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Low Birth Weight Is Associated with High Waist-to-Height Ratio in Japanese Elementary School Girls

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In Japan, the rate of low birth weight infants has increased, due to an increase in the number of women who smoke or are lean. A recent study showed that low birth weight was associated with a high adult waist-to-height ratio in adult Japanese women, but little data is available concerning children. In this cross-sectional study with 568 subjects (276 boys and 292 girls), we examined the association between birth weight and waist-to-height ratio in 7- or 8-year-old Japanese children, all born at full term. The mothers of the subjects responded to a questionnaire about the weight of the children at birth, and physical data were collected from the results of measurements conducted at each school. We divided the subjects into two groups by the median of the birth weight (3,000 g) by sex to elucidate the effects of birth weight on the waist-to-height ratio. There were 119 boys and 164 girls and 157 boys and 128 girls in the < 3,000 g and ≥ 3,000 g birth weight groups, respectively. The Mann-Whitney *U* test was used to compare the physical conditions in the two birth weight categories. Height was significantly lower in the birth weight < 3,000 g group among both the boys ($P < 0.001$) and girls ($P < 0.001$). The waist-to-height ratio was significantly higher in the < 3,000 g group in girls ($P = 0.004$), but not in the boys. Our results suggest that intrauterine environmental insults might have an effect on children, depending on sex.

Keywords: birth weight; elementary school children; girls; Japanese; waist-to-height ratio
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Introduction

Low birth weight infants might be at risk for cardiovascular diseases in adult life in England (Barker and Osmond 1986; Barker et al. 1989). At present, Barker's hypothesis has been advanced into the "Developmental Origins of Health and Disease" (DOHaD) concept (Gluckman and Hanson 2004), which considers that intrauterine growth restriction (IUGR) is associated with a high risk of metabolic syndrome and non-communicable diseases. It can be considered that low birth weight is an indicator of an undesirable environment in the uterus during pregnancy.

In 2008, the rate of low birth weight infants increased in Japan, up to 8.5% in boys and 10.7% in girls (Health, Labour and Welfare Statistics Association 2010). There are several reasons for this phenomenon, an increase in the number of women who smoked and the number of lean young women with a body mass index (BMI) less than 18.5, the number of late maternities has increased, many pregnant women went on a strict diet for their shape or to prevent maternity-diseases during the pregnancy, accidents at birth, infertility treatment has increased the number of multiple pregnancies, and modern high-level medical treatment technology has increased the survival rate of low birth weight newborn infants and decreased the number of fetal deaths. This tendency for an increasing number of low birth weight infants will lead to an increase in the number

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of non-communicable diseases cases in the future.

According to a Statistical Survey conducted by the Ministry of Education, Culture, Sports, Science and Technology Japan (2011), the rate of 8-year-old obese children was 4.3% in 1977, but this number increased up to 6.3% in 2011. In addition, there has been an increase in the number of diabetes cases (Tajima and Morimoto 2012), metabolic syndrome cases (Yoshinaga et al. 2008) and several allergic diseases in childhood (Kusunoki et al. 2009).

The waist-to-height ratio is a diagnostic criterion for metabolic syndrome in Japanese children. Ozeki et al. (2011), a research group at the Ministry of Health, Labour and Welfare, Japan, published diagnostic criteria, with a waist-to-height ratio ≥ 0.5, for the definition of metabolic syndrome in Japanese children.

In a previous study, low birth weight children showed low internal fat accumulation, measured by dual-energy X-ray absorptiometry (DXA) (Li et al. 2001). However, two other studies showed conflicting results, indicated that both low birth weight and high birth weight children had a high prevalence of diabetes in children (Wei et al. 2003; Sugihara et al. 2008). It is unclear that low birth weight is related to child obesity judging from the meta-analysis presented by Yu et al. (2011).

We reported that the waist-to-height ratio of non-obese women in the low birth weight group was higher than that in the high birth weight group (Harada et al. 2012), but no research results have been published on the relationship between birth weight and the waist-to-height ratio in healthy Japanese children. The purpose of this study was to clarify the relationship between birth weight and the waist-to-height ratio in Japanese children stratified by sex.

Participants and Methods

Study subjects

This was a cross sectional study using the baseline data of a prospective cohort study, the Lifestyle and Allergy among Kids in Elementary school (LAKE) Study (Takeuchi et al. 2013).

As shown in Fig. 1, the subjects of the study were 759 second-grade elementary school children, 7- or 8-year-old in Ohmi-hachiman City, Shiga Prefecture, who were born from April 2, 2003 to April 1, 2004. The parents of 664 children of the 759 subjects agreed to participate in our study. After a questionnaire survey was conducted, we excluded children based on the following criteria: premature birth, post-mature birth, multiple birth, incomplete data, birth Kaup index < 8.7 or ≥ 25.5 and corresponding to 0.5% at each end of the anthropometric measurements. The Kaup index (kg/m^2) was calculated as weight divided by height squared. A total of 568 children (276 boys and 292 girls) participated in the study.

All of the parents of the subjects in the study were informed of the purpose of the study and all gave their informed consent to the use their personal information for analysis. The study protocol employed was approved by the Ethics Committee of Kyoto University Graduate School of Medicine. (July 13th, 2010)

Study Methods

Anthropometrics and questionnaires

We explained our research purpose and the methods to be employed to all of the subjects and their parents prior to the study. Although the questionnaires were distributed at each school, the parents of the children had to complete them at home and each school collected the questionnaires another day. We assured all of the participants and parents that their collected data would be protected under the Personal Information Protection Law.

The questionnaires were composed of the following 12 items: date of birth, sex, relationship with the person filling out the questionnaire, gestational-age, birth weight, birth height, multiple birth, birth order, primiparity status, nutritional intake in the first six months after birth, passive smoking status, and the progress of the pregnancy period.

In order to research the nutritional intake of the infants during their first six months after birth, the questionnaires contained questions on the feeding methods employed: 100% breast-feeding, mostly breast-feeding, 50/50 breast-feeding and formula-feeding, mostly formula-feeding, and 100% formula-feeding. In regard to the course of a pregnancy, the questionnaires contained questions about: whether the pregnancy was normal, any toxemia during the pregnancy, any threatened miscarriage, any threatened premature delivery, and if there were any problems.

The school nurses measured each child's height, weight and waist circumference by 0.1 cm, 0.1 kg and 0.1 cm, respectively. Waist circumference was measured from the umbilical level in an upright position with the children wearing light clothes, standing, and breathing normally during the measurements.

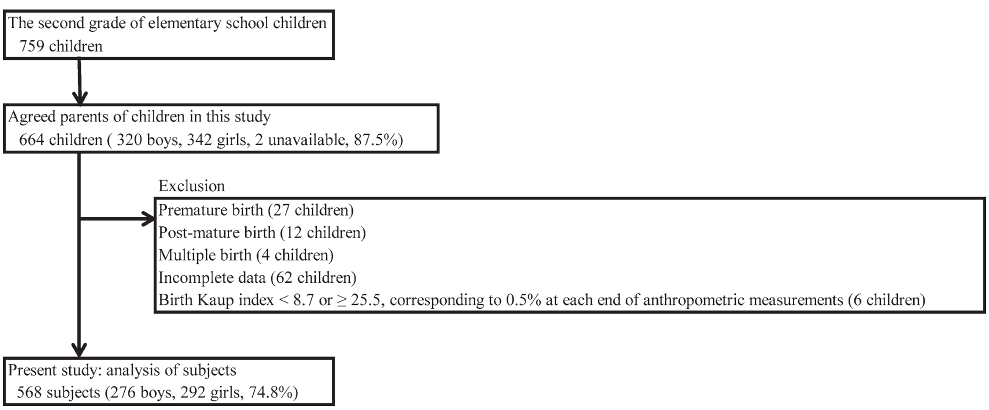

Fig. 1. Selection of subjects.

Statistical Analyses

A comparison was conducted with the anthropometric data obtained between those who filled in the sex item on the questionnaire. The differences between the sexes were analyzed using the Mann-Whitney *U* test.

The waist-to-height ratio was calculated as the waist circumference divided by height.

In the questionnaire, the nutritional intake of the infants during their first six months was categorized into the following 3 categories: 100% or mostly breast-feeding, 50/50 breast- and formula-feeding, and 100% or mostly formula-feeding.

The following items were analyzed using the Chi-square test or Fisher's exact test if the number of items selected was < 5: primiparity, nutritional intake in the first six months, passive smoking status, and events during the pregnancy course.

Statistical significance for the median of the continuous variables stratified by sex for the two birth weight categories was assessed using the Kruskal-Wallis method.

P values less than 0.05 were considered significant. The statistical software IBM SPSS Statistics for Windows Version 20.0 (IBM Japan Inc., Tokyo, Japan) was used for the analyses.

Results

Table 1 shows the anthropometric data and characteristics of the children and the course of the mother's pregnancy stratified by sex. Significantly higher birth height ($P < 0.001$) and birth weight ($P = 0.015$) were shown among the boys, compared with the girls. The number of children according to four birth weight categories stratified by sex. The rate of children in the birth weight < 2,500 g group was 5.4% for the boys and 6.5% for the girls. There were sig-

Table 1. Anthropometric data and characteristics of the children and mother's pregnancy course by sex.

n = 568

	Boys (*n* = 276)	Girls (*n* = 292)	*P* value[a]
At birth			
Height (cm)	49.2 (2.0)	48.5 (1.9)	< 0.001
Weight (g)	3,060 (377)	2,990 (349)	0.015
Kaup index (kg/m^2)	12.6 (1.0)	12.7 (1.0)	0.316
Birth weight category *n* (%)			
< 2,500	15 (5.4)	19 (6.5)	
2,500 ≤ < 3,000	104 (37.7)	145 (49.7)	0.008[b]
3,000 ≤ < 3,500	120 (43.5)	107 (36.6)	
3,500 ≤	37 (13.4)	21 (7.2)	
Mother's pregnancy course *n* (%)			
Toxemia of pregnancy	3 (1.1)	9 (3.1)	0.144[b]
Threatened miscarriage	16 (5.8)	16 (5.5)	1.000[b]
Threatened premature delivery	16 (5.8)	24 (8.2)	0.325[b]
Primiparity *n* (%)	141 (51.8)	147 (51.4)	0.933[b]
Nutritional intake in the first six months *n* (%)			
Breast-feeding	137 (50.6)	156 (54.2)	
50/50 of breast-feeding and formula-feeding	40 (14.8)	40 (13.9)	0.692[b]
Formula-feeding	94 (34.7)	92 (31.9)	
At the 2nd grade of elementary school			
Height (cm)	127.6 (5.3)	125.9 (5.1)	< 0.001
Weight (kg)	26.4 (4.4)	25.3 (4.1)	0.001
Kaup index (kg/m^2)	16.2 (2.0)	15.9 (1.9)	0.146
Waist circumference (cm)	56.1 (5.6)	54.7 (5.2)	0.001
Waist-to-height ratio	0.44 (0.04)	0.43 (0.04)	0.251
Waist-to-height ratio over 0.5 *n* (%)	21 (7.6)	15 (5.1)	0.234[b]
Passive smoking status *n* (%)			
Mother smoking / during pregnancy	25 (9.2)	18 (6.3)	0.208[b]
Mother or household smoking / one year after birth	167 (61.4)	161 (56.1)	0.229[b]
Mother or household smoking / current	133 (48.9)	122 (42.7)	0.149[b]

[a]Mann-Whitney *U* test: Anthropometric data compared by sex.
[b]Chi-square test: Basic characteristics compared by sex.
Data are presented as mean (SD) or *n* (%).

nificant differences shown in the four birth weight categories stratified by sex ($P = 0.008$). The girls showed a higher rate for the birth weight < 2,500 g group and the boys showed a higher rate for the birth weight ≥ 3,500 g group. At the second-grade of elementary school, significantly lower height ($P < 0.001$), weight ($P = 0.001$) and waist circumference ($P = 0.001$) were shown among the girls, compared with the boys. There were no significant differences between the rates of waist-to-height ratio over 0.5 stratified by sex. There were no other significant differences shown in the basic data stratified by sex.

Table 2 shows the anthropometric data and characteristics for the two birth weight categories stratified by sex. In the boys, a lower height ($P = 0.003$) was shown in the birth weight < 3,000 g group. In the girls, a lower height ($P < 0.001$) and weight ($P = 0.014$), and a higher waist-to-height ratio ($P = 0.004$) were shown in the birth weight < 3,000 g group. There were no significant differences between the two groups for the Kaup index (kg/m^2), or the waist circumference among the boys and girls. There were no significant differences shown in the rate of primiparity, mother's pregnancy course, nutritional intake in the first six months or the passive smoking status between the boys and girls.

Discussion

In the present study, for the girls, the waist-to-height ratio was higher in the birth weight < 3,000 g group, compared with the birth weight ≥ 3,000 g group. These results were consistent with the results shown in our study on birth weight and adult waist-to-height ratio (Harada et al. 2012). Chomtho et al. (2008) showed a negative correlation between the birth weight and fat mass index in 11 year-old subjects. Dolan et al. (2007) reported a relationship between birth weight and visceral fat measured by DXA in 12.4 ± 2.4 year-old healthy American children (n = 101).

Table 2. Anthropometric data and characteristics for the two birth weight categories for the boys and girls.

n = 568

	Boys			Girls		
	< 3,000 g	≥ 3,000 g	P value[a]	< 3,000 g	≥ 3,000 g	P value[a]
n	119	157		164	128	
At birth						
Height (cm)	47.8 (1.6)	50.3 (1.6)	< 0.001	47.6 (1.5)	49.7 (1.5)	< 0.001
Weight (g)	2,725 (222)	3,313 (251)	< 0.001	2,745 (198)	3,304 (228)	< 0.001
Kaup index (kg/m^2)	11.9 (0.7)	13.1 (0.8)	< 0.001	12.1 (0.7)	13.4 (0.8)	< 0.001
Mother's pregnancy course n (%)						
Toxemia of pregnancy	2 (1.7)	1 (0.6)	0.580[c]	4 (2.4)	5 (3.9)	0.512[c]
Threatened miscarriage	5 (4.2)	11 (7.0)	0.438[c]	9 (5.5)	7 (5.5)	1.000[c]
Threatened premature delivery	9 (7.6)	7 (4.5)	0.306[c]	16 (9.8)	8 (6.3)	0.391[c]
Primiparity n (%)	67 (57.8)	74 (47.4)	0.111[b]	83 (52.5)	64 (50.0)	0.722[b]
Nutritional intake in the first six months n (%)						
Breast-feeding	59 (51.3)	78 (50.0)		83 (51.9)	73 (57.0)	
50/50 of breast-feeding and formula-feeding	19 (16.5)	21 (13.5)	0.668[b]	20 (12.5)	20 (15.6)	0.305[b]
Formula-feeding	37 (32.2)	57 (36.5)		57 (35.6)	35 (27.3)	
At the 2nd grade of elementary school						
Height (cm)	126.5 (5.0)	128.5 (5.4)	0.003	124.9 (5.4)	127 (4.4)	< 0.001
Weight (kg)	26.0 (4.2)	26.8 (4.5)	0.114	24.9 (4.4)	25.8 (4.1)	0.014
Kaup index (kg/m^2)	16.2 (2.2)	16.1 (1.8)	0.523	15.8 (1.8)	15.9 (2.1)	0.576
Waist circumference (cm)	55.9 (5.8)	56.2 (5.5)	0.246	54.8 (4.9)	54.6 (5.5)	0.548
Waist-to-height ratio	0.44 (0.04)	0.44 (0.04)	0.846	0.44 (0.03)	0.43 (0.04)	0.004
Waist-to-height ratio over 0.5 n (%)	10 (8.4)	11 (7.0)	0.656[b]	8 (4.9)	7 (5.5)	1.000[b]
Passive smoking status n (%)						
Mother smoking / during pregnancy	11 (9.6)	14 (9.0)	1.000[c]	13 (8.3)	5 (3.9)	0.149[c]
Mother or household smoking / one year after birth	76 (65.5)	91 (58.3)	0.258[c]	90 (56.6)	71 (55.5)	0.905[c]
Mother or household smoking / current	54 (46.6)	79 (50.6)	0.541[c]	72 (45.3)	50 (39.4)	0.337[c]

[a]Mann-Whitney U test: Anthropometric data compared by sex.
[b]Chi-square test: Basic characteristics compared by sex.
[c]Fisher's exact test: Basic characteristics compared by sex.
Data are presented as mean (SD) or n (%).

The results of that study showed that the low birth weight group had more central adipose tissue. Tanaka et al. (2005) studied the relationships between birth weight and insulin, using the homeostasis model assessment-insulin resistance (HOMA-IR) and quantitative insulin sensitivity check index (QUICKI) in 6-15 year-old obese Japanese children (n = 967). The results showed that both boys and girls in the low birth weight group showed a high degree of insulin and HOMA-IR, but a low degree of QUICKI. Their results showed that the differences in the higher insulin and HOMA-IR, and lower QUICKI were significant in the low birth weight group for both the boys and the girls.

Gupta et al. (2007) reported a relationship between birth weight and HOMA-IR in 5-16 year-old children (n = 134) in the western part of India. The results showed significantly high HOMA-IR values in the low and high birth weight groups. Mori et al. (2012) reported a relationship between birth weight and HOMA-IR in Japanese high school girls. The results showed significantly high HOMA-IR values in the low birth weight group, compared with the high birth weight group.

However, it is unclear why low birth weight infants tend to have high insulin secretion. Low birth weight is an indicator of an undesirable environment in the uterus during pregnancy. A review by Warner and Ozanne (2010) reported that an undesirable environment during pregnancy lead to a permanently reduced number of renal glomerular cells and pancreatic β-cells.

In the present study, the birth weight < 3,000 g group showed low height and weight among both the boys and girls. Several studies have indicated that childhood obesity can be tracked to adulthood obesity (Power et al. 1997; Singh et al. 2008). On the other hand, meta-analysis in one study showed that adult height was inversely related to stroke mortality (Langenberg et al. 2005). Therefore, individuals who had a low birth weight and also show a lower adult height might have an increased risk of stroke mortality.

Kensara et al. (2005) reported a relationship between birth weight and body composition measured by DXA in a group of 64-72 year-old men. The results of that study showed that the low birth weight group had a significantly lower muscle mass. Jensen et al. (2007) reported a relationship between birth weight and muscles fibers shown by muscle biopsy in a group of 19-20 year-old men. The results of that study showed that the number of type IIb fibers was significantly higher in the low birth weight group, compared with the controls. Type IIb fibers have less capillary supply and less intake of glucose from capillaries than type I fibers, and decreased insulin sensitivity. A previous study showed that type 2 diabetic patients had more type IIb fibers than type I fibers (Gaster et al. 2001). Low birth weight infants may have more type IIb fibers. This change leads to insulin resistance. These muscle fiber changes might lead to the accumulation of visceral fat due to elevated levels of insulin in the plasma.

In the present study, the association between the birth weight and the waist-to-height ratio differed according to the sex of the children.

Interestingly, Togashi et al. (2010) reported an association between birth weight and visceral fat as judged by computed tomography, and an association between birth weight and insulin resistance by the oral glucose tolerance test (OGTT) in obese Japanese children. Their results showed a stronger positive correlation between birth weight and visceral fat in obese boys, and between birth weight and insulin resistance in obese girls. Furthermore, after reducing body weight and visceral fat by nutrition intervention, boys showed improved insulin resistance, but there was no change in the insulin resistance in girls.

The results of this study did not clarify the mechanism of the association between birth weight and waist-to-height ratio among girls. Other previous studies indicated that girls tend to have higher insulin resistance than boys (Murphy et al. 2004). Wilkin and Murphy (2006) hypothesized that gender-specific genes might lead to different insulin sensitivity. Hoffman et al. (2000) reported that girls in adolescence secreted a high level of insulin due to sustained insulin sensitivity. In the present study, the association between birth weight and the waist-to-height ratio differed according to the sex of the subjects. Our findings might be useful in order to clarify the mechanism of the concept DOHaD.

There were several limitations in this study that deserve mention. First, we did not collect data related to the characteristics of the pregnancies, such as the maternal physical constitution or the body weight gain during the pregnancies. The birth weight of infants may be affected by body weight gain during pregnancy (Takimoto et al. 2006). Thus, the maternal physical constitution and body weight gain during pregnancy may be confounding factors. Second, in regard to the birth weight information, we asked the parents of the study for data transcription from their maternity passbooks. Therefore, the birth weight data may have been defective due to erroneous birth information. Third, we did not collect data about insulin resistance, such as HOMA-IR or QUICKI. Therefore, we did not show an association between birth weight and impaired glucose metabolisms, which we intend to investigate in healthy children in a further study. Fourth, different height, weight and waist scales were used at the various schools, so we cannot deny the potential for errors in the values obtained. Finally, the subjects were divided two groups by the median (3,000 g) of the birth weight. The rates of children in the birth weight < 2,500 g were 5.4% for boys and 6.5% for girls and too small to analyze separately.

The first strength of the present study was that the participants were limited to those who were born at full term. Second, there was only a little selection bias in the study population that may have influenced the results, because the research subjects were 74.8% of the second-grade elementary school children in Ohmi-hachiman City, Shiga Prefecture.

Conclusion

In girls, the waist-to-height ratio was higher in the birth weight < 3,000 g group, compared with the birth weight ≥ 3,000 g group, but not in the boys. Our results show an association between birth weight and waist-to-height ratio in 7- or 8-year-old girls. These results suggest that intrauterine environmental insults might have an effect on children, depending on their sex.

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Conflict of Interest

The authors declare no conflict of interest.

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