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Gender and educational stage-specific association of birth weight with overweight and obesity among children and adolescents aged 7–18 years: a school-based cross-sectional study

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ABSTRACT

Objectives To investigate the associations between birth weight and overweight/obesity in school-aged children and adolescents according to different gender and educational stages, and explore the interactions among the lifestyle factors.

Design Cross-sectional study.

Setting Henan Province in China.

Participants A total of 27 009 children and adolescents aged 7–18 years were included.

Primary outcome measures Anthropometric parameters were measured and characteristics were collected by questionnaires. Logistic regression analysis was used to estimate the ORs and corresponding 95% CIs of overweight/obesity with birth weight. The relative excess risk due to interaction (RERI) and the attributable proportion of interaction (AP) indices were used to measure additive interaction.

Results In the adjusted logistic regression models, the overall population with high birth weight (HBW) (adjusted ORs 2.866, 95% CI 1.563 to 3.728) had an increased risk of overweight/obesity compared with those with normal birth weight (NBW), and the associations differed by gender-specific and educational stage-specific factors. When stratified by gender, children and adolescents with HBW had a higher risk of overweight/obesity as compared with the NBW group (adjusted ORs 2.582 and 2.356; 95% CIs 1.413 to 3.579 and 1.097 to 2.934, boys and girls, respectively). According to different educational stages, HBW was positively associated with an increased risk of overweight/obesity compared with the NBW group. The adjusted ORs of the three groups were 2.757 (95% CI 1.483 to 3.658), 2.317 (95% CI 1.451 to 2.795) and 2.216 (95% CI 1.532 to 2.873), respectively. In addition, we found the HBW group with insufficient physical activity time had significantly higher risk of overweight/obesity (OR 2.165, 95% CI 1.352 to 3.378) in the overall population. As expected, a significant additive interaction was found between birth weight and insufficient physical activity time (RERI 2.289, 95% CI 0.678 to 3.576; AP 0.723, 95% CI 0.521 to 1.126).

Conclusions HBW was significantly associated with an increased risk of overweight/obesity in school-aged children and adolescents, and the associations differed by gender-specific and educational stage-specific factors. Notably, HBW possibly interplayed synergistically with insufficient physical activity time to increase the risk of overweight/obesity across gender and educational stages.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ In this cross-sectional study, participants were randomly selected by stratified cluster sampling.
⇒ A large, population-based sample was investigated, and the study included available information on a broad range of covariates.
⇒ Using a self-administered questionnaire can bring about some biases such as recall bias and reporting bias.
⇒ The nature of the cross-sectional study cannot establish causality between birth weight and overweight/obesity.
⇒ The results were from Henan Province only and, therefore, the findings cannot be generalised to all of China.

BACKGROUND

Overweight and obesity in school-aged children and adolescents have become a critical issue with the continuous increase in prevalence worldwide over the past 30–40 years, especially in China.[1–6] According to the report from the WHO in 2022, more than 390 millions kids and teenagers between the ages of 5 and 19 were overweight. From only 8% in 1990 to 20% in 2022, the prevalence of overweight (including obesity) among children and adolescents aged 5–19 has increased significantly. Data from the China Health and Nutrition Survey in 2015 showed that the prevalence of overweight/obesity was 26.95% in children and adolescents aged 6–17 years old.[7] Similarly, according to the 2021 Children's Blue Book and China Children's Development Report,[8] the prevalence of overweight and obesity among Chinese children aged 6–18 years was 15.5%

in 2020, 24.2% in 2019, and increased to 29.4% in 2022. Overweight and obesity are considered high-risk factors for cardiovascular and metabolic complications,[9–11] and students with overweight/obesity are more likely to suffer physical and psychosocial problems in adulthood, such as dyslipidaemia, chronic inflammation, type 2 diabetes mellitus, hypertension. [12–14] Childhood and adolescence are the important stages of life for the development and maintenance of health and risk behaviours. Therefore, it is imperative to identify modifiable factors during early life that play a role in the development of overweight/obesity in school-aged children and adolescents.

Both genetic and environmental factors contributed to a child's possibilities of being overweight/obesity. The genetic factors determine the susceptibility to weight gain, while the environmental factors, characterised by the high availability of energy-dense food and increased sedentary behaviours, are the major contributor to overweight/obesity.[15–18] Recently, growing evidence indicated that perinatal characteristics have been recognised as contributing factors to the obesity epidemic.[19] Birth weight is frequently used as an indicator of intrauterine growth, which contributes to later overweight or obesity. Several studies have indicated the positive associations of high birth weight (HBW) with an increased risk of later overweight/obesity in children,[20–23] while some other studies contradict this result, reporting that HBW is unrelated to or protective against overweight/obesity.[24 25] Meanwhile, the conclusions drawn by studies evaluating the associations between low birth weight (LBW) and overweight/obesity appear to be controversial.[26–28] These inconsistencies might be related to the differences in study design, study population or small sample size. In addition, the potential interactions between birth weight and lifestyle factors were described to contribute to the increased risk of overweight/obesity, which may be another possible reason for inconsistent results across studies.

Although the relationships between birth weight and overweight/obesity have been extensively investigated in cross-sectional and longitudinal studies, the birth weight may also differ due to the gender-specific and educational stage-specific differences. In current literature, there is limited information on the association between birth weight and overweight/obesity by the gender-specific and educational stage-specific effect simultaneously. Additionally, this association remains obscure in the Henan Province school-aged population. Regional research is necessary in order to establish a representative study population and provide the evidence for preventing overweight/obesity among children and adolescents at different gender and educational stages in Henan Province. Thus, we conducted a cross-sectional study to explore the potential associations between birth weight and overweight/obesity, using strict inclusion criteria based on gender-specific and educational stage-specific differences. Additionally, we also used an additive model to analyse possible interactions between birth weight and lifestyle factors of overweight/obesity in Henan Province school-aged children and adolescents.

METHODS

Study design and population

The cross-sectional study design was performed from June 2019 to September 2021, which selected participants aged 7–18 years from the eastern, western, central, southern and northern regions of Henan Province. This survey used a standardised and uniform protocol in all the selected schools across the selected cities. A three-stage cluster random sampling method was used to select participants. Briefly, in the first stage of sampling, 20 cities were randomly selected from Henan Province using the method of probability proportional to size. In the second stage of sampling, 10 schools were randomly selected from all schools in each selected city using the same method. In the third stage of sampling, 10 classes were randomly selected in each school using the same method. The schools involved were as follows: Xincheng Street primary school of Pingdingshan City, Ziwei primary school of Anyang City, Huanggang primary school of Xinxiang City, Experimental middle school of Luohe City, Huiyang middle school of Zhoukou City, Experimental middle school of Shangqiu City, Xiangcheng high school of Xuchang City, Yuhua experimental high school of Jiaozuo City, Shihe high school of Xinyang City and Qixian high school of Kaifeng City. All of the students from the selected classes in all schools involved were selected as the participants in the survey. A staff member who has not been involved in the survey performed all processes of randomisation. All schools gave permission for questionnaires to be distributed to students. We contacted the school principals, and these principals conveyed this survey information to teachers subsequently. The investigators worked with the school teachers to send text messages to parents of school students and invite the parents to participate in the investigation in which the purpose of the study and the potential benefits for the participants were explained to them. All participants were ensured that their data would remain confidential. The students had the right to decline to participate in the study without any penalty, and they could drop out if they wanted to at any time during the investigation.

The sample size was estimated according to the sample size calculation formula of the cross-sectional study, where α=0.05, and p was the expected prevalence rate. The expected prevalence rates of overweight and obesity in children and adolescents were 12.2% and 7.3%, respectively, so the calculated minimum sample size was 11 059 students. To increase this study's validity and generalisability, a total sample size of 27 009 students (18 191 boys and 8818 girls) was recruited in this study. All children and adolescents aged 7–18 years old who did not have a history of chronic diseases including cardiovascular, pulmonary, gastrointestinal and renal diseases, as well as autoimmune diseases, diabetes and cancer, as well as

those who had not followed any special diets during the past year such as gluten-free, lactose-free or weight-loss diets, and inability to participate in school sport activities were eligible to participate in this study.

Patient and public involvement

Neither patients nor the public were involved in developing this project.

Data collection and questionnaire survey

Data on the children and adolescents aged 7–18 years were collected using a self-reported and standardised questionnaire that was filled in by the participants and one of their parents. The questionnaire obtained information on children and adolescents' age, gender, residence region, educational stages, height, weight, body mass index (BMI), birth weight, delivery mode, parental age, parental educational level, parental BMI, daily sleep duration, daily physical activity time and daily screen time. Before the implementation of the investigation, all investigators received unified training. Teachers distributed questionnaires to students, asked students to take the questionnaire home and fill in the information in company with their parents, then the teachers collected the completed questionnaires from their students and returned them to the investigator. We emphasised that the first caregiver of the child should answer the questionnaire for he or she knew the child well. Any question or confusion from students was clarified to ensure that every student understood all of the items, and parents were provided with instructions on answering the questions to prevent inaccurate information.[29] We sent text messages to parents in advance to remind the students to bring the completed questionnaires when they come back to school. When we collected the questionnaires from the students, we would carefully check whether all of the questionnaires were handed in. The team ensured that students would bring back the answered questionnaire to school. The completed questionnaires were checked for quality control. Those which had logical errors or had too many missing items were defined as invalid questionnaires. After each participant completed the on-site investigation, 5% of the students were randomly selected for repeated investigation, and the results were reproducible to ensure the authenticity of the survey results.

Birthweight collection and categorisation

Data on birth weight of children and adolescents were collected using a standard question: 'What is your birth weight?' in the questionnaire. Most of the parents/guardians of children and adolescents reported the birth weight of their child according to the birth certificate that was made by the hospital after birth. For those who do not have the birth certificate, we require parents/guardians to recall the birth weight based on the measurement by themselves. In this study, birth weight was categorised into three groups: when the birth weight was <2500 g, it was defined as LBW; when the birth weight was 2500–3999 g, it was defined as normal birth weight (NBW); when the birth weight was ≥4000 g, it was defined as HBW.[30]

Ascertainment of variables

In this study, we developed self-reported items for participants and parents to collect information on overweight/obesity-related factors, including parental education level, parental BMI, sleep duration, physical activity time and screen time. Socioeconomic status was defined as education levels of children and adolescents' parents, involving three levels: middle school or below, high school, university or above. Parental BMI was calculated as the quotient of weight in kg and height squared (m^2). In this analysis, parental BMI was classified into three following categories (according to WHO definitions): when the BMI was 18.5–24.9, it was defined as normal weight; when the BMI was 25.0–29.9, it was defined as overweight; when the BMI was ≥30, it was defined as obesity. Sleep duration was assessed by one question: on average, how many hours and minutes did you sleep on a typical day during the past 7 days? In this study, the sleep duration was divided into four levels according to the National Sleep Foundation guideline for age-specific sleep recommendations: very short, short, recommended and long sleep duration.[31] For students aged 7–14 years, sleep duration <7 hours/day was classified as very short, within 7–8 hours/day as short, within 9–11 hours/day as recommended, and more than 11 hours/day as long. For students aged 15–18 years, sleep duration <6 hours/day was classified as very short, within 6–7 hours/day as short, within 8–10 hours/day as recommended, and more than 10 hours/day as long. Physical activity time was assessed by the question: how many hours each day do you usually spend in physical activity? Based on engaging in physical activity, children and adolescents were divided into two groups (>2 hours/day vs ≤2 hours/day). For screen time, consisting of watching television, playing on phone and surfing on computer, children and adolescents were asked how many days and how many hours were spent on the three separate activities over the past 7 days. Following the calculation of (days×hours for each day)/7 for each activity, the average screen time was the sum of television, phone and computer time. Using the threshold of 2 hours/day proposed by current scientific evidence and guidelines, the respondents were classified as exceeding (>2 hours/day) or not exceeding (≤2 hours/day) the recommended daily time spent on watching TV or playing on phone.[29]

Anthropometric measurement

Height and weight were measured by the well-trained professional staff according to the standardised procedure. Height was assessed by the portable stadiometer to the nearest 0.1 centimeter with the participants standing straight without shoes. Weight was measured by the portable electronic scale to the nearest 0.1 kg with the participants wearing light clothes. Both the height and weight were measured twice, and the average value was calculated to eliminate measurement error. BMI was

calculated from the formula: weight (kg) divided by height squared (m^2).[29] Children and adolescents were classified into two weight status categorises: normal and overweight/obesity according to the BMI-based age and sex-specific criteria provided by the Working Group on Obesity in China.[32] We used the 85th and 95th percentiles to define overweight and obesity in adolescents. Overweight was defined as BMI ≥85th percentile but <95th percentile, relative to age and sex, whereas obesity was defined as BMI ≥95th percentile. It was a kind of age-specific and sex-specific BMI reference standard for Chinese children. This standard is one of the most broadly used ones in China that showed its superiority in both prospectivity and actuality and is consistent with the East Asian ethnic characteristics of body fat growth, which could eliminate the influence of different populations with different growth patterns and fat accumulation.

Statistical analysis

The questionnaire data were entered using Epidata V.3.1 software. Descriptive statistics were calculated for all of the variables, including continuous variables (presented as mean values and SEs) and categorical variables (displayed by number and percentages). The differences in continuous variables were evaluated by t-test between normal weight and overweight/obesity. For categorical variables, the χ^2 test was used to evaluate statistical differences between the two groups. We also performed the sample descriptive characteristics across different birth weight groups. As the remarkably different proportions of overweight/obesity among different groups were observed, stratified analysis based on gender-specific and educational stage-specific factors were conducted to evaluate whether there were effect modifications of overweight/obesity, respectively.

Logistic regression models were performed to assess the ORs and corresponding 95% CIs for overweight/obesity when participants with NBW were used as the reference group regarding gender and educational stage differences. In addition to the unadjusted model (model 1), model 2 was adjusted for children and adolescents' height, weight, BMI, delivery mode, parental age and parental educational level. Furthermore, we also carried out the interaction analysis between birth weight and lifestyle factors of overweight/obesity. In the later analysis process, LBW and NBW were merged as non-HBW to achieve power for the interaction analysis. The relative excess risk due to interaction (RERI) and the attributable proportion due to interaction (AP) were evaluated to measure the additive interaction, deriving 95% CI using the delta method. The additive interaction was considered significant when the 95% CIs of RERI and AP both excluded zero. To estimate the multiplicative interaction, the product term was included in the logistic regression model, calculating the interaction of OR (IOR) and its 95% CI. Significant multiplicative interaction was considered to exist if the 95% CI of IOR did not contain one.[23] All statistical analyses were conducted with IBM software SPSS (V.22). P values less than 0.05 with two sides were considered to be statistically significant.

RESULTS

Demographic characteristics of the study population

The descriptive statistics of the baseline characteristics and the potential influencing variables concerning the proportions of the study population are epitomised in table 1. A total of 27 009 children and adolescents were enrolled into this study. Among the respondents, 19 776 (73.2%) children and adolescents were of normal weight and 7233 (26.8%) children and adolescents were with overweight/obesity. There were no differences between the two groups with respect to age (p=0.067) and paternal age (p=0.326). Meanwhile, all other considered characteristics tested with statistically significant differences among the two groups(all p<0.05).

Sample descriptive characteristics across different birthweight groups

The sample descriptive characteristics of the participants stratified by different birthweight groups are presented in table 2. Among the 27 009 respondents, 3522 (13.0%) children and adolescents were with LBW, 14 172 (52.5%) children and adolescents were with NBW and 9315 (34.5%) children and adolescents were with HBW. All the considered characteristics were tested with statistically significant differences among the three groups(all p<0.05).

Subgroup analyses of birth weight according to different gender and educational stage groups

To investigate the distributions in subgroup analyses of birth weight, participants were divided into different gender and different educational stage groups. The proportions of different birthweight groups among children and adolescents at different gender and different educational stages are shown in table 3, respectively. We found that different birthweight groups were tested with statistically significant differences among the two groups according to different gender and different educational stages respectively (all p<0.05).

Association between birth weight and risk of overweight/obesity stratified by different gender and educational stages

To be specific, the results of the logistic regression analyses of birth weight associated with overweight/obesity according to different gender and different educational stages are presented in table 4. The unadjusted and adjusted OR and 95% CI are reported in model 1 and model 2, respectively. We found the associations differed based on the gender-specific and educational stage-specific factors. Stratified by gender, children and adolescents with HBW had a higher risk of overweight/obesity as compared with the NBW group (adjusted ORs 2.582 and 2.356; 95% CIs 1.413 to 3.579 and 1.097 to 2.934, boys and girls, respectively). Stratified by educational

Table 1 Demographic characteristics of the study population

Variables	Overall (N=27 009)	Normal weight (N=19 776)	Overweight/obesity (N=7233)	P value
Age (years)				0.067
7–12	7773 (28.8)	5650 (28.6)	2123 (29.4)	
13–15	9185 (34.0)	6805 (34.4)	2380 (32.9)	
16–18	10 051 (37.2)	7321 (37.0)	2730 (37.7)	
Gender				<0.001
Boy	18 191 (67.4)	13 917 (70.4)	4274 (59.1)	
Girl	8818 (32.6)	5959 (29.6)	2959 (40.9)	
Residence region				<0.001
Urban	19 069 (70.6)	13 406 (67.8)	5663 (78.3)	
Rural	7940 (29.4)	6370 (32.2)	1570 (21.7)	
Educational stages				<0.001
Primary school	7391 (27.4)	5367 (27.1)	2024 (28.0)	
Middle school	9349 (34.6)	7074 (35.8)	2275 (31.4)	
High school	10 269 (38.0)	7335 (37.1)	2934 (40.6)	
BMI (kg/m^2)	25.17±2.99	21.07±2.87	26.45±3.27	<0.001
Birth weight				
Low	3522 (13.0)	2306 (11.7)	1216 (16.8)	
Normal	14 172 (52.5)	10 699 (54.1)	3473 (48.0)	
High	9315 (34.5)	6771 (34.2)	2544 (35.2)	
Delivery mode				<0.001
Natural delivery	15 275 (56.6)	11 524 (58.3)	3751 (51.9)	
Caesarean section	11 734 (43.4)	8252 (41.7)	3482 (48.1)	
Paternal age	41.20±2.02	41.21±2.03	41.18±1.99	0.326
Paternal BMI				<0.001
Normal	15 659 (58.0)	11 595 (58.6)	4064 (56.2)	
Overweight	7327 (27.1)	5364 (27.1)	1963 (27.1)	
Obesity	4023 (14.9)	2817 (14.3)	1206 (16.7)	
Paternal education level				<0.001
Middle school or below	6969 (25.8)	5636 (28.5)	1333 (18.4)	
High school	8137 (30.1)	5736 (29.0)	2401 (33.2)	
University or above	11 903 (44.1)	8404 (42.5)	3499 (48.4)	
Maternal age	40.12±3.06	40.18±2.01	40.22±2.97	<0.001
Maternal BMI				<0.001
Normal	12 795 (47.4)	9837 (49.7)	2958 (40.9)	
Overweight	8506 (31.5)	6151 (31.1)	2355 (32.6)	
Obesity	5708 (21.1)	3788 (19.2)	1920 (26.5)	
Maternal education level				<0.001
Middle school or below	7092 (26.3)	5616 (28.4)	1476 (20.4)	
High school	8671 (32.1)	6351 (32.1)	2320 (32.1)	
University or above	11 246 (41.6)	7809 (39.5)	3437 (47.5)	
Sleep duration				<0.001
Very short	8637 (32.0)	5929 (30.0)	2708 (37.4)	
Short	8283 (30.7)	6099 (30.8)	2184 (30.2)	
Recommended	7111 (26.3)	5612 (28.4)	1499 (20.7)	

Continued

Table 1 Continued

Variables	Overall (N=27 009)	Normal weight (N=19 776)	Overweight/obesity (N=7233)	P value
Long	2978 (11.0)	2136 (10.8)	842 (11.7)	
Physical activity time				<0.001
≤2 hours/day	23 264 (87.5)	17 436 (88.2)	6188 (85.6)	
> 2 hours/day	3385 (12.5)	2340 (11.8)	1045 (14.4)	
Screen time				<0.001
≤2 hours/day	19 720 (73.0)	14 219 (71.9)	5501 (76.1)	
> 2 hours/day	7289 (27.0)	5557 (28.1)	1732 (23.9)	

BMI, body mass index.

stages, we found HBW were positively associated with an increased risk of overweight/obesity compared with the NBW group. The adjusted ORs of the three groups were 2.757 (95% CI 1.483 to 3.658), 2.317 (95% CI 1.451 to 2.795) and 2.216 (95% CI 1.532 to 2.873), respectively. We also performed the analysis based on the overall population of the associations. The results also showed HBW (adjusted ORs: 2.866, 95% CI 1.563 to 3.728) was associated with an increased odd of overweight/obesity. However, there were no statistically significant associations between LBW and overweight/obesity among the different groups.

Interaction analysis between birth weight and lifestyle factors of overweight/obesity across gender and educational stage groups

The results of interaction analysis between birth weight and lifestyle factors of overweight and obesity across gender and educational stages are shown in table 5. In this process, LBWs and NBWs were merged as non-HBW to achieve power for the interaction analysis. In the overall population, we found the HBW group with insufficient physical activity time had significantly higher risk of overweight/obesity (OR 2.165, 95% CI 1.352 to 3.378), when comparing to the non-HBW group with insufficient physical activity time. As expected, a significant additive interaction was found between birth weight and insufficient physical activity time (RERI 2.289, 95% CI 0.678 to 3.576; AP 0.723, 95% CI 0.521 to 1.126). The results of these interactions were consistent according to different gender and different educational stage groups. Additionally, no significant additive and multiplicative interactions were observed between birth weight and screen time for the odds of overweight/obesity in the overall population and subgroups across gender and educational stages.

DISCUSSION

This cross-sectional study revealed a prevalence rate of 26.8% for children and adolescents overweight/obesity in Henan Province, with the rates of overweight/obesity being 15.8% and 10.9% for boys and girls, respectively. The prevalence of overweight/obesity was higher than the results of Changsha city in 2018 (25.0%).[33] The levels found here were also higher than the proportion previously reported among students aged 7–18 years in China from 1985 to 2014, where 19.4% of survey participants were overweight/obese.[34] The reasons for the difference in different places are complicated, and variations in ethnicity, dietary behaviour, lifestyle and economic development may contribute to it. The result of this study indicates that the high prevalence of overweight/obesity in Henan Province is facing a severe situation and the development trend is not optimistic. Our study indicated that boys were more likely to have overweight/obesity than girls. This might be because boys spend more time in screen-based sedentary behaviours or eat a large amount of food, while girls are more conscious of their body shape control in daily life to reduce the occurrence of overweight/obesity.

Generally, this study showed that the proportions between birth weight and overweight/obesity were gender-specific and educational stage-specific. When evaluated by gender, the proportions of overweight/obesity were higher in boys than girls under LBW and HBW groups, respectively. When stratified by educational stages, the proportions of overweight/obesity were higher in middle school than high school and primary school in the LBW group; while the proportions of overweight/obesity were higher in high school than middle school and primary school in the HBW group. These findings remind us that gender and educational stages can be regarded as specific stratified characteristics for further investigation. The differences should be taken into account in the process of designing interventions aimed at reducing overweight/obesity in children and adolescents. Families and schools can combine these findings to strengthen health education efforts to improve health awareness and implement early interventions.

Many studies have also verified a high level of birth weight as one strong predictor of overweight/obesity among children or adolescents. However, few studies in China, to our knowledge, were limited to one specific gender group or educational stages in one provincial area, which cannot reveal the overall associations among

Table 2 Descriptive characteristics of participants stratified by different birth weight

Variables	Overall (N=27 009)	LBW (N=3522)	NBW (N=14 172)	HBW (N=9315)	P value
Age (years)					<0.001
7–12	7773 (28.8)	1029 (29.2)	4233 (29.9)	2511 (26.9)	
13–15	9185 (34.0)	1226 (34.8)	4647 (32.8)	3312 (35.6)	
16–18	10 051 (37.2)	1267 (36.0)	5292 (37.3)	3492 (37.5)	
Gender					<0.001
Boy	18 191 (67.4)	3195 (90.7)	9160 (64.6)	5836 (62.7)	
Girl	8818 (32.6)	327 (9.3)	5012 (35.4)	3479 (37.3)	
Residence region					<0.001
Urban	19 069 (70.6)	2383 (67.7)	10 161 (71.7)	6525 (70.0)	
Rural	7940 (29.4)	1139 (32.3)	4011 (28.3)	2790 (30.0)	
Educational stages					<0.001
Primary school	7391 (27.4)	623 (18.5)	4666 (32.9)	2072 (22.2)	
Middle school	9349 (34.6)	1656 (47.0)	4050 (28.6)	3643 (39.1)	
High school	10 269 (38.0)	1213 (34.5)	5456 (38.5)	3600 (38.7)	
BMI (kg/m^2)	25.17±2.99	22.43±2.98	21.99±2.98	26.35±2.98	<0.001
Delivery mode					
Natural delivery	15 275 (56.6)	1723 (48.9)	8246 (58.2)	5306 (57.0)	
Caesarean section	11 734 (43.4)	1799 (51.1)	5926 (41.8)	4009 (43.0)	
Paternal age	41.20±2.02	41.33±1.96	41.16±2.02	41.22±2.03	<0.001
Paternal BMI					<0.001
Normal	15 659 (58.0)	1989 (56.5)	8083 (57.0)	5587 (60.0)	
Overweight	7327 (27.1)	927 (26.3)	3985 (28.1)	2415 (25.9)	
Obesity	4023 (14.9)	606 (17.2)	2104 (14.9)	1313 (14.1)	
Paternal education level					<0.001
Middle school or below	6969 (25.8)	541 (15.3)	3933 (27.8)	2495 (26.8)	
High school	8137 (30.1)	1439 (40.9)	3842 (27.1)	2856 (30.7)	
University or above	11 903 (44.1)	1542 (43.8)	6397 (45.1)	3964 (42.5)	
Maternal age	40.12±3.06	40.13±2.85	40.06±2.97	40.09±3.09	<0.001
Maternal BMI					<0.001
Normal	12 795 (47.4)	1659 (47.1)	6405 (45.2)	4731 (50.8)	
Overweight	8506 (31.5)	1209 (34.3)	4358 (30.8)	2939 (31.5)	
Obesity	5708 (21.1)	654 (18.6)	3409 (24.0)	1645 (17.7)	
Maternal education level					<0.001
Middle school or below	7092 (26.3)	875 (24.9)	3403 (24.0)	2814 (30.2)	
High school	8671 (32.1)	1153 (32.7)	4786 (33.8)	2732 (29.3)	
University or above	11 246 (41.6)	1494 (42.4)	5983 (42.2)	3769 (40.5)	
Sleep duration					<0.001
Very short	8637 (32.0)	1553 (44.1)	4076 (28.8)	3008 (32.3)	
Short	8283 (30.7)	834 (23.7)	4290 (30.3)	3159 (33.9)	
Recommended	7111 (26.3)	951 (27.0)	4069 (28.7)	2091 (22.4)	
Long	2978 (11.0)	184 (5.2)	1737 (12.2)	1057 (11.4)	
Physical activity time					<0.001
≤2 hours/day	23 264 (87.5)	3245 (92.1)	12 222 (86.2)	8157 (87.6)	
> 2 hours/day	3385 (12.5)	277 (7.9)	1950 (13.8)	1158 (12.4)	

Continued

Table 2 Continued

Variables	Overall (N=27 009)	LBW (N=3522)	NBW (N=14 172)	HBW (N=9315)	P value
Screen time					<0.001
≤2 hours/day	19 720 (73.0)	2797 (79.4)	10 020 (70.7)	6903 (74.1)	
> 2 hours/day	7289 (27.0)	725 (20.6)	4152 (29.3)	2412 (25.9)	

BMI, body mass index.

children and adolescents more broadly. In the present study, we found the associations between HBW and the odds of overweight/obesity had gender-specific and educational stage-specific differences before and after adjusting for the covariables. More specifically, we also performed the analysis based on the overall population of the associations. The results showed HBW was positively associated with an increased risk of overweight/obesity, which is consistent with the previous studies. A meta-analysis of 66 studies from 26 countries demonstrated that HBW (>4 kg) was positively associated with increased odds of childhood overweight (OR 1.66; 95% CI 1.55 to 1.77) compared with NBW (<2.5–4 kg). [35] Oldroyd *et al*[36] stated a stronger association of HBW with childhood obesity in boys than that in girls, with the OR for boys of 2.42 (95% CI 2.06 to 2.86) vs that of 1.76 (95% CI 1.12 to 2.78) for girls. Another population-based cohort study from Denmark indicated an increased risk of overweight for children 6–13 years of age with birth weight ≥4.0 kg compared with those with birth weight between

Table 3 Proportions of different birthweight groups among children and adolescents according to different gender and different educational stages

Variables	Normal weight (N=19 776)	Overweight/obesity (N=7233)	P value
Boys			<0.001
LBW	2120 (15.2)	1075 (25.1)	
NBW	7337 (52.7)	1823 (42.7)	
HBW	4460 (32.1)	1376 (32.2)	
Girls			<0.001
LBW	186 (3.2)	141 (4.8)	
NBW	3362 (57.4)	1650 (55.8)	
HBW	2311 (39.4)	1168 (39.4)	
Primary school			<0.001
LBW	428 (8.0)	225 (11.1)	
NBW	3476 (64.8)	1190 (58.8)	
HBW	1463 (27.2)	609 (30.1)	
Middle school			<0.001
LBW	903 (12.8)	753 (33.1)	
NBW	3177 (44.9)	873 (38.4)	
HBW	2994 (42.3)	649 (28.5)	
High school			<0.001
LBW	975 (13.3)	238 (8.1)	
NBW	4046 (55.2)	1410 (48.1)	
HBW	2314 (31.5)	1286 (43.8)	

HBW, high birth weight; LBW, low birth weight; NBW, normal birth weight.

Table 4 Logistic regression analyses between birth weight and risk of overweight/obesity according to different gender and different educational stage groups

	Model 1*	Model 2†
Variables	Crude OR (95% CI)	Adjusted OR (95% CI)
Boys		
LBW	1.431 (0.978 to 2.123)	1.516 (0.806 to 2.572)
NBW	1.00 (reference)‡	1.00 (reference)‡
HBW	2.156 (1.378 to 3.262)	2.582 (1.413 to 3.579)
Girls		
LBW	1.155 (0.887 to 1.617)	1.363 (0.726 to 1.782)
NBW	1.00 (reference)‡	1.00 (reference)‡
HBW	2.075 (1.136 to 2.871)	2.356 (1.097 to 2.934)
Primary school		
LBW	0.427 (0.351 to 1.268)	0.534 (0.297 to 1.152)
NBW	1.00 (reference)‡	1.00 (reference)‡
HBW	2.473 (1.562 to 3.371)	2.757 (1.483 to 3.658)
Middle school		
LBW	0.572 (0.285 to 1.247)	0.691 (0.355 to 1.427)
NBW	1.00 (reference)‡	1.00 (reference)‡
HBW	2.156 (1.322 to 2.678)	2.317 (1.451 to 2.795)
High school		
LBW	1.157 (0.788 to 2.019)	1.256 (0.915 to 1.896)
NBW	1.00 (reference)‡	1.00 (reference)‡
HBW	1.978 (1.369 to 2.557)	2.216 (1.532 to 2.873)
Overall		
LBW	1.235 (0.562 to 1.673)	1.376 (0.691 to 1.878)
NBW	1.00 (reference)‡	1.00 (reference)‡
HBW	2.572 (1.379 to 3.561)	2.866 (1.563 to 3.728)

*Model 1: the unadjusted ORs.
†Model 2: adjusted ORs for children and adolescents height, weight, BMI, delivery mode, parental age and parental educational level.
‡1.00 (reference) meant the reference group.
BMI, body mass index; HBW, high birth weight; LBW, low birth weight; NBW, normal birth weight.

Table 5 The interaction analysis between birth weight and lifestyle factors of overweight/obesity across gender and educational stage groups

Variables	Birth weight	Adjusted OR (95% CI)	IOR (95% CI)	RERI (95% CI)	AP (95% CI)
Boys					
Physical activity time			2.926 (1.123 to 4.758)	1.932 (0.528 to 2.976)	0.691 (0.425 to 1.112)
≤2 hours/day	Non-HBW	1.00 (reference)*			
≤2 hours/day	HBW	2.218 (1.176 to 3.125)			
Screen time			1.135 (–0.567 to 2.642)	0.875 (–1.927 to 4.686)	0.512 (–0.367 to 2.013)
≤2 hours/day	Non-HBW	1.00 (reference)*			
≤2 hours/day	HBW	1.556 (0.483 to 1.812)			
Girls					
Physical activity time			2.875 (1.201 to 4.692)	1.867 (0.471 to 2.623)	0.564 (0.378 to 1.085)
≤2 hours/day	Non-HBW	1.00 (reference)*			
≤2 hours/day	HBW	2.057 (1.268 to 2.974)			
Screen time			1.096 (–0.459 to 2.367)	0.773 (–1.876 to 4.592)	0.469 (–0.287 to 1.978)
≤2 hours/day	Non-HBW	1.00 (reference)*			
≤2 hours/day	HBW	1.473 (0.369 to 1.721)			
Primary school					
Physical activity time			2.763 (1.125 to 4.396)	2.216 (0.591 to 3.435)	0.528 (0.317 to 1.092)
≤2 hours/day	Non-HBW	1.00 (reference)*			
≤2 hours/day	HBW	1.857 (1.033 to 2.869)			
Screen time			0.873 (–0.435 to 1.964)	0.615 (–1.514 to 3.979)	0.346 (–0.612 to 1.369)
≤2 hours/day	Non-HBW	1.00 (reference)*			
≤2 hours/day	HBW	1.258 (0.362 to 1.475)			
Middle school					
Physical activity time			2.829 (1.214 to 4.673)	2.357 (0.634 to 3.891)	0.619 (0.298 to 1.147)
≤2 hours/day	Non-HBW	1.00 (reference)*			
≤2 hours/day	HBW	1.932 (1.145 to 2.906)			
Screen time			0.956 (–0.527 to 2.105)	0.756 (–2.357 to 4.521)	0.472 (–0.721 to 1.613)
≤2 hours/day	Non-HBW	1.00 (reference)*			
≤2 hours/day	HBW	1.347 (0.453 to 1.562)			
High school					
Physical activity time			3.026 (1.311 to 4.857)	2.432 (0.756 to 4.123)	0.711 (0.435 to 1.289)
≤2 hours/day	Non-HBW	1.00 (reference)*			
≤2 hours/day	HBW	2.031 (1.216 to 3.217)			
Screen time			1.038 (–0.586 to 2.397)	0.837 (–3.126 to 4.275)	0.512 (–0.829 to 1.497)
≤2 hours/day	Non-HBW	1.00 (reference)*			
≤2 hours/day	HBW	1.412 (0.556 to 1.639)			
Overall					
Physical activity time			3.192 (1.071 to 5.678)	2.289 (0.678 to 3.576)	0.723 (0.521 to 1.126)
≤2 hours/day	Non-HBW	1.00 (reference)*			
≤2 hours/day	HBW	2.165 (1.352 to 3.378)			
Screen time			1.157 (–0.642 to 2.853)	0.986 (–3.536 to 5.728)	0.367 (–0.973 to 1.562)
≤2 hours/day	Non-HBW	1.00 (reference)*			
≤2 hours/day	HBW	1.362 (0.579 to 1.658)			

*1.00 (reference) meant the reference group.
AP, attributable proportion; HBW, high birth weight; IOR, interaction of OR; RERI, relative excess risk due to interaction.

3.0 and 3.49 kg.[37] There are some possible explanations for the associations. One possible explanation is that overnutrition during pregnancy led to the increase of fat mass in the fetus, which might play an important role in overweight/obesity.[38 39] Another explanation is that birth weight might modify the genetic predisposition and thus affect the risk of overweight/obesity later in life.[40 41] Even though underlying mechanisms have been raised, there

is no systematic explanation for birth weight and overweight/obesity. How birth weight affects overweight/obesity is a complex process within the life course and warrants further study.

More importantly, this study indicated a synergistic interaction effect between birth weight and insufficient physical activity time of overweight/obesity. In the overall population, the HBW children and adolescents with insufficient physical activity time suffered much higher risk of overweight/obesity (OR 2.165, 95% CI 1.352 to 3.378) compared with non-HBW children and adolescents with insufficient physical activity time. As expected, a significant additive interaction was found between birth weight and physical activity time (RERI 2.289, 95% CI 0.678 to 3.576; AP 0.723, 95% CI 0.521 to 1.126). The results of these interactions were consistent according to different gender and different educational stage groups. However, no significant additive and multiplicative interactions were observed between birth weight and screen time for the odds of overweight/obesity. An increasing number of children and adolescents have relatively insufficient physical activity time and spend a large percentage of their time in screen pursuits. The current physical activity guidelines for children recommend that each child performs at least 60 min per day of moderate-to-vigorous physical activity and reductions in sedentary time for health benefits in school-aged children.[42] Physical activity can increase energy expenditure and improve appetite regulation. With the current high prevalence of overweight/obesity and its comorbidities in children and adolescents, it is important to encourage a majority of children and adolescents to adhere to these guidelines. Efforts to develop and implement quality interventions for physically inactive children, especially if they are overweight or obese may be required. Therefore, a better understanding and consideration of the influences of sufficient physical activity is likely to favour mobilisation and compliance of children and their families to programmes aimed at increasing physical activity time and reducing the screen time of children and adolescents.

There were some limitations in the present study. First, because this study used original data from cross-sectional surveys, the data cannot be used to infer causality, and merely descriptive analyses were adopted due to the natural limitation of the cross-sectional study. Further carefully designed cohort studies are needed if permitted. Second, some of the data in this study were collected through the self-reported questionnaires, which are prone to introduce certain subjectivity and recall bias. We excluded the data with missing variables, which reduced the recall bias to a certain extent. Third, although we tried our best to identify relevant factors that may affect overweight and obesity, our data are still far from perfect, which may change the results from adjusting to potential confounding. For example, sleep patterns and physical activity behaviours in children and adolescents, which could further explain the true effects on overweight and obesity, were not collected details by validated and authoritative questionnaires available in this survey. The study relied on a single question or a few questions to gather information on these variables, which may affect the validity and reliability of the data. Future studies should take these factors into consideration to enhance the comprehensiveness of the design and provide more valuable insights for preventing and controlling overweight and obesity. Finally, this study was comprised of a sample of school-aged children and adolescents within a limited age range in the central region of China, which may not be representative of the total Chinese population. Whether the findings of the study are generalised to the broader population of Chinese school-aged children and adolescents in other geographical regions with different living habits remains to be answered. Comparisons with national-level data or other regions should be included to strengthen the argument for representativeness in the follow-up study.

CONCLUSIONS

In conclusion, HBW was independently positively associated with an increased risk of overweight/obesity in school-aged children and adolescents, and the associations differed by gender-specific and educational stage-specific factors. Data suggest that gender and educational stages should be regarded as specific stratified characteristics for the effects on overweight/obesity. More importantly, HBW possibly interplayed synergistically with insufficient physical activity time to increase the risk of overweight/obesity across gender and educational stages. Therefore, intensive attention should be paid earlier in life for the population born with high weight. Sufficient physical activity promotion seems to be a promising strategy for overweight/obesity intervention in children and adolescents with HBW.

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