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Association between weight at birth and body composition in childhood: A Brazilian cohort study

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ABSTRACT

Background and aim: Previous studies have shown that the association between birth weight and obesity later in life apparently follows a U-shaped curve. However, due to the continuous increase of mean birth weight in several countries worldwide, it is expected that higher birth weight will play a more important role as a risk factor for further obesity than low birth weight. This study investigated the association between birth weight and body composition of children in order to establish their relationship in an earlier period of life.
Study design and subjects: Prospective cohort study carried out from 1997 to 2006 in Jundiai city, Brazil, involving 486 children at birth and from 5 to 8 years of age. The following anthropometric measurements were determined: birth weight, weight, height, waist circumference and triceps skinfold thickness. Fat mass percentage, fat mass and fat-free mass were measured by electrical bioimpedance analysis by the 310 Body Composition Analyzer, Biodynamics®. Five multiple linear regression models were developed considering waist circumference, triceps skinfold thickness, fat mass percentage, fat mass and fat-free mass as markers of body composition, and outcomes.
Results: Significant positive associations were observed between birth weight and waist circumference ($p < 0.001$), triceps skinfold thickness ($p = 0.006$), fat mass ($p = 0.007$) and fat-free mass ($p < 0.001$). Approximately 10% of the children presented excess body fat assessed by bioimpedance, and 27.6% of them had central adiposity (waist circumference ≥95th percentile).
Conclusions: Intrauterine growth, assessed by weight at birth, was positively associated with body composition of children aged 5–8 years, indicating that those with the highest birth weight are more at risk for obesity, and probably to chronic diseases in adulthood.

1. Introduction

A worldwide increase in the prevalence of childhood overweight and obesity has been seen over the past few decades [1], even in developing countries like Brazil. In addition to psychosocial consequences, children with excess weight are at an increased risk of developing metabolic and endocrine diseases later in life [2].

According to the "Developmental Origins of Health and Disease Hypothesis" disturbances during critical windows of development, such as growth in the intrauterine period has long-term effect on the physiology, structure and functions of the organism [3,4]. Hyperplasia and/or hypertrophy of adipose cells result in an exacerbated expansion of adipose tissue, a characteristic of obesity, which tends to persist in childhood and adulthood [5].

Birth weight is a proxy of intrauterine growth and appears to be associated with body adiposity, not only in childhood [6], but also throughout an individual's life [7].

Previous studies have shown that the association between birth weight and obesity later in life apparently follows a U-shaped curve [8]. However, due to the continuous increase, in the last two decades, of mean birth weight in several countries worldwide [9,10], it is expected that higher birth weight will play a more important role as a risk factor for further obesity [5,11,12] than low birth weight.

The present study investigated the association between birth weight and body composition of Brazilian children in order to establish their relationship in an earlier period of life.

2. Materials and methods

This study is derived from a cohort, carried out between 1997 and 2000, initially composed of 865 low-income pregnant women from Jundiai city, São Paulo state, Brazil. The women were recruited from all health units and hospitals in the city and were followed before the

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16th week of pregnancy to the birth of their babies. All women were insured by the National Health Service (SUS) and were apparently healthy, considering that those who present any problem in pregnancy are usually reported to specialized antenatal services. Women with chronic infectious diseases, metabolic diseases, cardiopathy, mental diseases, hypertension/pre-eclampsia/eclampsia, vaginal bleeding and multiple deliveries were excluded from the study. Details of the cohort have been published previously [13].

Data on anthropometry and physical examination of the newborn babies were collected per protocol, from the hospital records, and checked on the next day after birth by a pediatrician. Gestational age (GA) was determined by a combination of ultrasonography performed up to the 20th week of gestation, the Capurro method [14] determined between 12 and 48 h of birth, and information on the date of the last menstrual period. When there was less than or a week discrepancy between at least two of the GA determinations, assessed by the three different methods, one of them was chosen, giving preference to the order of the methods cited above.

The present prospective cohort study was carried out between November 2004 and December 2006, and consisted of two phases. In the first phase, information from the questionnaire of the first cohort study was taken into account, and the mothers who at that time were living in Jundiai city and nearby municipalities were located. The mothers were invited to participate in the present study through telephone contact or by visiting their homes if they did not have a telephone. Next, a home visit was made, during which the objectives of the study were explained, and the ethical consent form was signed by the child's parents or guardians. At the time of this home visit, a general questionnaire was applied in order to assess demographic and socioeconomic factors, and information on breastfeeding and morbidity of the children. In the second phase of the study, the participants were contacted again by telephone to arrange to collect anthropometric measurements (weight, height, waist circumference, and triceps/subscapular skinfold thickness) and body composition data.

Out of the 865 mother–infant pairs from the previous cohort, 745 women and their children were located and invited to participate in the study, resulting in a sample of 649 children, whose parents signed a free informed consent form and answered a general questionnaire. However, 163 children had incomplete data or did not participate in the second phase of the study, resulting in a final sample of 486 children.

The anthropometric measurements (weight, height, waist circumference—WC, triceps and subscapular skinfold thickness) were obtained in accordance with the recommendations of Jelliffe and Jelliffe [15]. The children and respective mothers were weighed, after fasting for 10–12 h, by a portable electronic scale (Sohnle®, model 7500, Murrhardt, Germany), with accuracy of 100 g. Their height was measured using a SECA® stadiometer (Leicester Portable Height measure model, Hamburg, Germany), with accuracy of 0.1 cm. The nutritional status of the children and respective mothers was determined by the body mass index (BMI), and classified according to the WHO Growth Reference for children and teenagers: (<3rd) underweight; (3rd–85th) normal weight; (85th–97th) overweight; (97th–99th) obesity [16], and the WHO standards for adults [17]. Waist circumference measurements were obtained using a SECA® measuring tape (Hamburg, Germany) of accuracy 0.1 cm. Mean values of waist circumference were compared with a British standard [18]; children with WC <95th percentile were classified as non-obese and those ≥95th percentile as obese. Triceps and subscapular skinfold thickness measurements were determined by a Harpenden® skinfold caliper (Baty International, West Sussex, UK) of accuracy 1 mm. Triceps skinfold thickness, which is an indirect measure of body fat, was classified according to gender and age using the cut-off values proposed by Frisancho [19].

Fat mass percentage, fat mass and fat-free mass were measured by electrical bioimpedance analysis utilizing the *BIA 310e Body Composition Analyzer* (Biodynamics Corporation®, USA). The variable fat mass percentage was classified according to Lohman [20].

Table 1
Characteristics of the children and respective mothers ($n = 486$).

Variables	*n*	%	Mean (SD)
Birth weight (g)			3219.53 (470.82)
<2500	25	5.2	
2500–2999	123	25.3	
3000–3499	208	42.8	
3500–3999	107	22.0	
≥4000	23	4.7	
Gestational age (weeks)			39.20 (1.32)
Preterm	15	3.1	
Term	464	95.5	
Posterm	7	1.4	
Gender			
Male	227	46.7	
Female	259	53.3	
Child's age (months)			78.82 (7.99)
60–71.99	102	21.0	
72–83.99	254	52.3	
84–97	130	26.7	
Per capita income (MBW)			0.95 (0.81)
0–0.5	139	28.7	
0.5–1	191	39.3	
1–1.5	83	17.1	
1.5–2	42	8.6	
>2	31	6.3	
Persons per household			4.33 (1.4)
Breastfeeding (months)			12.23 (12.0)
<3	112	23.0	
4–6	87	17.9	
7–12	122	25.1	
13–18	63	13.0	
19–24	50	10.3	
>24	52	10.7	
Child's BMI			16.00 (2.47)
Underweight	16	3.3	
Normal weight	354	72.8	
Overweight	78	16.1	
Obesity	38	7.8	
Waist circumference*			56.72 (6.84)
Not obese (<95th percentile)	352	72.4	
Obese (≥95th percentile)	134	27.6	
Triceps skinfold thickness**			10.13 (3.29)
Thin	18	3.7	
Below average	34	7.0	
Average	309	63.6	
Above average	46	9.5	
Excessive fat	79	16.2	
Subscapular skinfold thickness (mm)			7 (3.25)
Fat mass percentage***			15.81 (6.28)
Very low	58	11.9	
Low	107	22.0	
Optimum	271	55.8	
Moderately high	36	7.4	
High	11	2.3	
Very high	3	0.6	
Fat mass (kg)			4.03 (2.45)
Fat-free mass (kg)			20.19 (3.69)
≤15	20	4.1	
15.1–26	431	88.7	
26.1–40.7	35	7.2	
Mother's marital status			
Single	116	23.9	
Married	334	68.7	
Separated/Divorced	31	6.4	
Widow	5	1.0	
Mother's age (years)			30.68 (6.04)
Mother's BMI^{+}			27.49 (4.13)
Eutrophic	115	23.8	
Overweight	246	50.9	
Obese grade I	92	19.1	
Obesity grade II	24	5.0	
Obesity grade III	6	1.2	

MBW — minimum Brazilian wage (R$ 350.00 = USD 77.00); BMI = body mass index (kg/m^2) — WHO (2007); *McCarthy et al. (2001); **Frisancho (1990); ***Lohman (1992); $^{+}n = 483$.

The Microsoft Office Excel 2003 (Microsoft Corporation, Washington DC, USA) and Stata 9.0 (Stata Corporation, College Station, TX, USA) software were used for storage and statistical analysis of the data. The data were described by absolute frequency, mean and standard deviation. Five multiple linear regression models were developed using backward stepwise elimination. For this purpose, the dependent variables (WC, triceps skinfold thickness, fat mass percentage, fat mass and fat-free mass) and each of the independent variables investigated were first submitted to univariate analysis, and those variables presenting a level of significance $p \le 0.20$ were entered into one of the five models. Next, variables that presented a p value ≤ 0.05 were maintained in the model. Birth weight was defined as the main independent variable and WC, triceps skinfold thickness, fat mass percentage, fat mass and fat-free mass were considered as dependent variables. The confounding variables used in the initial model were gestational age, gender, age, per capita income, persons per household, duration of breastfeeding, maternal age and maternal BMI.

3. Results

The final sample consisted of 486 children. Therefore, there were losses of 25% and 35% of the children, respectively, considering all the mothers who agreed to participate in the study ($n = 649$) and those who were located ($n = 745$). A significant difference was observed between the mean age of the children included in the cohort (6.5, SD = 0.7 years) and the children who did not conclude the study (5.9, SD = 0.8 years) ($p < 0.01$). However, there was no difference in relation to birth weight, gender, per capita income and mother's BMI.

The characteristics of the children and respective mothers are presented in Table 1. The prevalence of low birth weight was 5.2%, and their mean gestational age was 39.2 (1.32) weeks. Most of the children were girls (53.3%), aged 6 years (72–83.9 months) (52.3%). Their mean per capita income was 0.95 (0.81) Minimum Brazilian Wage — MBW (1MBW = US$77), and the mean number of persons per household was 4.3 (1.4). The children were breastfed, on average, until 1 year of age (12.23 ± 12 months), and most of them were exclusively breastfed up to 3 months of age (data not shown), confirming the relatively high breastfeeding rate in Brazil [21]. According to child's BMI, there were more overweight and obese children (23.9%) than underweight children (3.3%). With respect to central adiposity, 27.6% of the children had WC ≥95th percentile, characterizing obesity. The fat reserve results obtained by the measurement of triceps skinfold thickness and classified according to Frisancho [19] showed a prevalence of excess fat of 16.2%. Fat mass percentage measured by bioimpedance was classified as optimum in most children (55.8%) and moderately high to very high in 10.3% of them. Mean fat mass of the children was 4.03 (2.45) kg, and fat-free mass varied from 15.1 to 26 kg for 88.7% of them. The majority of the mothers were married (68.7%), overweight (50.9%), with a men age of 30.68 (6.04) years.

Table 2 shows the associations between birth weight and body composition measurements of the children, determined by multiple linear regression analysis. Significant positive associations were observed between birth weight and WC ($p < 0.001$), triceps skinfold thickness ($p = 0.006$), fat mass ($p = 0.007$) and fat-free mass ($p < 0.001$).

4. Discussion

In the present study, after adjustment of the linear regression models for several confounding variables, birth weight showed associations with most of the measurements of body composition investigated: WC, triceps skinfold thickness, fat mass and fat-free mass.

Similar to the study carried out by Ridgway et al. [22] there was a positive association between birth weight and WC. In contrast, some studies reported an inverse or U-shaped relationship between birth weight and abdominal adiposity in children and adolescents [7,23]. In addition to taking into account different confounding variables, according to Rolfe et al. [24], this inconsistency in the findings can be explained in part by differences in the methods used for assessment of abdominal adiposity.

Table 2
Linear regression models considering waist circumference, triceps skinfold thickness, fat mass percentage, fat-free mass, and fat mass as outcomes ($n = 486$).

Outcomes	Coefficient	SE	t	95% CI		P
Waist circumference						
Birth weight	0.22×10^{-2}	0.61×10^{-3}	3.72	0.10×10^{-2}	0.35×10^{-2}	0.001
Child's age	0.16	0.36×10^{-1}	4.47	0.09×10^{-1}	0.23	<0.001
Gender	1.51	0.57	2.64	0.38	2.64	0.008
Maternal BMI	0.42	0.07	6.0	0.28	0.55	<0.001
$R^2 = 0.14$; adj. $R^2 = 0.13$						
Tríceps skinfold thickness						
Birth weight	0.8×10^{-3}	0.3×10^{-3}	2.78	0.25×10^{-3}	0.14×10^{-2}	0.006
Gender	1.75	0.28	6.21	1.19	2.31	<0.001
Maternal BMI	0.17	0.03	4.95	0.10	0.23	<0.001
$R^2 = 0.12$; adj. $R^2 = 0.12$						
Fat mass percentage						
Gender	3.39	0.54	6.26	2.33	4.46	<0.001
Maternal BMI	0.23	0.06	3.55	0.10	0.35	<0.001
Persons per household	−0.63	0.19	−3.29	−1.01	−0.25	0.001
$R^2 = 0.11$; adj. $R^2 = 0.10$						
Fat mass						
Birth weight	0.6×10^{-3}	0.24×10^{-3}	2.69	-0.23×10^{-3}	0.17×10^{-3}	0.007
Gender	1.06	0.22	4.89	0.63	1.48	<0.001
Maternal BMI	0.11	0.03	4.36	0.06	0.16	<0.001
Persons per household	−0.18	0.07	−2.38	−0.33	−0.03	0.018
$R^2 = 0.11$; adj. $R^2 = 0.10$						
Fat −free mass						
Birth weight	0.17×10^{-2}	0.32×10^{-3}	5.43	0.11×10^{-2}	0.24×10^{-2}	<0.001
Child's age	0.18	0.19	9.75	0.15×10^{-3}	0.22×10^{-3}	<0.001
Maternal BMI	0.17	0.03	4.90	0.11	0.25	<0.001
$R^2 = 0.24$; adj. $R^2 = 0.24$						

WC, an important indicator of visceral fat reserves, is used to identify children at risk of developing metabolic and cardiovascular problems [25]. However, one of the main limitations for its use is the lack of universal cut-off values for children and teenagers. Based on WC percentiles for British children aged 5.0–16.9 years [18], 27.6% of the children included in this study had excess abdominal fat. In order to overcome the problem related to the lack of universal WC cut-off points for abdominal fat, in this study WC was considered as a continuous variable.

Triceps skinfold thickness, another marker of body adiposity showed a statistically significant association with birth weight. Evaluation of body adiposity by measurement of triceps skinfold thickness and bioimpedance analysis revealed a relevant percentage of excess fat, a risk factor for the emergence of childhood obesity and development of chronic diseases [26]. Triceps skinfold thickness measurements and fat mass showed a correlation coefficient of 0.57 ($p < 0.001$) (data not shown). Usually the sum of several skinfold thickness measurements is used as surrogate of total adiposity. However, studies have highlighted that triceps skinfold thickness, by itself, is a good and inexpensive indicator of adipose tissue reserves; one of the measures most widely used for this purpose. Among others researchers Tuan and Wang [27] support the use of triceps skinfold thickness as proxy indicator of adiposity compared with dual-energy X-ray absorptiometry in children.

Similar to this study, Euser et al. [28] did not find an association between birth weight and body fat percentage in 19-year-old adolescents, but a significant association between birth weight and fat-free mass. Sayer et al. [29] and Singhal et al. [30] confirmed the positive association between birth weight and fat-free mass in studies involving, respectively, British adults and adolescents. According to Chomtho et al. [31], the magnitude of the association between birth weight and fat-free mass seems to be stronger than that with fat mass. Considering that muscle tissue is an important component of fat-free mass, evidence from animal models demonstrated that both prenatal and postnatal malnutrition can reduce the number of secondary muscle fibers and that this effect may not be reversed by better subsequent nutrition [32]. However, in view of the controversial results regarding the association between birth weight and body composition [6,30], it is important to carry out prospective cohort studies for assessment of body composition at birth and in later life in different regions of the world. An important aspect that has been pointed out by Yajnik et al. [33] and Chomtho et al. [31] is that body composition at birth may vary even when birth weight is the same and within the normal range. Indian babies have more adiposity, despite being smaller and thinner than UK babies [33].

The results of this study have confirmed the gender-related differences in the programming effect of body composition. Ayyavoo et al. [34] also referred more body fat, less fat-free mass, and greater abdominal adiposity in girls compared to boys. Thus, gender and adiposity should be accounted for in studies examining metabolic and cardiovascular outcomes. Similar to previous studies [35–37], age has also been positively associated with abdominal adiposity and fat-free mass. Despite the difference observed between the mean age of the children included in the cohort study and the children who did not conclude the study, this result probably did not affect the associations observed between age and the outcomes investigated.

In the present study, maternal BMI was a confounding variable that interfered significantly with the association between birth weight and all parameters of body composition. It is important to emphasize the high prevalence of overweight and obesity among the mothers included in this study, a concern in Brazil, as well as in other countries around the world [38]. The et al. [39] also observed that maternal obesity modifies the relationship between birth weight and obesity even in adult life. Given the observed effect of maternal BMI, it is unlikely that this is the only explanation since the offspring of obese mothers can adopt diets and lifestyle habits that contribute to excess weight, in addition to sharing genes that cause obesity in both.

Another important finding of the present study was the inverse relationship between number of persons per household and fat percentage and fat mass. This result might be explained by the fact that environmental factors related to new lifestyle habits of the population also contribute to the determination of body composition during different phases of life [40], especially in the case of predominantly low-income populations such as the cohort from Jundiai city, Brazil.

According to Fewtrell et al. [41] loss to follow-up in observational cohorts is inevitable with time, even with the best study design and conduct. Rates of 50–80% follow-up have been suggested as acceptable in the context of epidemiological cohorts, although in most cases the validity of these recommendations has not been tested. According to the STROBE Guidelines for Observational Studies [42] attrition of the original sample represents a potential threat of bias if those who drop out of the study are systematically different from those who remain in the study. The result is that the remaining sample becomes different from the original sample. Therefore, in this study, there was a concern about the rate of follow-up. The original sample was compared with the final one, detecting a statistically significant difference in the child's age, which did probably not compromise the results of the study.

5. Conclusion

Intrauterine growth, assessed by weight at birth, was positively associated with body composition of children aged 5–8 years, indicating that those with the highest birth weight are more at risk for obesity, and probably to chronic diseases in adulthood, confirming the importance of the "Developmental Origins of Health and Disease Hypothesis".

Conflict of interest

The authors declare no conflict of interest.

Ethical information

The study was conducted in accordance with the Declaration of Helsinki of the World Medical Association, and was approved by the Ethics Committee of the University of São Paulo, Brazil.

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