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The association of high birth weight with overweight and obesity in Chinese students aged 6 to 18 years: a national cross-sectional study in China.

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The association of high birth weight with overweight and obesity in Chinese students aged 6 to 18 years: a national cross-sectional study in China.

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Abstract

Objectives: This paper aims to evaluate the association of high birth weight (HBW) with overweight and obesity in Chinese students aged 6-18 years.

- Methods: All the students with HBW (n=4981) were selected from a national intervention program against obesity in Chinese students aged 6-18 years, and other 4981 students with normal birth weight were randomly sampled with matched gender and age. Anthropometric parameters were measured and characteristics were collected by questionnaires. *Multi-variance logistic regression was used to estimate the odds ratio (OR) of overweight and obesity and high birth weight in unadjusted and adjusted for confounding factors.*
- **Results:** Students aged 6-18 years with HBW revealed higher body mass index (BMI) values in childhood. The prevalence of overweight and obesity was significantly higher in HBW group than normal group in both sexes (boys: 16.8% versus 14.6%; 20.0% versus 12.7%; girls: 13.0% versus 10.8%; 12.1% versus 7.4%). Additionally, birth weight was positively associated with overweight and obesity in both genders [boys: OR 1.24 (1.05-1.47); OR 1.61 (1.36-1.92); girls: OR 1.31 (1.05-1.62); OR 1.66(1.30-2.13)] after adjustment for covariates.

Conclusions: HBW may lead to childhood overweight and obesity in this study, and early health education before and during pregnancy should be paid more attention to in the prevention of overweight and obesity.

Key Words: high birth weight; body mass index; overweight; obesity

Trial registration: January 22, 2015; Registration number: NCT02343588

Strength and limitation of this study

- This study used a national multi-centered sample covering all-age children and adolescents in school
 - The 1:1 matching of gender, age and province in birth weight was used to enhance the study.
 - This study offered evidence for early prevention of obesity.
 - The way of collecting birth weight is a limitation of the study.

Introduction

Overweight and obesity in childhood has become a critical health issue with the continuous increase of prevalence worldwide [1], especially in China [2, 3]. The prevalence of obesity in Chinese students aged 7-18 years has increased from 0.1% in 1985, 2.6% in 2000 to 5.0% in 2010 [4], and the prevalence of overweight increased from 6.3% in 1991, 8.8% in 2000 and to 17.1% in 2011[5]. Overweight and obesity were considered as high-risk factors of cardiovascular and metabolic complications [6-8], and students with overweight and obesity were more likely to suffer physical and psychosocial problems in adulthood [9-11].

The hypothesis of Developmental Origins of Health and Disease (DOHaD), focusing on the early developmental phase of life, has offered a new way to the mechanism of overweight and obesity [12-13]. The hypothesis stated that adverse influence in intrauterine life can led to permanent readjustments in physiology and metabolism, which further caused increased risk of diseases in later life [13-14].

In childhood and puberty, the association between birth weight and obesity has been continually
observed in cross-sectional [15-16], longitudinal [17] and cohort [18] studies. Most study has found that high birth weight was related to elevated risk of obesity in children or adolescents [15-18]. One study focusing on primary school students found high birth weight (≥4000 g) was significantly associated with higher risk of overweight and obesity (OR=2.48, 95% CI: 1.62-3.81)
[19]. A Chinese study focusing on the large-scale population divided the subjects by 500 g intervals in birth weight, and found positive results in high birth weight (compared with 3000-3499 g group, 4000-4499 g: OR=1.39, 95% CI: 1.19-1.63; 4500-4999 g: OR=1.36, 95% CI: 1.06-1.76) [15]. However, another cohort study found no significant association between high birth weight and obesity after adjusted for parental education level and parental obesity [20]. Moreover, to our knowledge, very few studies focused on Chinese school-age children and adolescents aged 6-18 years, and a national multi-centered study has not been reported yet.

Using the data from a national school-based health lifestyles intervention program against obesity among Chinese children, 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 BMI z-score.

Methods

Sample and Participants

The sampling was based on a national multi-centered intervention trial against obesity involving nearly 70, 000 children and adolescents aged 6–18 years from 7 provinces in China (Liaoning, Tianjin, Ningxia, Shanghai, Chongqing, Hunan, and Guangdong), which covered all seven geographical areas of China. The protocol of the cluster randomized controlled trial was previously published [21]. 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 investigation.

Given the most common criteria of macrosomia [22], all the students aged 6-18 years with birth weight over 4.0 kg (n=4981) were selected from the baseline database of the national intervention program against obesity in Chinese students, and other 4981 students with normal birth weight (2.5 kg \leq birth weight < 4.0 kg) were randomly sampled with matched age, gender and province. Finally, 9962 students including 4981 students in HBW group and 4981 students in normal group

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90 were enrolled in the present study.

Birth weight data

Birth weight was collected using a standard parent questionnaire. Parents were required to record their children's birth weight of children based on the record of birth certificate or health clinic. If they do not have, they were asked to recall the birth weight based on the measurements
by themselves. About 70.9% of parents of participants were required to record the information of birth weight based on the health clinic card or birth certificate, and the proportions in the HBW group and normal birth weight group were 73.4% (3655/4981) and 68.4% (3406/4981), respectively. To ensure the reliability of birth weight data, parents were asked to repeat the same process of questionnaire survey six months later. The error in birth weight value between the baseline and six months later was lower than 10% and participants with the 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 in line with the standardized procedure. During the measurement, students were asked
to stand straight in light clothing and without shoes. A portable stadiometer and a lever type weight scale were validated and used to measure height and weight, respectively. Height was measured to the nearest 0.1 cm and weight was measured to the nearest 0.1 kg. The mean value for both height and weight was recorded after measuring twice. When rechecking 5% of students, the error was less than 10% or otherwise all students were re-measured according to the protocol.
Body mass index (BMI) was calculated as body weight divided by height (m) squared (kg/m²), and overweight and obesity were defined using the cut-offs references developed by the Working Group on Obesity in China (WGOC) [23].

Blood pressure was measured using a standardized mercury sphygmomanometer (model XJ1ID) recommended by 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 implemented after students were seated easefully for no less than 5 minutes, and the students were 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. An average of twice blood pressure measurement was recorded in this study. Elevated blood pressure in children and adolescents was defined as SBP or DBP or both are higher than the corresponding cut-offs. The cut-offs were age-, gender- and height-percentile-specific recommended by NHBPEP Working Group in 2004[24].

Questionnaires

- 125 Self-developed child-reported and parent-reported questionnaires were designed to collect information of obesity-related factors. Child-reported questionnaires were filled by students in the classroom with the interpretation by trained research staff, except that children under the third grade completed questionnaires at home with guardians' assistance. Parent-reported questionnaires were all finished by students' guardians.
- 130 Child-reported questionnaires contained diet intake (fruit, vegetable and sugar-sweetened beverage), moderate physical activity (PA), vigorous PA, sedentary time of students. For diet intake, students were asked how many days they eat fruits, vegetables or drink sugar-sweetened beverages and how many servings or cups for each day in the past 7 days. The average intake was

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calculated: (days × servings/cups for each day)/7. One serving of fruits and vegetables was both
defined as the amount of one fist of adults, while one cup of sugar-sweetened beverage as almost
250 ml. Moderate PA and vigorous PA 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
(e.g. walking) while vigorous PA included high-load activities on musculoskeletal tissues in the
body (e.g. sports and games)[25]. Sedentary time, consisting of doing homework, watching TV
and using a computer, asked how many days and how many hours for each day)/7 for each portion,
the average sedentary time was the sum of homework, TV and computer time.

Parent-reported questionnaire collected child's birth information (delivery, single birth or not and breast-feeding), single child or not, socioeconomic status (patents' education levels) and family history (hypertension, diabetes, obesity). Delivery mode included spontaneous delivery and cesarean delivery. Breast-feeding was categorized as ≥1 month and <1 month. Socioeconomic status was featured in education levels of children's parents, involving 3 levels: primary school or below, secondary school, and college or above. Family history covered parents' history in hypertension, diabetes and obesity in this study. Whether diagnosed with hypertension or diabetes was directly answered 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 reference [26].

Statistical Analyses

All the analyses were performed by IBM SPSS Statistics 22.0 (IBM Corp., Armonk, NY, USA). Age, birth weight, height, weight, BMI, DBP, SBP, sweet drinks, MVPA were recorded as the mean value (SD). Gender, delivery, single birth, breast feeding, elevated blood pressure, parental education, and family history were displayed as categorical variables (the number and percentage). *T*-test was conducted for the P value of BMI between HBW group and normal group by gender and age group and *Chi-square* test was verified for the percentage of overweight and obesity. Multivariate logistic regression was used to calculate the odds ratios (*OR*) and 95% confidence intervals (*CI*) of different birth weight groups for overweight and obesity by gender and age group, further adjusted for province, urban-rural area, single child, delivery, sedentary time, elevated blood pressure, paternal education level, maternal education level, paternal obesity, maternal obesity and maternal diabetes in different models. 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, 4981 in
study group (macrosomia) and 4981 in control group (normal birth weight). The distribution of characteristics in two groups was presented in Table 1. Gender and age were controlled in the design and thus there was no difference (*P*>0.05). The mean value of birth weight was 4.22±0.29 kg in study group and 3.24±0.36 kg in control group. Students in study group was observed with higher BMI average than those in control group (19.57 kg/m2 >18.64 kg/m2, P<0.001). Among all those factors, urban area, single child, spontaneous delivery, single birth, gestational age, fruit, family history (hypertension, diabetes and obesity) showed significant difference between study group and control group (*P*<0.05).

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As presented in Table 2, students in HBW group revealed higher BMI values than those in normal group. Boys in HBW group were observed with significantly higher BMI than in normal group (HBW group: 19.80±4.26 kg/m²; normal group: 18.77±3.86 kg/m²; P<0.001). The similar result was found among girls (HBW group: 19.21±3.95 kg/m²; normal group: 18.45±3.50 kg/m²; P<0.001). When categorized by gender and age, BMI in all sub-groups were observed higher in HBW group than in normal group and all difference was statistically significant except for 6~7 age group and 8~9 age group in girls.
185 The associations between birth weight and BMI z-score in boys and girls were documented in

The associations between birth weight and BMI z-score in boys and girls were documented in Table 3. Both boys and girls were observed with a significant association between BMI z-score and birth weight (β=0.253 for boys, 95% CI: 0.211-0.296; β=0.210 for girls, 95% CI: 0.157-0.264). When adjusted for province, urban-rural area, single child, delivery, sedentary time, elevated blood pressure, paternal education level, maternal education level, paternal obesity, maternal diabetes in Model 2, the associations remained to be significant both in boys and girls.

Table 4 presented the rate and odds ratio (OR) for overweight and obesity on current weight by gender and age. Overall, both boys and girls revealed a significantly higher rate of overweight and obesity in HBW group than those in normal group and the *OR* was 1.32 (95% *CI*: 1.14-1.52) and 1.81 (95% *CI*: 1.57-2.09) for boys and 1.31 (95% *CI*: 1.08-1.60) and 1.79 (95% *CI*: 1.44-2.23) for girls, respectively. After adjusted for province, urban-rural area, single child, delivery, sedentary time, elevated blood pressure in Model 2 and further adjusted for paternal education level, maternal education level, paternal obesity, maternal obesity and maternal diabetes in Model 3, both boys and girls of *OR* remained significant. Finally a slightly decreased but still significant association was observed with the *OR* of 1.24 (95% *CI*: 1.05-1.47) and 1.61 (95% *CI*: 1.36-1.92) for boys and 1.31 (95% *CI*: 1.05-1.62) and 1.66 (95% *CI*: 1.30-2.13) for girls.

Discussion

We evaluated the association of high birth weight and overweight and obesity using the baseline
database of a school-based intervention program in China. In the present study, high birth weight was significantly associated with the increase risk of overweight and obesity among Chinese children and adolescents after adjusting for the co-variables. More specifically, we found boys born with HBW were at an increasing risk of 1.24 and 1.61 times for overweight and obesity than those with normal birth weight, and girls born with HBW had a higher risk of 1.31 and 1.66 for overweight and obesity, respectively.

A significantly positive association between high birth weight and overweight and obesity was concluded in this study, which consists with the results in previous studies [27-29]. A meta-analysis gathering 643,902 persons aged 1 to 75 from 66 studies has proved that low birth weight and high birth weight were followed by opposite long-term effects on overweight compared with normal birth weight, and high birth weight predisposed for overweight in later life with OR of 1.66 (95% CI 1.55~1.77) [27]. Many studies also have verified high level of birth weight as one strong predictor of obesity among children or adolescents. A 12-country study assessed the full range of birth weight with obesity in children aged 9-11 and found high birth weight (≥ 4.0kg) was associated with increased odds of 2.08 (95% CI 1.47~2.93) on obesity [28].
220 Ren et al. [29] matched the exposed group with the non-exposed group by birth, gender, and type of institute at birth in Wuxi, China, which is the same as our study. Even though those studies have

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explored the association between high birth weight and overweight or obesity, most studies in China, to our knowledge, have limited in one specific age group or one parochial area, which cannot reveal the overall association among children and adolescents aged 6-18 in China. This study was based on a national multi-centered intervention trial against obesity involving nearly 70, 000 children and adolescents in China, recruited a national representative samples ranging from 6 to 18 years old, which possibly avoided any missing in age or region.

The association of low birth weight and obesity was not evaluated in our study. However, no consistent result was reached in that filed [15, 27, 30]. Some studies verified that low birth weight had the same effect as high birth weight on obesity [30], while others found no significant association [27] or low birth weight was the protective factor for obesity [15]. One possible reason for those contradictions was the small sample. Birth weight seemed to be higher because of the better nutritious environment during the pregnancy [31], thus leading to lower prevalence of low birth weight and higher prevalence of macrosomia.

Other factors such as sedentary time might also influence the risk of obesity in children and adolescents [12]. Some studies focused on the interaction of birth weight and diet and behavioral factors [27-28]. No interaction between high birth weight and physical activity was found in the two studies. However, Ren and his colleagues found the synergy effect of high birth weight and unhealthy diet on the high risk of obesity [29]. Thus high birth weight students were more likely to be the targeted population for diet intervention.

Birth weight is commonly regarded as an important indicator to depict development status in intrauterine environments [13-14]. The mechanism of how birth weight influences overweight and obesity in later life has also been explored [32-34]. Even though obesity-associated gene expression was found positively associated with birth weight, no systematic explanation for birth 245 weight and obesity has been given. This may be one way for further study. One possible explanation was that hyper-nutrition in pregnancy led to the increase of lean body mass or fat mass in the fetus, which might play an important role in obesity [34-35]. Another way was that birth weight might modify the genetic susceptibility in the later life and thus affected the risk of obesity [32-33]. Even though underlying mechanisms were raised, no systematic explanation for birth 250 weight and obesity has been given. How birth weight affected obesity was a long process of life for further study.

There are two limitations in this study. Firstly, the information of birth weight was retrospectively obtained from their parents by questionnaire. In this way, there was possibly memory bias. However, we have tried to weaken the bias though collecting information on their certificate or the health clinic card and repeating the survey after six months. Subjects with difference of birth weight in the two investigations over 10% were eliminated in the study. Secondly, 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.

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Conclusion

This study explored the association of HBW with overweight and obesity among students aged 6-18 years, based on a national survey of seven provinces in China. The results showed that high birth weight was positively associated with overweight and obesity in children. Both boys and girls with HBW held a higher risk of overweight and obesity in childhood, and birth weight

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remained positively associated with higher BMI z-score even after the adjustment. This study indicates that HBW is a high-risk influence factor of overweight and obesity in children, and thus early intervention of intrauterine environments is necessary in the prevention and control of overweight and obesity.

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275 Contributors

ZZY and YZP contributed equally to this paper. JM and YM were both co-corresponding authors.

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Competing interests

None of the authors had any personal or financial conflict of interest.

285 Ethics approval

Medical Ethical Committee of the Peking University

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44 45			cardiovascular disease[J]? Am J Cli	in Nutr, 2003, 77:726–730.		
45			Table 1. Char	racteristics of study subjects	in the study	
47				HBW group	Normal group	D
48				(4981)	(4981)	1
49 50	Μ	lale, n	(%)	3014 (60.5)	3014 (60.5)	
51	А	ge (ye	ear) / mean \pm SD	11.04 ± 3.34	11.00 ± 3.34	0.541
52	U	rban a	urea, n (%)	3209 (64.4)	2849 (57.2)	< 0.001
53 54	Si	ingle o	child, n (%)	3095 (62.1)	3377 (67.8)	< 0.001
55	В	irth iı	nformation			
56]	Birth v	weight (kg) / mean \pm SD	4.22 ± 0.29	3.24 ± 0.36	< 0.001
57				9		
58 59						

Caesarean birth, n (%)	2499 (48.9)	2149 (39.6)	< 0.001
Single birth, n (%)	4792 (98.1)	4594 (97.1)	< 0.001
Breast feeding, n (%)	4244 (86.6)	4047 (85.4)	0.089
Anthropometry, mean ± SD			
Height (cm)	148.59 ± 17.01	146.29 ± 17.06	< 0.001
Weight (kg)	44.74 ± 16.89	41.38 ± 15.47	< 0.001
WC (cm)	67.41 ± 11.46	65.04 ± 10.76	< 0.001
Systolic pressure (mmHg)	105.70 ± 12.11	105.28 ± 12.12	0.086
Diastolic pressure (mmHg)	66.71 ± 8.56	66.50 ± 8.67	0.228
Body mass index (kg/m ²)	19.57 ± 4.15	18.64 ± 3.72	< 0.001
Diet and physical activity, mean \pm SD			
Fruit (serving/day)	1.28 ± 1.06	1.22 ± 1.02	0.012
Vegetable (serving/day)	1.81 ± 1.44	1.78 ± 1.42	0.430
Sugar-sweetened beverage (cup/day)	0.44 ± 0.78	0.42 ± 0.76	0.226
Moderate PA (hour/day)	0.52 ± 0.81	0.49 ± 0.80	0.098
Vigorous PA (hour/day)	0.47 ± 0.74	0.46 ± 0.75	0.566
Sedentary time (hour/day)	5.83 ± 3.71	5.75 ± 3.74	0.305
Socioeconomic status, n (%)			
Parental education level			
none/primary	409 (8.4)	379 (8.1)	0.050
secondary	3172 (65.3)	3100 (65.9)	0.859
college and above	1274 (26.2)	1227 (26.1)	
Maternal education level			
none/primary	540 (11.1)	457 (9.8)	
secondary	3177 (65.5)	3155 (67.3)	0.464
college and above	1137 (23.4)	1073 (22.9)	
Family history, n (%)			
Parental hypertension	214 (4.5)	200 (4.4)	0.745
Maternal hypertension	151 (3.2)	95 (2.1)	0.001
Parental diabetes	69 (1.5)	61 (1.4)	0.614
Maternal diabetes	62 (1.4)	27 (0.6)	< 0.001
Parental obesity	623 (13.1)	519 (11.4)	0.012
Maternal obesity	311 (6.5)	182 (4.0)	0.000

Group		H	IBW group)	N	ormal grou	ıp	מ
		Ν	Mean	SD	N	Mean	SD	P
	6~7	551	17.44	2.86	551	16.59	2.84	< 0.00
Boys	8~9	729	18.73	3.68	729	17.53	3.22	< 0.00
	10~11	401	20.17	4.22	401	18.55	3.63	< 0.00
	12~13	621	20.88	4.27	621	19.94	3.97	< 0.00
	14~15	352	21.05	4.32	352	20.20	3.46	0.004
	16~18	360	22.08	4.78	360	21.43	4.01	0.047
	total	3014	19.80	4.26	3014	18.77	3.86	< 0.00
	6~7	320	16.35	2.64	320	15.97	2.35	0.052
	8~9	419	17.69	3.26	419	16.70	2.88	< 0.00
	10~11	237	18.68	3.35	237	18.20	3.35	0.123
Girls	12~13	395	19.92	3.68	395	19.20	3.18	0.004
	14~15	299	21.19	3.67	299	20.24	2.98	0.001
	16~18	297	21.91	4.08	297	21.01	3.27	0.003
	total	1967	19.21	3.95	1967	18.45	3.50	< 0.00

Table 3. The association between birth weight and BMI z-score in boys and girls by general linear regression model

		Model 1 ^a			Model 2 ^b	
	β	95% CI	Р	β	95% CI	Р
Boys (n=6028)		•				
Normal birth weight	Ref			Ref		
High birth weight	0.276	0.226-0.326	< 0.001	0.221	0.157-0.286	< 0.001
Birth weight ^c	0.253	0.211-0.296	< 0.001	0.234	0.178-0.290	< 0.001
Girls (n=3934)						
Normal birth weight	Ref			Ref		
High birth weight	0.225	0.163-0.287	< 0.001	0.212	0.131-0.292	< 0.001
Birth weight ^c	0.210	0.157-0.264	< 0.001	0.198	0.128-0.268	< 0.001

^a Model 1 was unadjusted for any covariates.

^b Model 2 was adjusted for province, urban-rural area, single child, delivery, sedentary time, elevated blood pressure, paternal education level, maternal education level, paternal obesity, maternal obesity,

maternal diabetes.

^c Continuous variable.

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		study group (n=4981)	control group (n=4981)	М	odel 1 ^a	М	odel 2 ^b	М	odel 3 ^c
	-	n (%)	n (%)	OR	95% CI	OR	95% CI	OR	95% Cl
Boys (n=	5028)								
Overwe	eight	505 (16.8)	441 (14.6)	1.32*	1.14-1.52	1.27^{*}	1.09-1.49	1.24*	1.05-1.4
Obesity	/	603 (20.0)	383 (12.7)	1.81*	1.57-2.09	1.80^{*}	1.53-2.11	1.61*	1.36-1.9
Girls (n=3	3934)								
Overwe	eight	255 (13.0)	212 (10.8)	1.31*	1.08-1.60	1.31*	1.07-1.60	1.31*	1.05-1.6
Obesity	/	238 (12.1)	145 (7.4)	1.79^{*}	1.44-2.23	1.78^{*}	1.42-2.23	1.66*	1.30-2.1
380	^c In Mand II mater	I pressure for bo fodel 3, boys we maternal diabete rnal obesity and	ys, and single child, ere further adjusted es, while girls furth maternal diabetes.	delivery, for patern her adjust	elevated blood p al education leve red for maternal	oressure for el, paternal l education	girls. obesity, matern level, paterna	al obesity al obesity,	
505	1								



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The association of high birth weight with overweight and obesity in Chinese students aged 6 to 18 years: a national cross-sectional study in China

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Abstract

Background: Childhood overweight and obesity prevalence in China has drastically increased 57 times during the past 30 years, and to control birth weight was an effective way to reduce the risk of overweight and obesity across the lifecourse.

Objectives: This paper aims to evaluate the association of high birth weight (HBW) with overweight and obesity in Chinese students aged 6-18 years.

Methods: All the students with HBW (n=4981) aged 6-18 years were selected from a cross-sectional survey from 7 provinces in China, and other 4981 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 odds ratio (OR) of overweight and obesity with high birth weight in unadjusted and adjusted for confounding factors.*

- Results: Students aged 6-18 years with HBW revealed higher body mass index (BMI) values in childhood. The prevalence of overweight and obesity was significantly higher in HBW group than NBW group (overweight 15.3% versus 13.1%, p<0.05; obesity 16.9% versus 10.6%, p<0.05), and results were similar in all age groups except age 6-7, age 14-15 and age 16-18 for overweight. Additionally, HBW was positively associated with overweight (OR=1.230; 95%CI: 1.056-1.432) and obesity</p>
- 35 (OR=1.611; 95%CI: 1.368-1.897) after adjustment for covariates.
 Conclusions: HBW may lead to childhood overweight and obesity in this study, thus weight management during pregnancy to control children's birth weight may play an important role in the prevention and control of childhood overweight and obesity.
- **Key Words:** high birth weight; body mass index; overweight; obesity

Trial registration: January 22, 2015; Registration number: NCT02343588

Strength and limitation of this study

- This study used a national multi-centered sample covering all-age children and adolescents in school.
- The 1:1 matching of gender, age and province in birth weight was used to enhance the study.
- Some maternal information 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 six months which may have recall bias.

Introduction

Overweight and obesity in childhood has become a critical health issue with the continuous increase of 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 2011[5]. Overweight and obesity are considered high-risk factors of cardiovascular and metabolic complications [6-8], and students with overweight and obesity were more likely to suffer physical and psychosocial problems in adulthood [9-11]. Previous studies have shown that an improvement to physical activity or dietary intake can produce stronger effects than those without it, while the number of health behaviors 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 lifestyles, the family environment as well as heavy marketing of unhealthy food products [13-14].

The hypothesis of Developmental Origins of Health and Disease (DOHaD) that adverse influence in intrauterine life can lead to permanent readjustments in physiology and metabolism, which further caused increased risk of diseases in later life. Thus, focusing on the early developmental phase of life, offered a new way to 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], longitudinal [18] and cohort [19] 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 before and during pregnancy could be effective to reduce the risk of HBW, which means a balanced diet with low glycemic load, light to moderate intensity physical activity, and moderate weight gain during pregnancy [20-21]. However, very few studies have focused on Chinese school-age children aged 6-18 years, nor they have accounted for regional difference and provincial disparities, thus a multicenter study is needed to clarify the associations.

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Using the baseline survey data from 7 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 BMI z-score.

Sample and Participants

Methods

The sampling was based on a cross-sectional baseline survey from 7 provinces in China (Liaoning, Tianjin, Ningxia, Shanghai, Chongqing, Hunan, and Guangdong) prior to the commencement of a national multi-centered intervention trial beginning, and these provinces covered all seven geographical areas of China. The protocol of the cluster randomized controlled trial was previously published [22]. This study was **BMJ** Open

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 commence.

Using the most common criteria of high birth weight (HBW) [16,18-19], all the students aged 6-18 years with birth weight over 4.0 kg (n=4981) were selected from the baseline survey in 65 347 students, and other 4 981 students with normal birth weight (NBW, 2.5 kg ≤ birth weight < 4.0 kg) were randomly sampled with matched age, gender and province. Finally, 9 962 students including 4 981 students in HBW group and 4 981 students in NBW group were enrolled in the present study, and were further divided into six groups 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-offs references developed by the Working Group on Obesity in China (WGOC) [23].

Birth weight data

Birth weight was collected using a standard parent questionnaire. Parents were required to record their children's birth weight based on the record of birth certificate or health clinic. If they did not have, 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 NBW group were 73.4% (3655/4981) and 68.4% (3406/4981), respectively. To ensure the reliability of birth weight data, parents were asked to repeat the same process of questionnaire survey six months later. The error in birth weight value between the baseline and six months later was lower than 10% and participants with the 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 the standardized 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 students, the error was less than 10% or if higher all students were re-measured according to the protocol. Body mass index (BMI) was calculated as body weight divided by height (m) squared (kg/m²),

Blood pressure was measured using a standardized mercury sphygmomanometer
(model XJ1ID) recommended by 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 minutes, 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

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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 are higher than the corresponding cut-offs. The cut-offs were age-, gender- and height-percentile-specific was recommended by NHBPEP Working Group in 2004[24].

Questionnaires

The research team developed self-reported questionnaires for children and prarents to collect information of obesity-related factors. Child-reported questionnaires were filled by students in the classroom with the interpretation by trained research staff, with the exception that children at the third grade or under in primary school completed 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 physical activity (PA), vigorous PA, sedentary time of students. For diet intake, students were asked how many days they eat fruits, 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 \times 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 as almost 250 ml. 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 $(\text{days} \times \text{hours for each day})/7$. Moderate PA included light activities (e.g. walking) while vigorous PA included high-load activities on musculoskeletal tissues in the body (e.g. sports and games)[25]. Sedentary time, consisting of doing homework, watching TV and using a computer, asked how many days and how many hours for the three separate activities over the past 7 days. Following the calculation of $(days \times hours for each day)/7$ for each activity, the average sedentary time was the sum of homework, TV and computer time.

Parent-reported questionnaire collected the child's birth information (delivery, single birth or not and breast-feeding), single child or not, socioeconomic status (patents' education levels) and family history (hypertension, diabetes, obesity). Delivery mode included spontaneous delivery and cesarean delivery. Breast-feeding
was categorized as ≥6 month and <6 month. Socioeconomic status was defined as education levels of children's parents, involving 3 levels: primary school or below, secondary school, and college or above. In this study, family history covered parents' history in hypertension, diabetes and obesity in this study. This was established through a diagnoses 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 they involved in the recruitment and conduct of the study. School doctors and class teachers help us to organize and maintain order of the physical examination by class held in the school.

Statistical Analyses

Epidata Software Version 3.02 was used to do data entry, and all the analyses were performed by IBM SPSS Statistics 22.0 (IBM Corp., Armonk, NY, USA). Age, birth weight, height, weight, BMI, DBP, SBP, sweet drinks, MVPA were recorded as the mean value (SD). Gender, delivery, single birth, breast feeding, elevated blood pressure, parental education, and family history were displayed as categorical variables (the number and percentage). T-test was conducted for the P value of BMI between HBW group and normal group by gender and age group and Chi-square test was verified for the percentage of overweight and obesity. Multivariate logistic regression was used to calculate the odds ratios (OR) and 95% confidence intervals (CI) of different birth weight groups for overweight and obesity by age group. This was further adjusted for urban-rural area, single child, delivery, food intake and physical activity, sedentary time, elevated blood pressure in Model 2, and adjusted for paternal and maternal education level, family history such as hypertension, diabetes and obesity in Model 3. Sensitivity analyses were conducted with different thresholds for HBW compared with NBW, which were displayed in 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 was 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 other three groups, students in 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). Results in Table 2 were similar between HBW obesity group and other three groups, except the rate of parental hypertension and parental diabetes was also significant higher (P<0.05).

The associations between BMI z-score and birth weight in different age groups were documented in Table 3. All age groups were observed with significant positive associations between BMI z-score and birth weight, highest in age 8-9 group. When adjusted for urban-rural area, single child, fruit and vegetable intake, sugar-sweetened beverage, moderate and vigorous physical activity, sedentary time, elevated blood pressure in Model 2, the associations remained significant in overall as well as different age groups.

Table 4 presented the rate and odds ratio (OR) for overweight and obesity on current weight by age groups. Overall, HBW group revealed a significantly higher rate of overweight and obesity in HBW group than those in NBW group and the OR was 1.308 (95% *CI*: 1.167-1.467) and 1.791 (95% *CI*: 1.591-2.016) respectively. After adjusting for confounding factors in Model 2 and in Model 3, a slightly

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decreased however still significant associations were observed with the AOR of 1.230 (95% *CI*: 1.056-1.432) for overweight and 1.611 (95% *CI*: 1.368-1.897) for obesity. In different age groups, the results were similar, and AOR in age 8-9 group for overweight and in most age groups for obesity remained significant. Results were similar in sensitivity analyses with different thresholds for HBW, which were 235 displayed in Supplementary Table 1.

Discussion

We evaluated the association of high birth weight and overweight and obesity using the cross-sectional survey from 7 provinces in China. In the present study, high birth weight was significantly associated with the increase risk of overweight and obesity among Chinese children and adolescents before and after adjusting for the co-variables. More specifically, we found age 8-9 group with HBW had the highest adjusted risk of 1.508 for overweight than those with NBW, 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 of depicting development status in intrauterine environments. A meta-analysis gathering 643,902 persons from 66 studies, aged 1 to 75, has proved that low birth weight and high birth weight were followed by opposite long-term effects on overweight compared with NBW, with high birth weight predisposed for overweight in later life with OR of 1.66 (95% CI 1.55-1.77) [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 high birth weight and overweight and obesity was concluded, which is consisted with the results of previous studies [27-29]. There are some possible explanations for the association. One possible explanation is that hyper-nutrition 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 affected 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 courses and warrants further study.

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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 high birthweight and large for gestational age infants[35-36]. The Institute of Medicine in US revised the gestational weight gain guidelines in 2009 encouraging health professionals and mothers to manage weight gain by following healthy dietary recommendations and increasing physical activity [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 interaction of birth weight and diet and behavioral factors [27-28], also Ren et al found the synergy effect of high birth weight and unhealthy diet on the high risk of obesity [29]. Thus diet intervention studies on children with HBW are needed in the future.

There are three limitations in this study. Firstly, the information of birth weight was retrospectively obtained from their parents by questionnaire. In this way, there was possibly memory bias. However, we have tried to weaken the bias though collecting information on their certificate or the health clinic card then repeating the survey after six months. Subjects with difference of birth weight in the two investigations over 10% were exclude in the study. Secondly, using dietary recall over last 7 days may be a less accurate method for daily intake of fruits, vegetables and sugar-sweetened beverages consuming, which may also influence the results. Thirdly, 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

290 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 high birth weight 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 remained positively associated with higher BMI z-score even after the adjustment. This study indicates that HBW is a high-risk influence factor of 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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Contributors

JM, Y Ma and ZZ conceived and designed the project; ZZ collected the data; ZZ and ZY analyzed the data and prepared the manuscript; ZY, XW, DG and YD were involved in writing the article and had a final approval of the submitted and published versions.

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Competing interests None declared.

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5 6 320	Ethics approval Medical Ethical Committee of the Peking University
7 8 9 10 11 12 13 14 15	Data sharing statement No additional data available
16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60	

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				n-2018-024532 yright, includin	
]	Table 1. Characteristics of st	udy subjects with normal	weight against overwe	ging on 22	
Baseline characteristics	NBW Normal group (3800)	NBW Overweight group (653)	HBW Normal group (3380)	HBW Enset HBW reight group ate (760)	P valı
Male, n (%)	2190 (57.6)	441 (67.5)	1906 (56.4)	to n D 505 (66.4)	<0.00
Age (year) / mean ± SD	11.16 ±0.05	10.76 ± 0.13	11.29 ± 0.06	te Sin 0.83 ± 0.12	<0.00
Urban area, n (%)	2146 (56.5)	388 (59.4)	2144 (63.4)	an pe 501 (65.9)	<0.00
Single child, n (%)	2488 (65.5)	479(73.4)	1966 (58.2)	d er d 524 (68.9)	< 0.0
Birth information				ata r	
Birth weight (kg) / mean \pm SD	3.22 ± 0.35	3.25 ± 0.36	4.21 ± 0.29	4.21± 0.26	< 0.0
Caesarean birth, n (%)	1330 (37.4)	269(43.7)	1424 (43.4)	ig · ig 420 (56.3)	< 0.0
Single birth, n (%)	3488 (97.0)	604 (98.1)	3242 (97.9)	A 3.739 (98.9)	0.00
Breast feeding, n (%)	3098 (86.0)	536 (86.3)	2887 (86.9)	rai 6 36 (85.1)	0.55
Anthropometry, mean \pm SD				ing,	
Height (cm)	146.08 ± 17.36	147.24± 16.49	148.44 ± 17.30	an $\frac{1}{10}$ $\frac{1}{1$	< 0.0
Weight (kg)	38.18 ± 13.00	48.30 ± 16.23	40.11 ± 13.13	s . 2 9.80 ± 16.69	< 0.0
WC (cm)	61.64 ± 8.09	72.51 ± 9.49	62.70 ±7.83	$\frac{1}{2}$ $\frac{1}$	< 0.0
Systolic pressure (mmHg)	103.88 ± 11.51	108.08 ± 12.121	103.98 ± 11.36	b 7.22 ± 12.17	<0.0
Diastolic pressure (mmHg)	65.71 ± 8.29	67.93 ± 8.99	65.78 ± 8.28	9 57.04 ± 8.55	<0.00
Body mass index (kg/m ²)	17.26 ± 2.39	21.47 ± 2.74	17.61 ± 2.32	b b 1.58 ± 2.71	<0.00
Diet and physical activity, mean \pm S	D			5 at gies	
Fruit (serving/day)	1.20 ± 1.03	1.25 ± 0.96	1.27 ± 1.08	$har l.20 \pm 0.95$	0.05
Vegetable (serving/day)	1.77 ± 1.40	1.79 ± 1.42	1.78 ± 1.43	6 1.78 ± 1.43	0.97
Sugar-sweetened beverage (cup/day)	0.42 ± 0.75	0.49 ± 0.92	0.45 ± 0.80	$\underline{\mathbf{B}}_{0}^{0.46 \pm 0.86}$	0.16
Moderate PA (hour/day)	0.49 ± 0.81	0.46 ± 0.72	0.52 ± 0.82	$\overline{000}.50\pm0.89$	0.19
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	Vigorous PA (hour/day)	0.47 ± 0.78	0.46 ± 0.65	0.47 ± 0.74	uding 20.49 ± 0.82	0.850
	Sedentary time (hour/day)	5.73 ± 3.76	5.75 ± 3.58	5.87 ± 3.73	572 + 376	0.442
	Socioeconomic status n (%)	0.10 - 0.10	0.10 - 0.00	0.07 - 0.70		0.112
	Parental education level				lay : nse es r	
	none/primary	313 (8 2)	55 (8 9)	313 (9.5)	elate 61 (8 2)	<0.001
	secondary	2407(67.3)	374 (60.6)	2207 (67.0)	ed m D 461 (62.4)	
	college and above	876 (24 5)	189 (30.5)	776 (23.5)	$6 \pi \sqrt{217} (294)$	
	Maternal education level				xt a	
	none/primary	369 (10.4)	57(9.3)	407 (12.4)	nd ded 73(9.9)	
	secondary	2417 (67.9)	392 (63.5)	2181 (66.3)	$a_{1} = f_{1}$	< 0.001
	college and above	772 (21.7)	168 (27.2)	702 (21.3)		
	Family history, n (%)			· · · · · · · · · · · · · · · · · · ·	s) .	
	Parental hypertension	144 (4.1)	27 (4.5)	128 (4.0)	2 3 7 (5.1)	0.558
	Maternal hypertension	66 (1.9)	17 (2.8)	95(3.0)	Tai b 25 (3.5)	0.014
	Parental diabetes	41 (1.2)	11 (1.9)	39 (1.2)	ning 14 (2.0)	0.251
	Maternal diabetes	17 (0.5)	4 (0.7)	31 (1.0)	ar <u>i</u> 11 (1.6)	0.017
	Parental obesity	176 (5.3)	49(8.5)	159 (5.1)	d s 59(8.6)	< 0.001
	Maternal obesity	108(3.2)	19 (3.3)	128 (4.1)	n 9 42 (6.1)	0.003
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Page 15 of 22				BMJ Open		/bmjopei	
1 2 3 4 5 6 425 7		Table 2. Cha	racteristics of	study subjects with norma	al weight against obesity	n-2018-024532 on 22 Ma vright, including for use	
8 9 10 11 12	Baseline characteristics	NBW group	Normal (3800)	NBW Obesity group (528)	HBW Normal group (3380)	reignemen Besity group (841)	P value
13	Male, n (%)	2190) (57.6)	383 (72.5)	1906 (56.4)	tex 2603 (71.7)	<0.001
14	Age (year) / mean \pm SD	11.1	6 ± 0.05	10.14 ± 0.13	11.29 ± 0.06	an e_{10} a_{00} a_{00} 23 ± 0.11	<0.001
15 16	Urban area, n (%)	2146	5 (56.5)	315 (59.7)	2144 (63.4)	a e f a 564 (67.1)	<0.001
17	Single child, n (%)	2488	8 (65.5)	410 (77.7)	1966 (58.2)		<0.001
18	Birth information					nini BES	
19 20	Birth weight (kg) / mean \pm SD	3.22	± 0.35	3.31 ± 0.35	4.21 ± 0.29	.	<0.001
20	Caesarean birth, n (%)	1330	0 (37.4)	256 (50.2)	1424 (43.4)	≥ 3534 (64.3)	<0.001
22	Single birth, n (%)	3488	8 (97.0)	502 (97.1)	3242 (97.9)	a i. b 811 (98.2)	0.511
23	Breast feeding, n (%)	3098	8 (86.0)	413 (79.7)	2887 (86.9)	ing 721(86.7)	0.017
24 25	Anthropometry, mean ± SD					, an	
26	Height (cm)	146.08	3 ± 17.36	146.62 ± 15.50	148.44 ± 17.30	s . 1 4 8.69 ± 15.87	<0.001
27	Weight (kg)	38.18	± 13.00	55.83 ± 19.37	40.11 ± 13.13	58.75 ± 20.96	<0.001
28	WC (cm)	61.64	1 ± 8.09	80.27 ± 11.25	62.70 ±7.83	t a .67 ± 11.63	<0.001
30	Systolic pressure (mmHg)	103.8	8±11.51	111.92 ± 13.43	103.98 ± 11.36	ີອີ 1991.24 ± 13.10	<0.001
31	Diastolic pressure (mmHg)	65.7	± 8.29	70.43 ±9.59	65.78 ± 8.28	8 2 0 .15 ± 8.78	<0.001
32	Body mass index (kg/m ²)	17.20	5 ± 2.39	25.09 ± 3.94	17.61 ± 2.32	$a_{5.62} \pm 4.26$	<0.001
33 34	Diet and physical activity, mean \pm SI	D				Ag	
35	Fruit (serving/day)	1.20	± 1.03	1.32 ± 1.03	1.27 ± 1.08	36 ± 1.09	< 0.001
36	Vegetable (serving/day)	1.77	± 1.40	1.90 ± 1.57	1.78 ± 1.43	፼ <u>ਯ</u> .95 ± 1.49	0.003
37	Sugar-sweetened beverage (cup/day)	0.42	± 0.75	0.37 ± 0.59	0.45 ± 0.80	5 .40 ± 0.61	0.041
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	Moderate PA (hour/day)	0.49 ± 0.81	0.51 ± 0.82	0.52 ± 0.82	ding 20.50 ± 0.69	0.375
	Vigorous PA (hour/day)	0.47 ± 0.78	0.48 ± 0.45	0.47 ± 0.74	for 100.47 ± 0.67	0.967
	Sedentary time (hour/day)	5.73 ± 3.76	5.87 ± 3.75	5.87 ± 3.73	ຮູ ຫຼຸສູ .74 ± 3.56	0.431
	Socioeconomic status, n (%)				ay 2 Ps rei	
	Parental education level				019. Plate	
	none/primary	313 (8.2)	29 (5.7)	313 (9.5)		<0.001
	secondary	2407(67.3)	319 (62.5)	2207 (67.0)	te s 504 (61.5)	
	college and above	876 (24.5)	162 (31.8)	776 (23.5)	ar be a281 (34.2)	
	Maternal education level				ied f	
	none/primary	369 (10.4)	31 (6.1)	407 (12.4)	$ata \hat{A} = 60 (7.3)$	<u>/0.001</u>
	secondary	2417 (67.9)	346 (67.9)	2181 (66.3)	missing 529 (64.0)	\0.001
	college and above	772 (21.7)	168 (26.0)	702 (21.3)	ing. 198 (28.7)	
	Family history, n (%)				Alt	
	Parental hypertension	144 (4.1)	29 (5.8)	128 (4.0)	Tain 4 9 (6.0)	0.002
	Maternal hypertension	66 (1.9)	12 (2.4)	95(3.0)	bing 31 (3.8)	0.067
	Parental diabetes	41 (1.2)	9 (1.8)	39 (1.2)	an in 16 (2.1)	0.032
	Maternal diabetes	17 (0.5)	6 (1. 2)	31 (1.0)	a 20 (2.6)	<0.001
	Parental obesity	176 (5.3)	59 (12.4)	159 (5.1)	B 8 (11.5)	<0.001
	Maternal obesity	108(3.2)	25 (5.3)	128 (4.1)	T U 65 (8.5)	< 0.001
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Table 3. The association between BMI z-score and birth weight in different age groups

8 9		Model 1 ^a			Model 2 ^b			
10		Standardized coefficients	95% CI	Р	Standardized coefficients	95% CI	Р	-
11 12	Birth weight	0.117	0.100-0.133	< 0.001	0.100	0.079-0.120	< 0.001	-
12	age 6-7	0.121	0.082-0.160	< 0.001	0.145	0.091-0.198	< 0.001	
14	age 8-9	0.162	0.126-0.197	< 0.001	0.161	0.116-0.205	< 0.001	P
15	age 10-11	0.134	0.090-0.179	< 0.001	0.103	0.048-0.158	< 0.001	rote
16 17	age 12-13	0.098	0.061-0.135	< 0.001	0.091	0.044-0.139	< 0.001	cte
18	age 14-15	0.090	0.045-0.134	< 0.001	0.102	0.043-0.161	0.001	d by
19	age 16-18	0.079	0.032-0.126	0.001	0.076	0.016-0.136	0.013	col
20 21		Note: General linear regressio	n model was use	ed to calcul	ate the association between BM	II z-score		pyri
22	435	(dependent variable) and birth	weight (indepe	ndent varia	ble).			ght,
23		^a Model 1 was unadjusted for	any covariates.					inc
24		^b Model 2 was adjusted for url	oan-rural area, s	ingle child,	delivery, fruit and vegetable in	take,		lud
25 26		sugar-sweetened beverage, mo	oderate and vigo	rous physic	cal activity, sedentary time, elev	vated		ing
27		blood pressure.		1 5	5, 5, ,			for
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110			diffe	rent age groups	5			
	HBW group (n=4981)	NBW group (n=4981)	Model 1 ^a		M	Iodel 2 ^b	N	Iodel 3 ^c
	n (%)	n (%)	OR^a	95% CI	AOR^b	95% CI	AOR ^c	95% CI
Overweight	760 (15.3)*	653 (13.1)	1.308*	1.167-1.467	1.242*	1.077-1.433	1.230*	1.056-1.432
age 6-7	138 (15.8)	132 (15.2)	1.155	0.887-1.505	1.163	0.806-1.677	1.244	0.847-1.828
age 8-9	177 (15.4) *	148 (12.9)	1.422^{*}	1.118-1.808	1.492*	1.111-2.005	1.508^{*}	1.102-2.062
age 10-11	116 (18.2) *	88 (13.8)	1.566*	1.151-2.132	1.441	0.978-2.124	1.354	0.895-2.049
age 12-13	160 (15.7) *	135 (13.3)	1.318*	1.026-1.693	1.123	0.823-1.534	1.043	0.739-1.471
age 14-15	80 (12.3)	68 (10.4)	1.269	0.899-1.793	1.139	0.726-1.787	1.292	0.788-2.118
age 16-18	89 (13.5)	82 (12.5)	1.160	0.839-1.604	1.155	0.779-1.711	1.078	0.700-1.659
Obestiy	841 (16.9) *	528 (10.6)	1.791*	1.591-2.016	1.673*	1.436-1.949	1.611*	1.368-1.897
age 6-7	162 (18.6) *	108 (12.4)	1.658*	1.276-2.168	1.692*	1.158-2.470	1.741*	1.167-2.596
age 8-9	266 (23.2) *	162 (14.1)	1.952*	1.567-2.431	1.954*	1.456-2.622	1.844*	1.343-2.531
age 10-11	134 (21.0) *	89 (13.9)	1.789*	1.325-2.415	1.867^{*}	1.270-2.744	1.813*	1.203-2.730
age 12-13	141 (13.9) *	86 (8.5)	1.823*	1.369-2.428	1.628*	1.116-2.373	1.641*	1.078-2.496
age 14-15	65 (10.0) *	37 (5.7)	1.896*	1.244-2.889	1.837*	1.070-3.153	1.986*	1.097-3.597
age 16-18	73 (11.1) *	46 (7.0)	1.696*	1.150-2.502	1.546	0.922-2.593	1.256	0.705-2.238
	Note: Odds ra	atios of high bir	th weight	(HBW) group	for overw	eight and obes	ity were	
	assessed by m	nultivariate logi	stic regre	ssion with the c	dependent	variable (over	weight	
	or obesity) an	d independent	variable (birthweight)				
450	^a Model 1 was	unadjusted for an	, actoriator					
400	^b A diusted for	unaujusted for any	covariates	I daliyary fruit u	nd vogetabl	a intoka sugar s	waatanad	
	heverage mode	erate and vigorous	nhysical a	i, delivery, fiuit al	time eleve	ted blood pressur		
	^c Eurther adjuste	d for paternal and	maternal e	ducation level by	nertension	diabetes and obe	eity	
	* <i>P</i> <0.05	a for paternar and			pertension,	diabetes and obe	Sity.	
455	<i>F</i> < 0.03							
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4/ 48 49 50 51 52 53 54 55	

	HBWgroup	NBW group	Mo	Model 1		Model 2 12		Model 3	
	n (%)	n (%)	OR^a	95% CI	AOR^b	95 % (CI	AOR ^c	95% C	
Sample number						019. Iner late			
HBW defined over 3.5kg	6455	3507	-	-	-	nent d to	-	-	
HBW defined over 4.0kg	4981	4981	-	-	-	vnlc t Su text	-	-	
HBW defined over 4.5kg	689	9273	-	-	-)ade peri t an	-	-	
HBW defined over 5.0kg	176	9786	-	-	-	ieur d da	-	-	
Overweight						.om (AE			
HBW defined over 3.5kg	965 (14.9)	448 (12.8)	1.336*	1.183-1.509	1.319*	1. 1.307 .538	1.334*	1.133-1	
HBW defined over 4.0kg	760 (15.3)	653 (13.1)	1.308*	1.167-1.467	1.242^{*}	1. @ 77 .	1.230^{*}	1.056-1	
HBW defined over 4.5kg	112 (16.3)	1301 (14.0)	1.322*	1.065-1.640	1.277	0. 2 27 <mark>-</mark> .678	0.911	0.775-1	
HBW defined over 5.0kg	27 (15.3)	1386 (14.1)	1.186	0.777-1.810	0.854^{*}	0. ¥ 36 <mark>4</mark> 0.992	0.899	0.766-1	
Obesity						ing,			
HBW defined over 3.5kg	1059 (16.4)	310 (8.8)	2.119*	1.851-2.426	1.905*	1.803 2.264	1.940^{*}	1.612-2	
HBW defined over 4.0kg	841 (16.9)	528 (10.6)	1.791^{*}	1.591-2.016	1.673^{*}	1. £ 36 - .949	1.611^{*}	1.368-1	
HBW defined over 4.5kg	138 (20.0)	1231 (13.3)	1.721^{*}	1.408-2.104	1.762*	1.254-2.293	1.820^{*}	1.377-2	
HBW defined over 5.0kg	33 (18.8)	1336 (13.7)	1.504^{*}	1.017-2.224	0.796*	0. 6 80- 5 .931	0.857	0.721-1	
Adjusted for urban-rural area, sin blood pressure. Further adjusted for paternal and <i>P</i> <0.05	gle child, delivery, maternal educatior	fruit and vegetable a level, hypertensic	e intake, sugar- on, diabetes an	-sweetened beverag	ge, moderate an	ologoust at Agence Bibliographique c	activity, sedenta	ry time, ele	

Page	21	of	22
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	ST	ROBE 2007 (v4) Statement—Checklist of items that should be included in reports of cress-sectional studies	
Section/Topic	ltem #	Recommendation	Reported on page
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1#
		් සිද්දි (b) Provide in the abstract an informative and balanced summary of what was done and what væfeund	1#
Introduction		aner terr	
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported 5	2#
Objectives	3	State specific objectives including any prespecified hypotheses	2#
Methods			
Study design	4	Present key elements of study design early in the paper	3#
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, by provide and data collection	3# 4#
Participants	6	(<i>a</i>) Give the eligibility criteria, and the sources and methods of selection of participants	4#
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers diagnostic criteria, if	4# 5#
Data sources/	8*	For each variable of interest, give sources of data and details of methods of assessment (meas greatent). Describe	4# 5#
measurement		comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	4#
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which Boukings were chosen and why	5#
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	5#
		(b) Describe any methods used to examine subgroups and interactions	5#
		(c) Explain how missing data were addressed	5#
		(d) If applicable, describe analytical methods taking account of sampling strategy	5#
		(e) Describe any sensitivity analyses	6#
Results		ique	

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Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, exangine of religibility,	6#
		confirmed eligible, included in the study, completing follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	6#
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on a second potential confounders	6#
		(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	15*	Report numbers of outcome events or summary measures	6#
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision egg, 95% confidence	6#
		interval). Make clear which confounders were adjusted for and why they were included 🕺 호 🙍	
		(b) Report category boundaries when continuous variables were categorized	6#
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful and ended	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	6#
Discussion		ing Spin	
Key results	18	Summarise key results with reference to study objectives	6#
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and	7#
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of a subject results from	7#
interpretation	20	similar studies and other relevant evidence	/#
Generalisability	21	Discuss the generalisability (external validity) of the study results	
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, original study on	8#
		which the present article is based	

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in case-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published exan bless of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine bress of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.spobe-statement.org.

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The association of high birth weight with overweight and obesity in Chinese students aged 6 to 18 years: a national cross-sectional study in China.

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The association of high birth weight with overweight and obesity in Chinese students aged 6 to 18 years: a national cross-sectional study in China

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Abstract

Background: Childhood overweight and obesity prevalence 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.

Objectives: 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 the students with HBW (n=4981) aged 6-18 years were selected from a cross-sectional survey from 7 provinces of China, and other 4981 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 odds ratio (OR) of overweight and obesity with HBW in unadjusted and adjusted for confounding factors.

- Results: Participants with HBW revealed higher body mass index (BMI) in childhood.
 The prevalence of overweight and obesity were significantly higher in HBW group than NBW group (overweight 15.3% versus 13.1%, p<0.05; obesity 16.9% versus 10.6%, p<0.05), and results were similar in all age groups except age 6-7, age 14-15 and age 16-18 for overweight. Additionally, HBW was positively associated with overweight (OR=1.230; 95%CI: 1.056-1.432) and obesity (OR=1.611; 95%CI: 1.026-1.432)
- 1.368-1.897) 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.
- **Key Words:** high birth weight; body mass index; overweight; obesity

Trial registration: January 22, 2015; Registration number: NCT02343588

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Strength and limitation of this study

- This study used a national multi-centered sample covering all-age children and adolescents in school.
- The 1:1 matching of gender, age and province between high birth weight (HBW) group and normal birth weight (NBW) group was used to enhance the study.
- Some maternal information 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 six months which may have recall bias. to beet terien only

Introduction

Overweight and obesity in childhood has become a critical health issue with the continuous increase of 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 2011.5 Overweight and obesity are considered high-risk factors of 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 to physical activity or dietary intake could produce stronger effects than those without it, while the number of health behaviors 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 lifestyles, the family environment as well as heavy marketing of unhealthy food products.^{13,14}

The hypothesis of Developmental Origins of Health and Disease (DOHaD) postulates that adverse influence in intrauterine life can lead to permanent readjustments in physiology and metabolism, which further causes increased risk of diseases in later life. Thus, focusing on the early developmental phase of life, offers a new way to 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} longitudinal ¹⁸ and cohort ¹⁹ studies. Most studies have found that 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 to reduce the risk of HBW, which meant a balanced diet with low glycemic load, light to moderate intensity physical activity, and moderate weight gain during pregnancy.^{20,21} However, very few studies have focused on Chinese school-age children, nor they have accounted for regional difference and provincial disparities, thus a multi-centered study is needed to clarify the associations.

Using the baseline survey data from 7 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 BMI z-score.

90 Methods

Sample and Participants

The sampling was based on a cross-sectional baseline survey from 7 provinces in China (Liaoning, Tianjin, Ningxia, Shanghai, Chongqing, Hunan, and Guangdong) prior to the commencement of a national multi-centered intervention trial, and these provinces covered all seven geographical areas of China. The protocol of the cluster randomized controlled trial was previously published.²² 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 commence.

Using the common criteria of HBW,^{16,18,19} all the students aged 6-18 years with birth weight over 4.0 kg (n=4981) were selected from the baseline survey in 65 347 students, and other 4 981 students with normal birth weight (NBW, 2.5 kg ≤ birth weight < 4.0 kg) were randomly sampled with matched age, gender and province. Finally, 9 962 students including 4 981 students in HBW group and 4 981 students in NBW group were enrolled in the present study, and were further divided into six subgroups 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=841), while overweight and obesity were defined using the cut-offs references developed by the Working Group on Obesity in China (WGOC).²³

Birth weight data

Birth weight was collected using a standard parent questionnaire. Parents were required to record their children's birth weight based on the record of birth certificate or health clinic. If they did not have, 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 NBW group were 73.4% (3655/4981) and 68.4% (3406/4981), respectively. To ensure the reliability of birth weight data, parents were asked to repeat the same process of questionnaire survey six months later. The error in birth weight values between the baseline and six months later was lower than 10% and participants with the 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 the standardized 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 students, the error was less than 3% or if higher all students were re-measured according to the protocol. Body mass index (BMI) was calculated as body weight divided by height (m) squared (kg/m²),

Blood pressure was measured using a standardized mercury sphygmomanometer (model XJ1ID) recommended by 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 minutes, 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

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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 are higher than the corresponding cut-offs. The cut-offs were age-, gender- and height-percentile-specific was recommended by NHBPEP Working Group in 2004.²⁴

Questionnaires

The research team developed self-reported questionnaires for children and parents to collect information of obesity-related factors. Child-reported questionnaires were filled by students in the classroom with the interpretation by trained research staff, with the exception that children at the third grade or under in primary school completed 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 physical activity (PA), vigorous PA, sedentary time of students. For diet intake, students were asked how many days they eat fruits, 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 \times 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 as almost 250 ml. 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 $(\text{days} \times \text{hours for each day})/7$. Moderate PA included light activities (e.g. walking) while vigorous PA included high-load activities on musculoskeletal tissues in the body (e.g. sports and games).²⁵ Sedentary time, consisting of doing homework, watching TV and using a computer, asked how many days and how many hours for the three separate activities over the past 7 days. Following the calculation of $(days \times hours for each day)/7$ for each activity, the average sedentary time was the sum of homework, TV and computer time.

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, obesity). Delivery mode included spontaneous delivery and cesarean delivery. Breast-feeding was categorized as ≥6 month and <6 month. Socioeconomic status was defined as education levels of children's parents, involving 3 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 diagnoses 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 they involved in the recruitment and conduct of the study.

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School doctors and class teachers help us to organize and maintain order of the physical examination by class held in the school.

Statistical Analyses

EpiData Software Version 3.02 was used to do data entry, and all the analyses were performed by IBM SPSS Statistics 22.0 (IBM Corp., Armonk, NY, USA). Age, birth weight, height, weight, BMI, DBP, SBP, sweet drinks, MVPA were recorded as the mean value (SD). Gender, delivery, single birth, breast feeding, elevated blood pressure, parental education, and family history were displayed as categorical variables (the number and percentage). T-test was conducted for the P value of BMI between HBW group and normal group by gender and age group and Chi-square test was verified for the percentage of overweight and obesity. Multivariate logistic regression was used to calculate the odds ratios (OR) and 95% confidence intervals (CI) of different birth weight groups for overweight and obesity by age group. This was further adjusted for urban-rural area, single child, delivery, food intake and physical activity, sedentary time, elevated blood pressure in Model 2, and adjusted for paternal and maternal education level, family history such as hypertension, diabetes and obesity in Model 3. Sensitivity analyses were conducted with different thresholds for HBW compared with NBW, which were displayed in 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 was 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±0.36kg, 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 210 Overweight group. Compared with other three groups, students in 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). Results in Table 2 were similar between HBW obesity group and other three groups, except with the rate of parental hypertension and parental diabetes significant higher (*P*<0.05).

The associations between BMI z-score and birth weight in different age groups were documented in Table 3. All age groups were observed with significant positive associations between BMI z-score and birth weight, highest in age 8-9 group. When adjusted for urban-rural area, single child, fruit and vegetable intake, sugar-sweetened beverage, moderate and vigorous physical activity, sedentary time, elevated blood pressure in Model 2, the associations remained significant in overall as well as different age groups.

Table 4 presented the rate and odds ratio (OR) for overweight and obesity on current weight by age groups. Overall, HBW group revealed a significantly higher rate of overweight and obesity in HBW group than those in NBW group and the OR was 1.308 (95% *CI*: 1.167-1.467) and 1.791 (95% *CI*: 1.591-2.016) respectively. After adjusting for confounding factors in Model 2 and in Model 3, a slightly

decreased however still significant associations were observed with the AOR of 1.230 (95% CI: 1.056-1.432) for overweight and 1.611 (95% CI: 1.368-1.897) for obesity.
In different age groups, the results were similar, and AOR in age 8-9 group for overweight and in most age groups for obesity remained significant. Results were similar in sensitivity analyses with different thresholds for HBW, which were displayed in Supplementary Table 1.

Discussion

We evaluated the associations of HBW and overweight and obesity using the cross-sectional survey from 7 provinces in China. In the present study, HBW was significantly associated with the increase risk of overweight and obesity among Chinese children and adolescents before and after adjusting for the co-variables. More specifically, we found age 8-9 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 of depicting development status in intrauterine environments. A meta-analysis gathering 643,902 persons from 66 studies, aged 1 to 75, has proved that low birth weight and HBW were followed by opposite long-term effects on overweight compared with NBW, with HBW predisposed for overweight in later life with OR of 1.66 (95% CI 1.55-1.77).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 consisted with the results of previous studies.²⁷⁻²⁹ There are some possible explanations for the association. One possible explanation is that hyper-nutrition 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 affects 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 courses 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 high birthweight and large for gestational age infants.^{35,36} The
Institute of Medicine in US revised the gestational weight gain guidelines in 2009 encouraging health professionals and mothers to manage weight gain by following healthy dietary recommendations and increasing physical activity,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 behavioral

factors,^{27,28} and Ren et al also found the synergy effects of HBW and unhealthy diet on increased risk of obesity.²⁹ Thus diet intervention studies on children with HBW are needed in the future.

275 There are three limitations in this study. Firstly, the information of birth weight was retrospectively obtained from their parents by questionnaire. In this way, there was possibly memory bias. However, we have tried to weaken the bias though collecting information on their certificate or the health clinic card then repeating the survey after six months. Subjects with difference of birth weight in the two investigations over 10% were exclude in the study. Secondly, using dietary recall over last 7 days may be a less accurate method for daily intake of fruits, vegetables and sugar-sweetened beverages consuming, which may also influence the results. Thirdly, 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 remained positively associated with higher BMI z-score even after the adjustment. This study indicated that HBW is a high-risk influence factor of 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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Contributors

305 JM, YM and ZZ conceived and designed the project; ZZ collected the data; ZZ and ZY analyzed the data and prepared the manuscript; ZY, XW, DG and YD were involved in writing the article and had a final approval of the submitted and published versions.

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Competing interests None declared.

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4		Patient consent Obtained.
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6 7		Ethics approval Medical Ethical Committee of the Peking University
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9	320	Data sharing statement No additional data available
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Tal	ole 1. Characteristics of stu	dy subjects with norma	al weight against overweig	fon g⊈r 22	
Pasalina characteristics	NBW Normal group	NBW Overweight	HBW Normal group	W Overweight	D ,
Baseline characteristics	(3800)	group (653)	(3380)		ΓV
Male, n (%)	2190 (57.6)	441 (67.5)	1906 (56.4)	ate 9,505 (66.4)	<0
Age (year) / mean ± SD	11.16 ± 0.05	10.76 ± 0.13	11.29 ± 0.06	$5 - 0.83 \pm 0.12$	<0
Urban area, n (%)	2146 (56.5)	388 (59.4)	2144 (63.4)	tex 2501 (65.9)	<0
Single child, n (%)	2488 (65.5)	479(73.4)	1966 (58.2)	t per 68.9)	<0
Birth information				ieur d da	
Birth weight (kg) / mean \pm SD	3.22 ± 0.35	3.25 ± 0.36	4.21 ± 0.29		<0
Caesarean birth, n (%)	1330 (37.4)	269(43.7)	1424 (43.4)	420 (56.3)	<0
Single birth, n (%)	3488 (97.0)	604 (98.1)	3242 (97.9)	ig · i 739 (98.9)	0.
Breast feeding, n (%)	3098 (86.0)	536 (86.3)	2887 (86.9)	≥ 3 636 (85.1)	0.
Anthropometry, mean ± SD				pen	
Height (cm)	146.08 ± 17.36	147.24± 16.49	148.44 ± 17.30	ng 1 9.16 ± 16.92	<0
Weight (kg)	38.18 ± 13.00	48.30 ± 16.23	40.11 ± 13.13	a b b b b c b c c c c c c c c c c	<0
WC (cm)	61.64 ± 8.09	72.51 ± 9.49	62.70 ±7.83	s . 22.65 ± 9.39	<0
Systolic pressure (mmHg)	103.88 ± 11.51	108.08 ± 12.121	103.98 ± 11.36	$\mathbf{P}_{\mathbf{R}}$	<0
Diastolic pressure (mmHg)	65.71 ± 8.29	67.93 ± 8.99	65.78 ± 8.28	1 1 1 1 1 1 1 1 1 1	<0
Body mass index (kg/m ²)	17.26 ± 2.39	21.47 ± 2.74	17.61 ± 2.32	9 21.58 ± 2.71	<0
Diet and physical activity, mean \pm SD				202	
Fruit (serving/day)	1.20 ± 1.03	1.25 ± 0.96	1.27 ± 1.08	$a_1.20 \pm 0.95$	0.
Vegetable (serving/day)	1.77 ± 1.40	1.79 ± 1.42	1.78 ± 1.43	b 1.78 ± 1.43	0.
Sugar-sweetened beverage (cup/day)	0.42 ± 0.75	0.49 ± 0.92	0.45 ± 0.80	30.46 ± 0.86	0.
Moderate PA (hour/day)	0.49 ± 0.81	0.46 ± 0.72	0.52 ± 0.82	$\underline{\mathbf{u}}_{0.50 \pm 0.89}$	0.
Vigorous PA (hour/day)	0.47 ± 0.78	0.46 ± 0.65	0.47 ± 0.74	500.49 ± 0.82	0.
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1 2 3					n-2018-0249 yright, inclu	
4 5	Sedentary time (hour/day)	5.73 ± 3.76	5.75 ± 3.58	5.87 ± 3.73	ding 53.72 ± 3.76	0.442
6	Socioeconomic status, n (%)				for	
7	Parental education level				use En	
9	none/primary	313 (8.2)	55 (8.9)	313 (9.5)		< 0.001
10	secondary	2407(67.3)	374 (60.6)	2207 (67.0)	lange 9461 (62.4)	
11	college and above	876 (24.5)	189 (30.5)	776 (23.5)		
12	Maternal education level				wnl nt Su	
14	none/primary	369 (10.4)	57(9.3)	407 (12.4)	ar 19 og 73(9.9)	<0.001
15	secondary	2417 (67.9)	392 (63.5)	2181 (66.3)	d d 467 (63.3)	<0.001
16 17	college and above	772 (21.7)	168 (27.2)	702 (21.3)	ata 2 198 (26.8)	
18	Family history, n (%)				BES	
19	Parental hypertension	144 (4.1)	27 (4.5)	128 (4.0)	jų · 37 (5.1)	0.558
20 21	Maternal hypertension	66 (1.9)	17 (2.8)	95(3.0)	≥ 25 (3.5)	0.014
22	Parental diabetes	41 (1.2)	11 (1.9)	39 (1.2)	14 (2.0)	0.251
23	Maternal diabetes	17 (0.5)	4 (0.7)	31 (1.0)	11 (1.6)	0.017
24	Parental obesity	176 (5.3)	49 (8.5)	159 (5.1)	an 5 9 (8.6)	< 0.001
26	Maternal obesity	108 (3.2)	19 (3.3)	128 (4.1)	a 2 (6.1)	0.003
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P value

< 0.001

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	Table 2. Characteristics of NBW Normal group	study subjects with norm	nal weight against obesit HBW Normal group	-024532 on 22 including for ustress y ustressay Obesity
Baseline characteristics	(3800)	(528)	(3380)	s reig reig (841)
Male, n (%)	2190 (57.6)	383 (72.5)	1906 (56.4)	ate 9603 (71.7
Age (year) / mean ± SD	11.16 ±0.05	10.14 ± 0.13	11.29 ± 0.06	$t = 0.23 \pm 0.1$
Urban area, n (%)	2146 (56.5)	315 (59.7)	2144 (63.4)	tex 1 564 (67.1
Single child, n (%)	2488 (65.5)	410 (77.7)	1966 (58.2)	an per 605 (71.9
Birth information				ieur d da
Birth weight (kg) / mean \pm SD	3.22 ± 0.35	3.31 ± 0.35	4.21 ± 0.29	a 204.24± 0.3
Caesarean birth, n (%)	1330 (37.4)	256 (50.2)	1424 (43.4)	
Single birth, n (%)	3488 (97.0)	502 (97.1)	3242 (97.9)	.
Breast feeding, n (%)	3098 (86.0)	413 (79.7)	2887 (86.9)	≥ 3.721(86.7
Anthropometry, mean \pm SD				rain
Height (cm)	146.08 ± 17.36	146.62±15.50	148.44 ± 17.30	B1 8.69 ± 1:
Weight (kg)	38.18 ± 13.00	55.83 ± 19.37	40.11 ± 13.13	a 68.75 ± 20
WC (cm)	61.64 ± 8.09	80.27 ± 11.25	62.70 ±7.83	s . a 1.67 ± 11
Systolic pressure (mmHg)	103.88 ± 11.51	111.92 ± 13.43	103.98 ± 11.36	$P11.24 \pm 13$
Diastolic pressure (mmHg)	65.71 ± 8.29	70.43 ± 9.59	65.78 ± 8.28	Te 50.15 ± 8.
Body mass index (kg/m ²)	17.26 ± 2.39	25.09 ± 3.94	17.61 ± 2.32	5 .62 ± 4.
Diet and physical activity, mean \pm SE)			202! plog
Fruit (serving/day)	1.20 ± 1.03	1.32 ± 1.03	1.27 ± 1.08	$\frac{31}{100}$ at 1.36 ± 1.0
Vegetable (serving/day)	1.77 ± 1.40	1.90 ± 1.57	1.78 ± 1.43	• 6 1.95 ± 1.4
Sugar-sweetened beverage (cup/day)	0.42 ± 0.75	0.37 ± 0.59	0.45 ± 0.80	$\ddot{0}0.40 \pm 0.0$
Moderate PA (hour/day)	0.49 ± 0.81	0.51 ± 0.82	0.52 ± 0.82	$\underline{\mathbf{u}}_{0.50\pm0.6}$
Vigorous PA (hour/day)	0.47 ± 0.78	0.48 ± 0.45	0.47 ± 0.74	50.47 ± 0.6
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1 2 3					an-2018-0245 yright, inclu	
4 5	Sedentary time (hour/day)	5.73 ± 3.76	5.87 ± 3.75	5.87 ± 3.73	ding 25.74 ± 3.56	0.431
6	Socioeconomic status, n (%)				for	
7	Parental education level				use Er	
9	none/primary	313 (8.2)	29 (5.7)	313 (9.5)		<0.001
10	secondary	2407(67.3)	319 (62.5)	2207 (67.0)	line 019504 (61.5)	
11	college and above	876 (24.5)	162 (31.8)	776 (23.5)		
12	Maternal education level				o tey	
14	none/primary	369 (10.4)	31 (6.1)	407 (12.4)	ar up oad 60 (7.3)	(0.001
15	secondary	2417 (67.9)	346 (67.9)	2181 (66.3)	nd ed 529 (64.0)	<0.001
16 17	college and above	772 (21.7)	168 (26.0)	702 (21.3)	ata (An 198 (28.7)	
18	Family history, n (%)				n htt	
19	Parental hypertension	144 (4.1)	29 (5.8)	128 (4.0)	49 (6.0)	0.002
20	Maternal hypertension	66 (1.9)	12 (2.4)	95(3.0)	≥ 31 (3.8)	0.067
21	Parental diabetes	41 (1.2)	9 (1.8)	39 (1.2)	fai b 16 (2.1)	0.032
23	Maternal diabetes	17 (0.5)	6 (1. 2)	31 (1.0)	ning 20 (2.6)	<0.001
24	Parental obesity	176 (5.3)	59 (12.4)	159 (5.1)	ar <u>88 (11.5)</u>	<0.001
25 26	Maternal obesity	108 (3.2)	25 (5.3)	128 (4.1)	bd s 65 (8.5)	< 0.001
27					ini on	
28 29 30 420 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45		For peer review only - http:	15 ://bmjopen.bmj.com/sit	e/about/guidelines.xht	June 6, 2025 at Agence Bibliographique de l lar technologies.	
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	Mode] 1a	Mode	l 2 ^b		
	Standardized coefficients	95% CI	Р	Standardized coefficients	95% CI	P
Birth weight	0.117	0.100-0.133	< 0.001	0.100	0.079-0.120	< 0.001
age 6-7	0.121	0.082-0.160	< 0.001	0.145	0.091-0.198	< 0.001
age 8-9	0.162	0.126-0.197	< 0.001	0.161	0.116-0.205	< 0.001
age 10-11	0.134	0.090-0.179	< 0.001	0.103	0.048-0.158	< 0.001
age 12-13	0.098	0.061-0.135	< 0.001	0.091	0.044-0.139	< 0.001
age 14-15	0.090	0.045-0.134	< 0.001	0.102	0.043-0.161	0.001
age 16-18	0.079	0.032-0.126	0.001	0.076	0.016-0.136	0.013
425	Note: General linear regressio	n model was us	ed to calcul	ate the association between BM	II z-score	
	(dependent variable) and birth	weight (indepe	ndent varial	ble).		
	^a Model 1 was unadjusted for	any covariates.				
	^b Model 2 was adjusted for ur	ban-rural area, s	ingle child,	delivery, fruit and vegetable in	take,	
	sugar-sweetened beverage, me	oderate and vigo	orous physic	al activity, sedentary time, elev	vated	
430	blood pressure.					

6 7 8	435	Table 4. Odds	s ratio of high b	oirth weig diffe	ht (HBW) grou rent age groups	p for ove	rweight and ob	esity in		_
9 10		HBW group (n=4981)	NBW group (n=4981)	N	Iodel 1 ^a	N	Iodel 2 ^b	Ν	1odel 3 ^c	_
11 12 13		n (%)	n (%)	OR^a	95% CI	AOR^b	95% CI	AOR ^c	95% CI	
14	Overweight	760 (15.3)*	653 (13.1)	1.308*	1.167-1.467	1.242*	1.077-1.433	1.230*	1.056-1.432	-
15	age 6-7	138 (15.8)	132 (15.2)	1.155	0.887-1.505	1.163	0.806-1.677	1.244	0.847-1.828	rote
17	age 8-9	177 (15.4) *	148 (12.9)	1.422^{*}	1.118-1.808	1.492*	1.111-2.005	1.508^{*}	1.102-2.062	cteo
18	age 10-11	116 (18.2) *	88 (13.8)	1.566*	1.151-2.132	1.441	0.978-2.124	1.354	0.895-2.049	d by
19	age 12-13	160 (15.7) *	135 (13.3)	1.318*	1.026-1.693	1.123	0.823-1.534	1.043	0.739-1.471	ŝ
20 21	age 14-15	80 (12.3)	68 (10.4)	1.269	0.899-1.793	1.139	0.726-1.787	1.292	0.788-2.118	oyri
22 23	age 16-18	89 (13.5)	82 (12.5)	1.160	0.839-1.604	1.155	0.779-1.711	1.078	0.700-1.659	ght, inc
24 25	Obesity	841 (16.9)*	528 (10.6)	1.791*	1.591-2.016	1.673*	1.436-1.949	1.611*	1.368-1.897	ludi
25 26	age 6-7	162 (18.6) *	108 (12.4)	1.658*	1.276-2.168	1.692*	1.158-2.470	1.741*	1.167-2.596	ing .
27	age 8-9	266 (23.2)*	162 (14.1)	1.952*	1.567-2.431	1.954*	1.456-2.622	1.844*	1.343-2.531	foru
28	age 10-11	134 (21.0) *	89 (13.9)	1.789*	1.325-2.415	1.867^{*}	1.270-2.744	1.813*	1.203-2.730	JSe
29 30	age 12-13	141 (13.9) *	86 (8.5)	1.823*	1.369-2.428	1.628*	1.116-2.373	1.641*	1.078-2.496	s rely
31 32	age 14-15	65 (10.0) *	37 (5.7)	1.896*	1.244-2.889	1.837*	1.070-3.153	1.986*	1.097-3.597	ated t
33 34	age 16-18	73 (11.1) *	46 (7.0)	1.696*	1.150-2.502	1.546	0.922-2.593	1.256	0.705-2.238	o text
 35 36 37 38 39 40 41 42 43 	Note: Odds ratios of HBW group for overweight and obesity were assessed by multivariate logistic regression with the dependent variable (overweight or obesity) and independent variable (birthweight) Adjusted for any covariates. Adjusted for urban-rural area, single child, delivery, fruit and vegetable intake, sugar-sweetened									and data mining, Al traini
44 45 46 47 48 49	445	° Further adjusted * <i>P</i> <0.05	d for paternal and	maternal eo	ducation level, hy	pertension,	diabetes and obe	sity.		ng, and similar tec
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			111		IVIC		IVI0	bael 3
	n (%)	n (%)	OR^a	95% CI	AOR^b	93% CI	AOR ^c	9:
Sample number)19. Jnen later		
HBW defined over 3.5kg	6455	3507	-	-	-	nen: d to	-	
HBW defined over 4.0kg	4981	4981	-	-	-	vnic t Su tex	-	
HBW defined over 4.5kg	689	9273	-	-	-	oade peri t an	-	
HBW defined over 5.0kg	176	9786	-	-	-	d da	-	
Overweight						om (AB Ita r		
HBW defined over 3.5kg	965 (14.9)	448 (12.8)	1.336*	1.183-1.509	1.319^{*}	1.13.538	1.334^{*}	1.
HBW defined over 4.0kg	760 (15.3)	653 (13.1)	1.308*	1.167-1.467	1.242^{*}	1. 6 77 4 .433	1.230^{*}	1.(
HBW defined over 4.5kg	112 (16.3)	1301 (14.0)	1.322*	1.065-1.640	1.277	0. 2 27 3 .678	0.911	0.7
HBW defined over 5.0kg	27 (15.3)	1386 (14.1)	1.186	0.777-1.810	0.854^{*}	0. <u>¥</u>36-<mark>3</mark>9.992	0.899	0.7
Obesity						ing,		
HBW defined over 3.5kg	1059 (16.4)	310 (8.8)	2.119*	1.851-2.426	1.905*	1. 8 03-2.264	1.940^{*}	1.6
HBW defined over 4.0kg	841 (16.9)	528 (10.6)	1.791^{*}	1.591-2.016	1.673^{*}	1. ¥ 36- 3 .949	1.611^{*}	1.3
HBW defined over 4.5kg	138 (20.0)	1231 (13.3)	1.721^{*}	1.408-2.104	1.762*	1.554-2.293	1.820^{*}	1.3
HBW defined over 5.0kg	33 (18.8)	1336 (13.7)	1.504^{*}	1.017-2.224	0.796^{*}	0. 6 80-7.931	0.857	0.7
^a Unadjusted for any covariates.						6, 2 hno		
^b Adjusted for urban-rural area, sin	gle child, delivery,	fruit and vegetable	intake, sugar-	sweetened beverage	e, moderate and	l vig	activity, sedenta	ry tim
blood pressure.						at A es.		
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	ST	로 끌 ROBE 2007 (v4) Statement—Checklist of items that should be included in reports of cress-쯓ctional studies 을 译	
Section/Topic	ltem #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1#
		්ර ශ්රී (b) Provide in the abstract an informative and balanced summary of what was done and what vකුළුfœund	1#
Introduction		an er	
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported 6	2#
Objectives	3	State specific objectives, including any prespecified hypotheses	2#
Mothods			
Study design	4	Present key elements of study design early in the paper	3#
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, by by -up, and data	3# 4#
Participants	6	(<i>a</i>) Give the eligibility criteria, and the sources and methods of selection of participants	4#
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers Give diagnostic criteria, if	4# 5#
Data sources/	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe	4# 5#
measurement		comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	4#
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which good by the second se	5#
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	5#
		(b) Describe any methods used to examine subgroups and interactions	5#
		(c) Explain how missing data were addressed $\overline{\mathbf{c}}$	5#
		(d) If applicable, describe analytical methods taking account of sampling strategy	5#
		(e) Describe any sensitivity analyses	6#
Results			

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Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, exany net for eligibility,	6#
		confirmed eligible, included in the study, completing follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	6#
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information of magosures and potential	6#
		confounders	
		(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	15*	Report numbers of outcome events or summary measures	6#
Main results 16	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision egg, 95% confidence	6#
		interval). Make clear which confounders were adjusted for and why they were included 축 호 요	
		(b) Report category boundaries when continuous variables were categorized	6#
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful and eriod	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses \overline{a} \overline{m}	6#
Discussion		ning Sty	
Key results	18	Summarise key results with reference to study objectives	6#
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Dia both direction and magnitude of any potential bias	7#
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from	7#
		similar studies, and other relevant evidence	
Generalisability	21	Discuss the generalisability (external validity) of the study results	
Other information		arte	
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, original study on	8#
		which the present article is based	

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cational studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine 🛱 rg/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www. \Re obe-statement.org.