Does Low Birth Weight Predict Hypertension and Obesity in Schoolchildren?

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Abstract
Background: Birth weight appears to play a role in determining high blood pressure (BP) and obesity during childhood. The purpose of this study is to investigate the association between birth weight and later obesity and hypertension among 10- to 13-year-old schoolchildren.

Methods: A total of 1,184 primary school students were selected from 20 randomized schools between 2011 and 2012 in Iran. Height, weight, waist circumference and BP were measured using standard instruments. Data were analyzed using stepwise regression and logistic regression models.

Results: 13.5% of children had a history of low birth weight. First-degree family history of obesity, excessive gestational weight gain and birth weight were significantly correlated with overweight/obesity and abdominal obesity (p = 0.001), whereas only birth weight was associated with high BP (p = 0.001). An inverse correlation was found between waist circumference and systolic/diastolic BP. The duration of breastfeeding in children with low birth weight was inversely correlated with obesity/overweight, abdominal obesity and hypertension.

Conclusion: The results suggest that birth weight is inversely associated with BP and more so with obesity and abdominal obesity. The duration of having been breastfed could have an influence on later hypertension, obesity and abdominal obesity. Further results are needed to test these correlations as well as diagnosing early life factors to prevent young adult overweight/obesity or hypertension.

Key Words
Low birth weight · Children · Obesity · Hypertension

Introduction

The new International Obesity Taskforce analysis estimates that globally up to 200 million school-aged children are either overweight or obese, with 40–50 million classified as obese [1]. Likewise, the prevalence of overweight children in Iran was recently reported as 19.7% [2]. Moreover, the prevalence of hypertension in children is increasing [3] and it was reported to be approximately 0.8% among children in Iran [4]. Factors known to affect blood pressure (BP) and obesity in children include genetic, sex, age, body size, socioeconomic status and race/
ethnicity [5]. Low birth weight appears to play a role in hypertension [6] and in subsequent obesity in children as well [7].

While there are numerous studies that demonstrate the inverse relationship between low birth weight and BP in adults [8–10], few pediatric studies currently exist [6, 11]. Previously, the association between birth weight and later BP reported a negative trend which was only significant for diastolic BP (DBP), whereas this trend was found to be significant for both systolic BP (SBP) and DBP after body mass index (BMI) was added to the statistical model [6]. It was also observed that although SBP values were higher among low-birth-weight obese youths, the presence of obesity blunts the increment of SBP in low-birth-weight subjects [12]. Low birth weight was found to be associated with SBP along with other metabolic syndrome factors such as insulin resistance and triglyceride level [10], and the correlation between birth weight and BP was not detected independently.

On the other hand, several other studies have reported the inverse association between birth weight and later obesity prevalence in children [7, 13–14]. Most did not consider crucial factors affecting weight gain, such as history and duration of breastfeeding among low-birth-weight subjects [7, 14]. In addition, abdominal obesity was discovered to be related to reduced birth weight, which could also influence insulin resistance [15].

The present study attempts to investigate the association of birth weight with overweight/obesity, and higher BP among schoolchildren aged 10–13 years and taking into account the effect of other important factors, such as the duration and history of breastfeeding, family history of obesity and socioeconomic status, in order to engender accurate and efficient outcomes.

**Methods and Materials**

**Participants**

The target population in this cross-sectional study conducted between 2011 and 2012 included 1,184 primary school students whose ages ranged from 10 to 13 years. A standardized and validated questionnaire was provided for compiling information about participants’ family economics and educational level, obesity prevalence in first degree relatives (parents, full siblings and offspring), season of birth, nutritional status, food patterns, puberty and birth weight. Information on the birth weight of children was collected retrospectively based on newborn demographic data. Exclusion criteria included cardiovascular disease, diabetes mellitus, renal disease, consumption of any vitamin supplements, influenza and dental infectious disease. Ethical approval was provided by the committee of ethics at Tehran University of Medical Science.

**Procedures and Terminology**

Participants were weighed without shoes and heavy clothing using a digital scale with a precision of 0.1 kg, and their height was measured without shoes to the nearest 0.1 cm using a portable stadiometer (Seca model 207). BP was recorded by trained nutritionists using a digital sphygmomanometer with a precision of 0.1 mm Hg (model 1002/Presameter; Riester, Tuttinglen, Germany) twice consecutively, with the subject in the sitting position after a rest of 10 min, and the average of the two readings was reported.

Likewise, waist circumference was measured over skin by an inelastic plastic tape and measurements were assessed by standard score adjusted for age and sex [16]. Trained interviewers applied the standardized and pretested questionnaires to the children’s mothers and finally the mothers participated in a 2-hour session held for troubleshooting any problems.

Low birth weight was defined by the World Health Organization as weight at birth <2,500 g (5.5 pounds) [17]. High BP hypertension was defined as either SBP or DBP at or above the 95th percentile for gender, age and height of the child [18]. Abdominal obesity status was classified as a waist circumference at or above the 85th percentile of age- and gender-matched children from the National Health and Nutrition Examination Survey III cohort [19]. Overweight in children was defined as a BMI at or above the 85th percentile and lower than the 95th percentile for children of the same age. Obesity was also defined as a BMI above the 95th percentile for children of the same age and sex [20]. BMI was calculated by dividing weight (kg) by height squared (m²). Excessive weight gain during pregnancy was defined as gaining 35 or more pounds for normal weight and 25 or more pounds for overweight women [21].

**Statistical Analyses**

All data are reported as mean ± SD, and frequency and relative frequency for quantitative and categorical data, respectively. The SPSS version 18 statistical package for Windows (SPSS Inc., Chicago, Ill., USA) was used for all statistical analysis. χ², t test and ANOVA were used for comparing means and proportions. For multivariate analysis, regression and logistic regression was used.

**Results**

The study sample comprised 52.8% male and 47.2% female students. The birth-weight distributions amongst participants are shown in figure 1. Mean values of anthropometric indicators (weight, height, BMI and waist circumference), SBP and DBP of subjects were assessed according to gender and birth weight. Of these variables, weight (p = 0.02), height (p = 0.04) and waist circumference (p = 0.05) were greater in girls than boys. Table 1 and 2 indicate the mean values of anthropometric indicators, SBP and DBP in participants based on sex and birth weight, respectively.

13.5% of children had a history of low birth weight. Only first-degree family history of obesity was higher in girls than boys. Regardless of that, the gender of subjects...
Table 1. Anthropometric indicators, SBP and DBP in participants

<table>
<thead>
<tr>
<th></th>
<th>Boys (n = 557)</th>
<th>Girls (n = 627)</th>
<th>Total (n = 1,184)</th>
<th>p^a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>11.5±0.5</td>
<td>11.5±0.5</td>
<td>11.5±0.5</td>
<td>0.20</td>
</tr>
<tr>
<td>BMI, kg/m^2</td>
<td>19.0±3.8</td>
<td>19.7±4.0</td>
<td>19.4±3.9</td>
<td>0.16</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>40.1±10</td>
<td>43.3±11.0</td>
<td>41.8±10.7</td>
<td>0.02</td>
</tr>
<tr>
<td>Height, cm</td>
<td>144.4±6.3</td>
<td>147.7±7.3</td>
<td>146.1±7</td>
<td>0.004</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>70.4±10.9</td>
<td>71.7±10.2</td>
<td>71.1±10.5</td>
<td>0.05</td>
</tr>
<tr>
<td>SBP, mm Hg</td>
<td>100.7±13.5</td>
<td>102.4±13.8</td>
<td>101.6±13.7</td>
<td>0.42</td>
</tr>
<tr>
<td>DBP, mm Hg</td>
<td>67.7±11.6</td>
<td>68.0±10.7</td>
<td>67.9±11.1</td>
<td>0.82</td>
</tr>
</tbody>
</table>

Data are means ± SD.
^a Obtained from independent t tests.

Table 2. Anthropometric indicators, SBP and DBP in participants based on birth weight

<table>
<thead>
<tr>
<th></th>
<th>&lt;2,500 g</th>
<th>2,500–4,000 g</th>
<th>&gt;4,000 g</th>
<th>p^a</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI, kg/m^2</td>
<td>21.9±5.2</td>
<td>18.7±3.4</td>
<td>19.4±3.6</td>
<td>0.02</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>47.2±14</td>
<td>40±9.5</td>
<td>42.8±10.1</td>
<td>0.01</td>
</tr>
<tr>
<td>Height, cm</td>
<td>145.9±7</td>
<td>145.4±7</td>
<td>147.7±7</td>
<td>0.34</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>77±13.3</td>
<td>69.6±9.6</td>
<td>71.2±9.8</td>
<td>0.034</td>
</tr>
<tr>
<td>SBP, mm Hg</td>
<td>106.3±16.1</td>
<td>100.4±13.1</td>
<td>101.5±12.8</td>
<td>0.03</td>
</tr>
<tr>
<td>DBP, mm Hg</td>
<td>70.6±15.2</td>
<td>67.4±10.4</td>
<td>67.4±10</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Data are means ± SD.
^a Obtained from ANOVA.
^b Significantly different from the <2,500-gram group, based on post hoc tests.
^c Significantly different from the 2,500- to 4,000-gram group, based on post hoc tests.
^d Significantly different from the >4,000-gram group, based on post hoc tests. Significantly differences are shown with a, b, c.

had no significant correlation with duration of pregnancy and excessive gestational weight gain.

Table 3 shows the prevalence of obesity, hypertension and abdominal obesity in participants based on their gender. The results show that the prevalence of obesity/overweight had an odds ratio of response of 1.4 in subjects with a birth weight of 2,500–4,000 g compared with subjects with a birth weight under 2,500 g. Moreover, overweight/obesity was more prevalent among those with first-degree family history of obesity and also among subjects whose mothers had excessive gestational weight gain. Odds ratio of response was 0.386 and 0.665, respectively. On the other hand, abdominal obesity prevalence seemed to be greater in groups with a history of low birth weight, subjects with a first-degree family history of obesity and in children whose mothers had excessive gesta-

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Fig. 1. Prevalence of birth weight in participants.
tional weight gain; odd ratios of response were 0.323, 0.441 and 0.579, respectively.

By contrast, in the final regression analysis model, only birth weight was a significant predictor variable of the prevalence of high BP. In other words, the prevalence of hypertension had an odds ratio of response of 0.339 in students with a birth weight of 4,000 g or more compared with those with a birth weight less than 2,500 g.

Results indicated that there was an inverse correlation between waist circumference and SBP/DBP. In contrast, weight was positively associated with SBP/DBP, although this correlation was statistically weak.

According to table 3, low prevalence of obesity/overweight and abdominal obesity was observed among both male and female students according to their sex; however, obesity/overweight was more prevalent in females, while the prevalence of abdominal obesity and hypertension was greater in males.

Weight status, BP and abdominal obesity status are illustrated in figure 2, categorized by birth weight. Obesity/overweight, abdominal obesity and high BP were more prevalent among subjects with low birth weight compared to subjects with normal birth weight (2,500–4,000 g) or high birth weight (more than 4,000 g), with values of near 40, 50 and <30%, respectively, for each variable. The low-birth-weight group was significantly different from other groups for all three variables (p < 0.001; fig. 2).

The correlations of history of breastfeeding with obesity, abdominal obesity and BP status were assessed in subjects with a birth weight under 2,500 g (low birth weight). Subjects who were breastfed had a lower prevalence of hypertension. In other words, breastfeeding of subjects with a birth weight under 2,500 g could prevent later hypertension.

**Discussion**

Three major aims motivated this study. We sought to assess the relation of birth weight to BP, obesity and abdominal obesity among students 10–13 years of age. Moreover, data in this study included information on various indicators such as the level of parental education, parental occupation and family history of obesity, as well as history and duration of breastfeeding and gestational weight gain.

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**Table 3.** Prevalence of obesity, hypertension and abdominal obesity in participates based on sex

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>Total</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>74.4</td>
<td>71.0</td>
<td>72.6</td>
<td>0.04</td>
</tr>
<tr>
<td>Overweight</td>
<td>21.1</td>
<td>22.8</td>
<td>22.0</td>
<td></td>
</tr>
<tr>
<td>Obese</td>
<td>4.4</td>
<td>6.0</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>Blood pressure, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>84.8</td>
<td>87.2</td>
<td>86.0</td>
<td>0.001</td>
</tr>
<tr>
<td>Hypertension</td>
<td>15.1</td>
<td>12.7</td>
<td>13.9</td>
<td></td>
</tr>
<tr>
<td>Abdominal obesity, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>73.5</td>
<td>75.6</td>
<td>74.6</td>
<td>0.02</td>
</tr>
<tr>
<td>Abdominal obesity</td>
<td>26.4</td>
<td>24.3</td>
<td>25.3</td>
<td></td>
</tr>
</tbody>
</table>

* Obtained from χ² test.
In the present study, overweight was more prevalent than obesity among schoolchildren, more so in females than in males. These findings are similar to previous reports [22, 23], although Kelishadi et al. [23] found that abdominal obesity is more prevalent in boys than in girls, which is in conflict with our results. The outcomes of various studies have been inconsistent regarding the relationship between birth weight and childhood obesity [7, 13, 14, 24–32]. In accordance with our results, an inverse correlation was found previously [7, 13, 14, 28]. As was discussed by Scerri et al. [13], although statistical significance in mean body weight was shown for the higher-birth-weight group, the proportion of overweight/obesity in 9-year-old children born with low birth weight was greater than those born with high birth weight, which could be due to less exposure to a practically limitless supply of energy caused by ending the catch-up growth period at 9 years of age. Furthermore, it was observed that as birth weight decreased, proportionately more subcutaneous fat was accumulated in the body among children aged 7–12 years [14]. Notably, it was recently published that different birth-weight categories could influence the prevalence of obesity during childhood [28] and high rapid weight gain in the first year of life could be an important predictor of obesity status in low-birth-weight preterm infants [28, 33–35], or in post-term [36] or term-birth children [37]. Likewise, considering a genetic trait, it was observed that functional −243 A→G polymorphism in the 5′ promoter region of glutamic acid decarboxylase 2 (GAD2) genes could result in decreasing insulin resistance and influence feeding behavior, which could be an important determinant of subsequent risk of obesity among low-birth-weight children [7]. Family history of obesity may also identify children at risk of overweight/obesity or high BMI, especially in girls [38]. Similarly, we found that family history of obesity was gender specific and was higher in females than in males, though we did not investigate any effect of parental obesity on the later life of offspring. By contrast, many recent studies reported a positive relationship between birth weight and obesity or overweight [24–27, 29–32], even when it was specified by gender [24]. One might argue that, compared with Peter et al. [25], we did not measure total body fat percentage or tricep skinfold to analyze the engendered outcomes in detail. Astonishingly, Hirschler et al. [26] postulated not only that low birth weight is not associated with overweight or obesity, but also proved it to be a predictive factor against those conditions, whereas high birth weight is correlated with obesity and metabolic syndrome in children. A recent meta-analysis conducted by Yu et al. [27] suggested that, although low birth weight is associated with decreased risk of obesity even in subgroup analyses based on different growth and developmental stages, no association was found when two studies which exhibited selection bias were removed, or in cohort studies, studies with large sample sizes and studies with high-quality grades. Differences in study design, sample size and quality grade of the study were thought to influence these results.

On the other hand, evidence on the association between birth weight and abdominal obesity is also controversial. Our observations show that low birth weight is significantly correlated with higher waist circumference during childhood, which confirms previous findings [15, 39–40]. Hng et al. [15] conducted a twin study and reported that reduced birth weight was linked to an increased risk of abdominal obesity. Similarly, it was published that children short for gestational age are viscerally adipose compared to children appropriate for gestational age since they have higher serum leptin, visfatin, insulin-like growth factor 1 and fasting insulin levels, which are independently determinant of visceral fat in the body [39]. However, we did not measure any of these endocrine metabolic factors. Similar to our results, Barker et al. [40] demonstrated that low birth weight was associated with a tendency to store fat centrally among 14-year-old girls, which was linked to insulin resistance and thus implications for long-term health. Regardless of these findings, several studies have reported a higher obesity rate among children born large for gestational age [41, 42].

Our study population was selected from different regions. We observed that parental educational level was positively associated with overweight/obesity or abdominal obesity, although this correlation reached significance only for the fathers’ educational level. A similar relationship was also evident between parental occupational level and obesity/overweight and abdominal obesity in children, particularly for those whose fathers and mothers were employed. It might be explained by the assumption that self-employed parents who work more hours outside their homes probably spend less time with their children and, therefore, might have less control over their food intake, eating habits and physical activity levels [43]. Although these socioeconomic results are consistent with those of Ozer et al. [44], some prior studies have postulated conflicting findings [45–48]. Ogden et al. [46] concluded that the prevalence of childhood obesity was increased at all levels of income and education, while others
believed that it was inversely correlated with socioeconomic status [45, 47–48]. One might argue that we did not consider all socioeconomic factors, such as nutritional status, poverty level or family income, and consequently these different characteristics might attribute to the loss of statistical strength in our study per se, or the conflicting results in general. Recent studies have concluded that gestational weight gain in all trimesters is associated with birth weight [49] and excessive gestational weight gain is linked with an increase in child BMI Z-score [50] and, furthermore, family history of obesity is definitely proven to be a factor correlated with childhood obesity [51, 52].

Previously published data on birth weight-BP correlations were inconsistent, with studies reporting inverse, positive or no associations [6, 8–12, 53–57]. According to the hypotheses of Barker et al. [8] and Barker [53], hypertension originates in slow fetal growth followed by rapid compensatory growth in childhood and, furthermore, they assumed that low birth weight and distributed intrauterine growth is associated with hypertension in adult life, although this was not tested in children. The findings engendered by the present study also indicate a negative correlation between birth weight and BP, specifically reporting that mean SBP was higher in the low-birth-weight group, although this difference was not statistically significant. One advantage of our study was that we used a digital sphygmomanometer which reduces possible errors compared to other methods. In spite of this, some limitations should be considered. BP was measured twice on the same day, whereas clinical recommendations suggest measurements be taken on different days [58]. Although not all previous studies are in agreement that birth weight has a relation to BP levels later in life [38, 59], most report that an inverse correlation exists [6, 9–12, 54, 55, 60]. It was previously published that low-birth-weight children who became obese have the highest ambulatory SBP values [12]. Huxley et al. [54] analyzed a total of 45 published articles describing that this inverse relationship between birth weight and SBP was present in adolescence though attenuated compared with preadolescence periods. Interestingly, this inverse correlation has been genetically proven. Aja-la et al. [11] recently reported that angiotensin-converting enzyme had a significant association with SBP and its activity levels were significantly elevated in low-birth-weight children compared with the normal-birth-weight group. As a result, it can be interpreted as a major factor in the association between low birth weight and high BP levels in children. A meta-analysis conducted by Min Mu et al. [55] also recently confirmed this inverse correlation. Likewise, there is evidence to support that low birth weight is related to increasing DBP [9, 10]. On the other hand, as we found a significant interaction between low birth weight and childhood obesity, it is possible that some other factors which were not identified might affect both high BP and obesity in low-birth-weight children. We observed that every 1 kg increase in current body weight leads to an estimated SBP and DBP increase of 0.618 and 0.364 mm Hg, respectively, after excluding the height indicator, whereas a decrease of 0.173 mm Hg in SBP and 0.164 mm Hg in DBP was found per 1-cm increase in waist circumference. Although previous findings found that weight and BMI have a positive association with BP levels [23, 61–63], the present weak inverse association between waist circumference and SBP/DBP was not in accordance with other reports [23, 62]. It has also been reported that the height indicator is positively correlated with BP [23, 59], though we were unable to find any correlation. Discrepancies in findings might be due to the large sample size in the mentioned study.

Similar to previous findings [64–66], our observations suggest that history and duration of breastfeeding both prevent any later childhood hypertension among low-birth-weight groups, although previous studies have shown no differences between different birth-weight ranges [64–66]. Salgado et al. [67] also concluded that the positive relationship between low birth weight and duration of breastfeeding could be worrisome since children predisposed to future cardiovascular diseases are those who were breastfed for a short time [67, 68]. On the other hand, we could not ascertain whether excessive gestational weight gain was associated with a child’s BP, while evidence of this correlation has been variously reported [69–71]. Most recent studies suggest that gestational weight gain is positively correlated with BP during childhood [69, 72] and adulthood, which might be mediated by the effect of gestational weight gain on offspring adiposity and BMI [70]. One might argue that the present study contains a small sample size or different age groups compared to other related studies [71, 72].

In summary, our study supports the belief that birth weight is associated with high BP, particularly high SBP, and especially with obesity and abdominal obesity, as well as current BMI and waist circumference among 10- to 13-year-old children. Obesity and elevated BP were often detected in subjects who had a low birth weight. Family history and gestational weight gain are key predictors of hypertension and obesity in schoolchildren.
The duration of having been breastfed could also be significant in the prevention of later hypertension. Consequently, as high BMI Z-scores and cardiovascular diseases have been increasing over recent decades, focusing on effective prevention and interventions is necessary. Further results are needed to test these correlations as well as to diagnose and demonstrate the early life factors and life-course exposures associated with young adult overweight/obesity, hypertension and cardiovascular disease risks.

References


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