Birth Weight is Associated with Body Composition in a Multiethnic Pediatric Cohort

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Abstract: Several studies have indicated that birth weight is associated with increased risk for excess fat accumulation later in life. Our objective was to evaluate the association between birth weight and body composition measures in a multiethnic pediatric population while controlling for environmental factors previously associated with increased adiposity. Dual-energy x-ray absorptiometry was performed on 256 European-American, African-American, and Hispanic-American boys and girls. Body composition measurements were adjusted by height to create a fat mass index, fat-free mass index, and trunk fat mass index. After adjusting for age, pubertal status, sex, race/ethnicity, socioeconomic status, and physical activity, we found that higher birth weights were associated with significant increases in all three body composition indices (P < 0.05). After adjusting for physical activity in analysis of covariance, the relationship between birth weight and the fat-free mass index was no longer significant. This study suggests that higher birth weight is a risk factor for later unfavorable body composition changes in children, and that current environment and physical activity habits can affect these outcomes.

Keywords: Birth weight, pediatric, adiposity, fat mass index, fat-free mass index.

INTRODUCTION

Scientists have proposed that the *intrauterine* environment can influence adult health outcomes, particularly those related to obesity such as cardiovascular disease and type 2 diabetes [1-3]. Low birth weight (< 2500 g), an indicator of the *intrauterine* environment, is linked to risk for these chronic diseases [4-6]. Paradoxically, additional studies suggest that a high birth weight (macrosomia; > 4000 g) is related to increased body mass index (BMI) and body weight, which may also increase risk for type 2 diabetes and cardiovascular disease [7-9]. Although the etiology of obesity is difficult to disentangle, a contribution of the intrauterine environment is likely.

Most studies investigating the association between birth weight and body size have used BMI or other anthropometric measures as proxy measures for body "fatness". However, among children it is unclear whether these associations with BMI are due to greater fat mass or fat-free mass. Age-adjusted BMI in children is more related to lean mass and can overestimate actual body fat in taller children, while underestimating fatness in shorter children [10-13]. More precise measurements of fat mass and fat-free mass, adjusted for height^2, can provide independent, more accurate indicators of leanness, fatness, and central adiposity in children [14].

Environmental/behavioral components may interact with birth outcomes to modify body composition. However,

previous studies relating birth weight to pediatric body composition often lack environmental/behavioral measures that also affect current body mass. Physical activity and dietary intake are associated with pediatric fat and fat-free mass, as well as central adiposity [15,16]. Additionally, socioeconomic status (SES) serves as an indicator of environmental status, with lower SES associated with worse health outcomes in children [17]. Hence, the aim of this study was to evaluate the relationship between birth weight and more precise measures of fat mass, fat-free mass, and central adiposity, while controlling for environmental/ behavioral factors that could also influence current body composition in a multiethnic pediatric population.

MATERIALS AND METHODOLOGY

Participants included 256 children aged 7-12 years and classified by parental self-report as African-American (AA), European-American (EA), or Hispanic-American (HA). Data includes all children measured as part of an on-going cross-sectional study between 2004 and 2008 designed to evaluate genetic associations with diabetes risk factors. Children were recruited with community fliers and presentations, and newspaper advertisements. The participants were required to have no medical diagnoses that were contraindicative to study participation (including hypercholesterolemia, diabetes, or hypertension) and were not taking any medications known to affect body composition levels. During the study visits, body composition and anthropometric measurements were taken, and birth weight was obtained by parental report. Children were instructed to wear an accelerometer for 7 days to record physical activity levels. A 24-hour diet recall was administered at each visit using the triple-pass method.

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Physician exam determined pubertal status to be ≤ 3 according to the criteria of Marshall and Tanner [18,19]. The study was approved by the University of Alabama at Birmingham (UAB) Institutional Review Board for Human Use, with children and parents providing informed written consent prior to participation.

Body Composition

Body weight was measured to the nearest 0.1 kg in light clothing without shoes (Scale-tronix 6702W; Scale-tronix, Carol Stream, IL), and height was determined using a mechanical stadiometer. Body mass index (weight (kg) / height (m^2)) was calculated from these values. Total fat mass, trunk fat mass, and total fat-free mass were evaluated via dual energy x-ray absorptiometry (DXA) with a GE Lunar Prodigy densitometer (Lunar Radiation Corp., Madison, WI). Subjects were scanned in light clothing while lying flat on their backs with arms at their sides. DXA scans were analyzed with pediatric software enCORE 2002 version 6.10.029. Values were used to calculate the fat mass index (FMI; fat mass (kg) / height (m^2)), trunk fat index (trunk FMI), and fat-free mass index (FFMI; fat-free mass (kg) / height (m^2)).

Socioeconomic Status

Socioeconomic status (SES) was measured with the Hollingshead 4-factor index of social class, which combines the educational attainment and occupational prestige for the number of working parents in the child's family. Scores ranged from 8 to 66, with the higher scores indicating higher theoretical social status [20].

Diet recalls and Physical Activity

A registered dietitian administered two 24-hour diet recalls using the triple-pass method. Both parent and child participated during the recalls. Data was entered into the Nutrition Data System for Research software version 2006 (Nutrition Coordinating Center, University of Minnesota, Minneapolis), and values from the two visits were averaged for analysis. Average intakes of several variables, including total caloric intake and percentage calories from carbohydrate, fat, protein, and sugar were analyzed for this study.

Physical activity levels were recorded with a uniaxial ActiGraph accelerometer (GT1M – Standard Model 198-0100-02, ActiGraph LLC, Pensacola, FL). Actigraph monitors have been shown to exhibit high inter-instrument reliability [21]. Epoch length was set at one minute and data expressed as counts per minute (counts min^{-1}). Children wore the monitors on and elastic belt at the waist, over the right hip, for seven full days prior to the overnight stay. They were instructed to only remove the monitor during bathing, swimming, or sleeping. Daily counts were analyzed as average time (minutes/day) spent on moderate and vigorous physical activities (MVPA).

Statistical Analysis

Birth weight was divided into quintiles for analyses, with quintile 1 composed of children with low birth weight (< 2500 g), and quintile 5 composed mainly of children with a high birth weight (> 4000 g). Descriptive statistics were analyzed by quintile of birth weight using analysis of variance (ANOVA) with Tukey's post-hoc test. After failing to conform to tests for normality, the following variables were log-transformed for analyses: total fat mass, total fat-free mass, trunk fat mass, BMI, and BMI percentile. Analysis of covariance (ANCOVA) was used to evaluate the effect of birth weight quintile on these variables after controlling for height, age, pubertal status, sex, SES, and MVPA. Additionally, ANCOVA was utilized to determine the association of birth weight with FMI, FFMI, and trunk FMI controlling for the covariates age, pubertal status, sex, SES, and MVPA. After confirming a linear relationship of birth weight (g) with body composition variables, linear regression analysis was used to evaluate the association

Table 1.   Characteristics of Study Participants by Birth Weight Quintile

	Quintile 1 (n = 50)	Quintile 2 (n = 52)	Quintile 3 (n = 52)	Quintile 4 (n = 51)	Quintile 5 (n = 51)
Age	9.6 ± 1.6	9.5 ± 1.5	9.4 ± 1.6	9.5 ± 1.6	9.6 ± 1.7
Ethnicity(EA/AA/HA)	8/23/19	17/19/16	31/14/7	26/15/10	24/16/11 *
Sex (n,% male)	26 (52%)	23 (43%)	26 (50%)	34 (64%)	27 (53%)
Tanner Stage (1/2/3)	30/9/11	30/13/9	40/8/4	37/11/3	25/18/8 *
Height (cm)	138.5 ± 11.8	139.3 ± 10.1	138.0 ± 8.8	139.4 ± 10.7	141.5 ± 12.1
Weight (kg)	35.2 ± 9.7	35.4 ± 8.4	34.6 ± 7.2	37.0 ± 10.7	39.6 ± 10.2
Birth Weight (kg)	2.3 ± 0.4	3.0 ± 0.1	3.3 ± 0.1	3.6 ± 0.1	4.1 ± 0.3 †
BMI (kg/m^2)	18.1 ± 2.9	18.0 ± 2.5	18.0 ± 2.6	18.8 ± 3.5	19.5 ± 2.8 *
BMI percentile	62.4 ± 27.9	62.8 ± 25.7	64.0 ± 26.3	65.5 ± 29.1	75.7 ± 20.6
Fat mass (kg)	8.2 ± 5.5	8.2 ± 4.7	7.7 ± 4.0	9.1 ± 7.0	10.3 ± 6.1
FMI (kg/m^2)	4.2 ± 2.3	4.1 ± 2.0	4.0 ± 2.1	4.5 ± 3.0	5.1 ± 2.6
Fat-free mass (kg)	24.9 ± 6.0	24.9 ± 5.0	25.1 ± 4.9	25.8 ± 4.6	27.0 ± 5.8
FFMI (kg/m^2)	12.9 ± 1.4	12.8 ± 1.3	13.1 ± 1.4	13.3 ± 1.2	13.4 ± 1.2
Trunk fat (kg)	3.4 ± 2.7	3.3 ± 2.3	3.0 ± 1.9	3.8 ± 3.4	4.2 ± 2.9
Trunk FMI (kg/m^2)	1.7 ± 1.2	1.7 ± 1.0	1.6 ± 1.0	1.9 ± 1.5	2.1 ± 1.3
SES	34.4 ± 13.4	35.1 ± 13.6	43.6 ± 13.6	39.2 ± 15.1	40.6 ± 15.3 †
MVPA (min/d)	52.6 ± 37.2	57.2 ± 32.5	60.2 ± 31.6	68.8 ± 32.4	57.5 ± 31.5

* = difference at P < 0.05; † = difference at P < 0.01.

between these factors controlling for the covariates listed above. All analyses were performed using SAS version 9.2 (SAS Institute, Cary, NC) with a significance level of P < 0.05.

RESULTS

Participants who exceeded 3.5 standard deviations from the mean birth weight (n = 2) were removed from the analysis to avoid bias in the current analyses. Descriptive statistics are presented in Table **1**. A greater number of AA and HA children were in the lower quintiles of birth weight (quintiles 1 and 2). Children in the highest quintile of birth weight (quintile 5) were reproductively more mature (P < 0.05) when participating in the study independent of gender or race/ethnicity. Children in quintile 3 had a greater SES level than all other groups (P < 0.01), and children in quintiles 4 and 5 exhibited a higher BMI compared to the other groups (P < 0.05). There were no other differences in body composition in unadjusted ANOVA models.

After controlling for covariates, no dietary variables contributed to differences in body composition and were subsequently removed from the models. A significant difference by birth weight quintile was noted for BMI (r^2 = 0.29, P < 0.01), BMI percentile (r^2 = 0.27, P < 0.01), and fat mass (r^2 = 0.35, P < 0.01). A significant difference by quintile was noted in fat-free mass (r^2 = 0.69, P < 0.02); however, this difference was not significant when physical activity (MVPA) was added to the model. When indexed variables were analyzed, FMI and trunk FMI significantly differed by

birth weight quintile (Fig. **1**, p < 0.01). FFMI differed by birth weight quintile when not controlling for MVPA; however, there was no difference by quintile after including MVPA as a model covariate.

When linear regression was used to assess the relationship between birth weight (g) and body composition variables, birth weight was positively associated with fat mass, BMI, BMI percentile, and fat-free mass (all at p < 0.01) after controlling for covariates. A positive association with birth weight was also observed for FMI (p < 0.01), FFMI (p = 0.02), and trunk FMI (p < 0.01; Table **2**).

Table 2. Association of Birth Weight with Fat Mass Index (FMI), Fat-Free Mass Index (FFMI), and Trunk FMI*

	FMI		FFMI		Trunk FMI	
Covariates	**ß**	**p**	**ß**	**p**	**ß**	**p**
Birth weight (g)	0.01	<0.01	<0.01	0.02	0.61	<0.01
Age (years)	-0.03	0.83	0.04	0.49	-0.18	0.55
Pubertal status	0.64	0.02	0.69	<0.01	0.18	0.02
Female sex	0.21	0.52	-1.08	<0.01	0.18	0.03
AA ethnicity	-0.71	0.08	0.41	0.05	-0.24	0.02
HA ethnicity	1.05	0.03	0.33	0.18	0.36	<0.01
SES	-0.03	0.02	<0.01	0.56	-0.26	0.02
MVPA (min/day)	-0.02	<0.01	<0.01	0.06	-0.16	0.02

* AA = African-American; HA = Hispanic-American; SES = socioeconomic status; MVPA = moderate/vigorous physical activity.
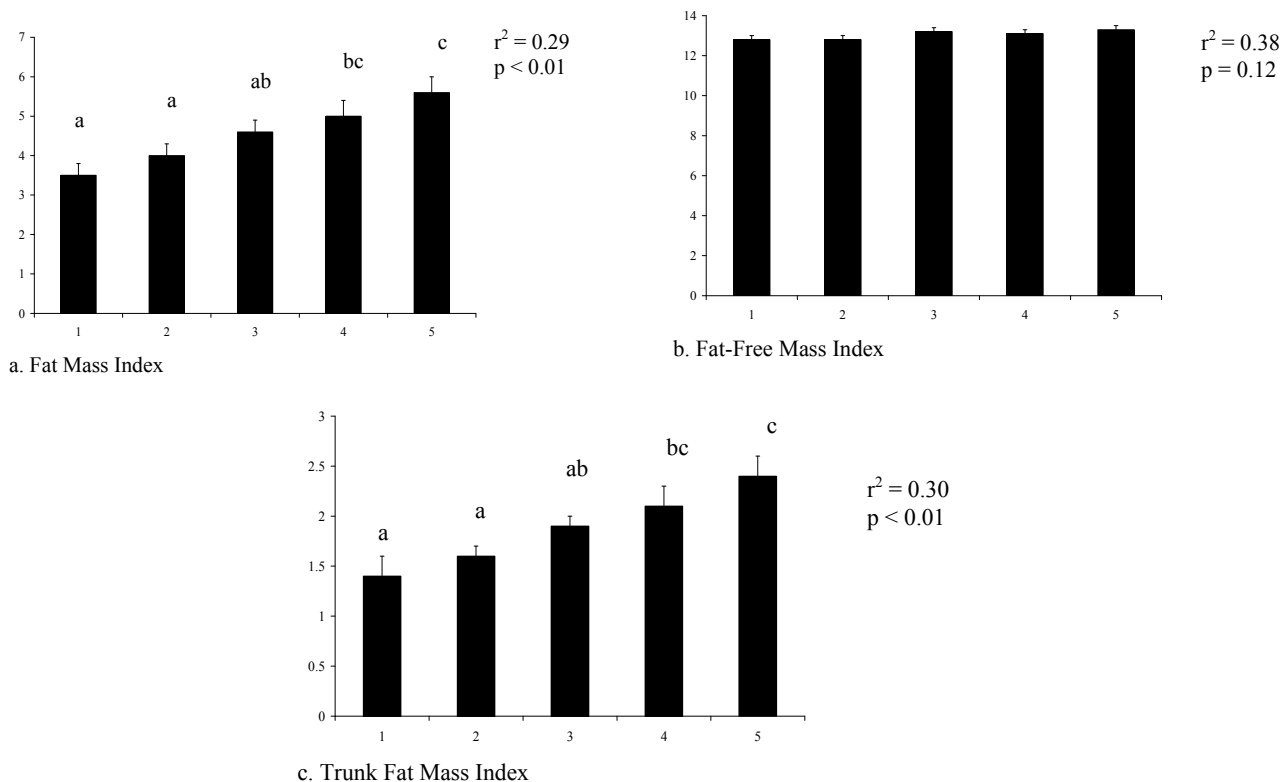

a. Fat Mass Index

b. Fat-Free Mass Index

c. Trunk Fat Mass Index

Fig. (1). Least square means fat mass index (FMI), fat-free mass index (FFMI), and trunk FMI by birth weight quintile*

*All models adjusted for age, pubertal status, sex, socioeconomic status, physical activity. [a,b,c] superscripts indicate group differences.

Additional covariates were also associated with the three indices. Greater pubertal status (higher Tanner stage) was positively associated with FMI, FFMI, and trunk FMI ($p < 0.05$). Hispanic ethnicity was related to a higher FMI and trunk FMI while SES and MVPA were negatively associated with FMI and trunk FMI (all at $p < 0.05$). Additionally, female sex was associated with a lower FFMI and greater trunk FMI.

DISCUSSION

Our results indicate that birth weight is positively associated with body composition among children ages 7-12 years, and that these relationships are independent of age, pubertal status, sex, physical activity, and SES. Additionally, we show that controlling for physical activity attenuates the relationship of birth weight with FFMI. These results suggest that the *intrauterine* environment may affect later body composition of the child, and additional studies are needed to improve methods of detecting mothers at-risk for having macrosomic babies. The association of environmental factors with current pediatric FMI and trunk FMI indicate that interventions designed to attenuate fat mass gain could benefit children born at a high birth weight.

Studies using BMI as a proxy for body fat have shown equivocal results in the relationship between body composition and birth weight among children and adults [22,23]. However, BMI does not distinguish fat mass from fat-free mass, and may be an imprecise measure of adiposity in children [12]. Our use of the FMI allowed us to evaluate the relationship of birth weight with body fat independent of the associations with fat-free mass or height. Our finding that higher birth weight predicted a greater FMI is consistent with the results of Whitaker *et al.* [9], who noted a greater percentage of obesity among children born at a high birth weight [10]. Similarly, we note that birth weight was positively associated with trunk FMI, which is an indicator of central adiposity. Central adiposity is linked to greater risk for the metabolic syndrome [24,25], and could promote higher rates of diabetes and cardiovascular disease throughout the lifespan.

Our finding that higher birth weight is associated with a higher FFMI is consistent with studies that report a positive relationship between birth weight and fat-free mass, as reviewed by Wells *et al.* [26]. However, we also show that including physical activity in the models attenuates the contribution of birth weight to FFMI. Most studies have not included physical activity in studies of relationship, and those that did were unable to report precise measures of fat-free mass [27]. Including this and other environmental covariates allowed us to further elucidate the contributions of early life versus current environment on body composition. In addition, SES is related to negative health outcomes in children and adults, and in our study higher SES is associated with lower FMI and trunk FMI [28,29]. Hence, including a combination of biological and environmental covariates in the model allowed us to more accurately assess the association of birth weight with FFMI, FMI, and trunk FMI, and this approach should be considered for future studies evaluating the effects of birth weight on health outcomes.

This study benefited from the use of more precise measures of body composition from DXA analysis that allowed us to calculate height-adjusted indices for fat and fat-free mass compartments. Inclusion of three ethnicities and both sexes also allowed us to adjust for the known ethnic and sex-related differences in body composition. Of note, our results indicate differing associations of AA and HA with measures of adiposity, indicating that additional research is needed to determine whether birth weight affects future body composition differently among differing racial/ethnic groups. It is also possible that the lack of association between body composition and dietary factors in this study is due to use of a smaller sample size than is typically utilized in diet association studies. However, these results indicate that birth weight is associated with differences in pediatric body composition, and through this propensity for increased fat mass could indirectly contribute to increased chronic disease risk.

CONCLUSION

This study suggests that birth weight is positively associated with pediatric adiposity and fat-free mass as measured by DXA. Additional factors, such as racial ancestry, current socioeconomic status and physical activity, can also influence body composition and should be considered when evaluating the relationship of prenatal growth (birth weight) to childhood body mass. Understanding of the prenatal environment's relationship to future disease risk is essential to design effective interventions to decrease the rate of high birth weight babies born, and to identify older children at risk for excess adiposity.

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