesity	108 (3.2)	25 (5.3)	128 (4.1)	65 (8.5)	<0.001

HBW, high birth weight; NBW, normal birth weight; PA, physical activity; WC, waist circumference.

The parent-reported questionnaire collected the child's birth information (delivery, single birth or not, and breast feeding), single child or not, socioeconomic status

(parents' education levels) and family history (hypertension, diabetes and obesity). Delivery mode included spontaneous delivery and caesarean delivery. Breast feeding

was categorised as ≥ 6 months and < 6 months. Socioeconomic status was defined as education levels of children's parents, involving three levels: primary school or below, secondary school, and college or above. In this study, family history covered father's and mother's history of hypertension, diabetes and obesity. This was established through a diagnosis of hypertension or diabetes according to their medical history, while BMI was calculated by weight/height² (kg/m²) for height and weight values provided in the questionnaire. Adult obesity was defined as BMI ≥ 28 kg/m² in the Chinese guideline for adult obesity.²⁶

Patient and public involvement

Students and their parents were not involved in setting the research question or outcome measures, nor were they involved in the recruitment and conduct of the study. School doctors and class teachers helped us to organise and maintain order of the physical examination by class held in the school.

Statistical analyses

EpiData Software V.3.02 was used for data entry, and all analyses were performed using IBM SPSS Statistics V.22.0. Age, birth weight, height, weight, BMI, DBP, SBP, sweet drinks and MVPA were recorded as mean value (SD). Gender, delivery, single birth, breast feeding, elevated blood pressure, parental education and family history were displayed as categorical variables (number and percentage). t-Test was conducted for the p value of BMI between the HBW group and the normal group by gender and age group, and χ^2 test was verified for the percentage of overweight and obesity. Multivariate logistic regression was used to calculate the OR and 95% CI of different birthweight groups for overweight and obesity by age group. This was further adjusted for urban–rural area, single child, delivery, food intake and PA, sedentary time, and elevated blood pressure in model 2, and adjusted for

paternal and maternal education level, and family history such as hypertension, diabetes and obesity in model 3. Sensitivity analyses were conducted with different thresholds for HBW compared with NBW, which are displayed in online supplementary table 1. The criterion for statistical significance was p value < 0.05 .

RESULTS

A total of 9962 children and adolescents aged 6–18 years were recruited in this study, and the distribution of characteristics in all groups is presented separately in table 1 and table 2. As presented in table 1, the mean value of birth weight was 3.22 ± 0.35 kg, 3.25 ± 0.36 kg, 4.21 ± 0.29 kg and 4.21 ± 0.26 kg, respectively, for NBW normal weight group, NBW overweight group, HBW normal group and HBW overweight group. Compared with the other three groups, students in the HBW overweight group were observed with significantly higher rate of caesarean birth, urban area, single child, single birth, maternal hypertension, diabetes, obesity and parental obesity ($p < 0.05$). The results in table 2 were similar between the HBW obesity group and the other three groups, except for the rate of parental hypertension and parental diabetes, which was significantly higher ($p < 0.05$).

The associations between BMI z-score and birth weight in different age groups are shown in table 3. All age groups were observed with significantly positive associations between BMI z-score and birth weight, the highest being in the 8–9 age group. When adjusted for urban–rural area, single child, fruit and vegetable intake, sugar-sweetened beverage, MVPA, sedentary time, and elevated blood pressure in model 2, the associations remained significant overall as well as in different age groups.

Table 4 presents the rate and OR for overweight and obesity on current weight by age groups. Overall, the HBW group revealed a significantly higher rate of

Table 3 Association between BMI z-score and birth weight in different age groups

	Model 1*			Model 2†		
	Standardised coefficients	95% CI	P value	Standardised coefficients	95% CI	P value
Birth weight	0.117	0.100 to 0.133	< 0.001	0.100	0.079 to 0.120	< 0.001
Age 6–7	0.121	0.082 to 0.160	< 0.001	0.145	0.091 to 0.198	< 0.001
Age 8–9	0.162	0.126 to 0.197	< 0.001	0.161	0.116 to 0.205	< 0.001
Age 10–11	0.134	0.090 to 0.179	< 0.001	0.103	0.048 to 0.158	< 0.001
Age 12–13	0.098	0.061 to 0.135	< 0.001	0.091	0.044 to 0.139	< 0.001
Age 14–15	0.090	0.045 to 0.134	< 0.001	0.102	0.043 to 0.161	0.001
Age 16–18	0.079	0.032 to 0.126	0.001	0.076	0.016 to 0.136	0.013

General linear regression model was used to calculate the association between BMI z-score (dependent variable) and birth weight (independent variable).

*Model 1 was unadjusted for any covariates.

†Model 2 was adjusted for urban–rural area, single child, delivery, fruit and vegetable intake, sugar-sweetened beverage, moderate and vigorous physical activity, sedentary time, and elevated blood pressure.

BMI, body mass index.

Table 4 OR of HBW group for overweight and obesity in different age groups

	NBW		Model 1†		Model 2‡		Model 3§	
	HBW group (n=4981)	group (n=4981)	OR†	95% CI	AOR‡	95% CI	AOR§	95% CI
	n (%)	n (%)						
Overweight	760 (15.3)*	653 (13.1)	1.308*	1.167 to 1.467	1.242*	1.077 to 1.433	1.230*	1.056 to 1.432
Age 6–7	138 (15.8)	132 (15.2)	1.155	0.887 to 1.505	1.163	0.806 to 1.677	1.244	0.847 to 1.828
Age 8–9	177 (15.4)*	148 (12.9)	1.422*	1.118 to 1.808	1.492*	1.111 to 2.005	1.508*	1.102 to 2.062
Age 10–11	116 (18.2)*	88 (13.8)	1.566*	1.151 to 2.132	1.441	0.978 to 2.124	1.354	0.895 to 2.049
Age 12–13	160 (15.7)*	135 (13.3)	1.318*	1.026 to 1.693	1.123	0.823 to 1.534	1.043	0.739 to 1.471
Age 14–15	80 (12.3)	68 (10.4)	1.269	0.899 to 1.793	1.139	0.726 to 1.787	1.292	0.788 to 2.118
Age 16–18	89 (13.5)	82 (12.5)	1.160	0.839 to 1.604	1.155	0.779 to 1.711	1.078	0.700 to 1.659
Obesity	841 (16.9)	528 (10.6)	1.791*	1.591 to 2.016	1.673*	1.436 to 1.949	1.611*	1.368 to 1.897
Age 6–7	162 (18.6)*	108 (12.4)	1.658*	1.276 to 2.168	1.692*	1.158 to 2.470	1.741*	1.167 to 2.596
Age 8–9	266 (23.2)*	162 (14.1)	1.952*	1.567 to 2.431	1.954*	1.456 to 2.622	1.844*	1.343 to 2.531
Age 10–11	134 (21.0)*	89 (13.9)	1.789*	1.325 to 2.415	1.867*	1.270 to 2.744	1.813*	1.203 to 2.730
Age 12–13	141 (13.9)*	86 (8.5)	1.823*	1.369 to 2.428	1.628*	1.116 to 2.373	1.641*	1.078 to 2.496
Age 14–15	65 (10.0)*	37 (5.7)	1.896*	1.244 to 2.889	1.837*	1.070 to 3.153	1.986*	1.097 to 3.597
Age 16–18	73 (11.1)*	46 (7.0)	1.696*	1.150 to 2.502	1.546	0.922 to 2.593	1.256	0.705 to 2.238

ORs of the HBW group for overweight and obesity were assessed by multivariate logistic regression with the dependent variable (overweight or obesity) and independent variable (birth weight).

*P<0.05.

†Model 1 was unadjusted for any covariates.

‡Adjusted for urban–rural area, single child, delivery, fruit and vegetable intake, sugar-sweetened beverage, moderate and vigorous physical activity, sedentary time, and elevated blood pressure.

§Further adjusted for paternal and maternal education level, hypertension, diabetes and obesity.

AOR, adjusted OR; HBW, high birth weight; NBW, normal birth weight.

overweight and obesity than those in the NBW group, and the OR was 1.308 (95% CI 1.167 to 1.467) and 1.791 (95% CI 1.591 to 2.016), respectively. After adjusting for confounding factors in models 2 and 3, slightly decreased but still significant associations were observed with an adjusted OR (AOR) of 1.230 (95% CI 1.056 to 1.432) for overweight and 1.611 (95% CI 1.368 to 1.897) for obesity. In different age groups, the results were similar, and AOR in the 8–9 age group for overweight and in most age groups for obesity remained significant. The results were similar in sensitivity analyses with different thresholds for HBW, which are displayed in online supplementary table 1.

DISCUSSION

We evaluated the associations of HBW and overweight and obesity using cross-sectional survey from seven provinces in China. In the present study, HBW was significantly associated with an increased risk of overweight and obesity among Chinese children and adolescents before and after adjusting for the covariables. More specifically, we found the 8–9 age group with HBW had the highest adjusted risk of 1.508 for overweight, and all age groups except age 16–18 with HBW had a higher risk for obesity.

Birth weight is commonly regarded as an important indicator for depicting development status in intra-uterine environments. A meta-analysis gathering 643 902 persons from 66 studies, aged 1–75, has proved that low birth weight and HBW were followed by opposite long-term effects on overweight compared with NBW, with HBW predisposed to overweight in later life with an OR of 1.66 (95% CI 1.55 to 1.77).²⁷ Many studies have also verified high level of birth weight as one strong predictor of obesity among children or adolescents.^{25 26} However, most studies in China, to our knowledge, were limited to one specific age group or one provincial area, which cannot reveal the overall association among children and adolescents more broadly. In this study, a significantly positive association between HBW and overweight and obesity was concluded, which is consistent with the results of previous studies.^{27–29} There are some possible explanations for the association. One possible explanation is that hypernutrition in pregnancy led to the increase of lean body mass or fat mass in the fetus, which might play an important role in obesity.^{30 31} Another explanation is that birth weight might modify the genetic predisposition and thus affect the risk of obesity later in life.^{32 33} Even though underlying mechanisms have been raised, there is no systematic explanation for birth weight and obesity. How

birth weight affects obesity is a complex process within the life course and warrants further study.

Weight management during pregnancy was reported to be an effective way to control birth weight,^{20 21 34} and evidence had proved that excessive gestational weight gain may lead to HBW and large-for-gestational age infants.^{35 36} The Institute of Medicine in the USA revised the gestational weight gain guidelines in 2009, encouraging health professionals and mothers to manage weight gain by following healthy dietary recommendations and increasing PA,³⁶ and noted phone-based interventions can help pregnant women control gestational weight gain by providing guidance, reminders and educational materials.³⁷ Other factors such as sedentary time might also influence the risk of obesity in children and adolescents.¹⁵ Some studies focused on the interactions of birth weight and diet and behavioural factors,^{27 28} and Ren *et al*²⁹ also found the synergy effects of HBW and unhealthy diet on increased risk of obesity. Thus diet intervention studies on children with HBW are needed in the future.

There are three limitations to this study. First, data on birth weight were retrospectively obtained from their parents using a questionnaire. In this way, there was a possibility of memory bias. However, we have tried to weaken the bias by collecting information on their certificate or the health clinic card, then repeating the survey after 6 months. Subjects with a difference in birth weight of over 10% in the two investigations were excluded from the study. Second, using dietary recall over the last 7 days may be a less accurate method for daily intake of fruits and vegetables and sugar-sweetened beverage consumption, which may also influence the results. Third, some maternal confounders were not adjusted in the study because those factors were not collected in the survey, such as maternal age of pregnancy and gestational weight gain, which may also influence the results.

CONCLUSION

This study explored the association of HBW with overweight and obesity among students aged 6–18 years based on a national cross-sectional survey in China. The results showed that HBW was positively associated with overweight and obesity in children. Most younger age groups with HBW were found to have a higher risk of overweight and obesity in childhood, with birth weight remaining positively associated with higher BMI z-score even after the adjustment. This study indicated that HBW is a high-risk factor for overweight and obesity in children, and thus measures to control birth weight, such as controlling gestational weight gain, should be taken as they may play an important role in the prevention and control of childhood overweight and obesity.

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Competing interests None declared.

Patient consent for publication Obtained.

Ethics approval This study was approved by the Medical Ethical Committee of the Peking University (IRB00001052-13034), and written informed consent was given by all students and their guardians before the baseline survey commenced.

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