Prenatal compared with parental origins of adolescent fatness[1,2]

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ABSTRACT
Background: Differences in prenatal growth influence postnatal body fat.
Objective: The objective was to investigate the role of parental body composition on the "tracking" of adolescent fatness.
Design: The study population consisted of 1993 white subjects and their parents. Measurements were taken at birth and again at the age of either 15, 16, or 17 y. The newborns were classified in 3 groups: small for gestational age, appropriate for gestational age, and large for gestational age. The mothers and fathers of the adolescents were classified into low and high subgroups on the basis of measurements of body mass index (BMI). Similarly, the mothers of the adolescents were classified into lean and fat subgroups on the basis of measurements of triceps skinfold thickness.
Results: Heavy newborns became heavier or fatter adolescents only when the mother or father was also fat and, among heavy newborns, the risk of becoming fat adolescents was ≈5.7 times higher when the mother was fat rather than lean.
Conclusions: Large newborns become fat adolescents only when the mother or father is also overweight or fat (ie, has either a high BMI or large skinfold thickness). These findings suggest that fatness during adolescence is related to parental fatness but not to prenatal fatness. Therefore, preventing higher levels of adiposity among newborns is unlikely to reduce overall adiposity in adolescence. *Am J Clin Nutr* 2000;72:1186–90.

KEY WORDS Obesity, overweight, newborns, adolescents, body composition, triceps skinfold thickness, gestational age, body mass index

INTRODUCTION

Obesity is an increasingly prevalent health problem in children and adolescents (1). Numerous studies showed that adiposity "tracks" throughout the life span. That is, individuals who tend to be relatively fat or heavy during early life tend to be relatively fat or heavy during later life. This inference is based on the results of studies showing that heavy newborns tend to become fat children (2–9) and that fat children tend to become fat adults (10–13). Similarly, several studies linked low birth weight to increased central adiposity in adolescence, as measured by the ratio of triceps skinfold thickness to subscapular skinfold thickness (14), and to central obesity in adult life, as measured by the waist-hip ratio (15). Accordingly, it has been postulated that the tendency to store fat abdominally may be a persistent response to adverse conditions and growth in fetal life (15). However, the results of longitudinal studies in infants (16) and children (17) suggest that parental body composition is an important predisposing factor in the development of obesity in children. Similarly, parental obesity more than doubles the risk of adult obesity in children aged <10 y (18). In addition, studies of biological (19) and adopted (20) children and twins (21) showed the heritability of obesity. Therefore, the role of parental body composition on the tracking of obesity is not clear. With this purpose in view, I evaluated the relation of parental body composition to birth weight and to measures of adiposity during adolescence.

SUBJECTS AND METHODS

Subjects

The present study made use of a large body of data collected in the Child Health and Development Studies (CHDS) and in the Adolescent Study, which were conducted by the School of Public Health of the University of California–Berkeley. After the termination of the CHDS, the data sets were made available by the National Technical Information Service of the US Department of Commerce.

The CHDS were initiated in 1959 and entailed prospective, longitudinal observations of mothers during pregnancy and delivery and of the development of the children born. The study population consisted of 20 530 pregnancies, which resulted in 19 044 live-born infants. Some 65% of the pregnant women were white, 24% were black, 3% were Mexican American, 4% were Asian, and 4% were of other ethnic backgrounds. The families resided in the San Francisco East Bay area of California and were members of the Kaiser Foundation Health Plan, a prepaid medical insurance program. Extensive data on the mothers and their children were collected through interviews, by abstracting the medical records, and through developmental examinations.

The CHDS included 3 subcohorts defined by date of birth as 5-y-olds, 9–11-y-olds, and 15–17-y-olds. The 15–17-year-old cohort was referred to as the Adolescent Study. The group of adolescents in this study had birth dates from April 1960 to April

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TABLE 1
Characteristics of the subjects studied at birth and during adolescence and of their parents[1]

	Males	Females
Subjects at birth		
Gestation (wk)	39.6 ± 0.10 [997]	39.6 ± 0.1 [996]
Birth weight (g)	3431.4 ± 15.50 [997]	3293.9 ± 15.9 [996]
Adolescents		
Age (y)	16.5 ± 0.02 [997]	16.5 ± 0.02 [996]
Height (cm)	175.0 ± 0.30 [997]	163.4 ± 0.20 [996]
Weight (kg)	67.3 ± 0.40 [997]	58.6 ± 0.30 [985]
BMI (kg/m^2)	22.0 ± 0.10 [997]	21.9 ± 0.10 [984]
Triceps skinfold thickness (mm)	11.6 ± 0.30 [996]	20.4 ± 0.30 [985]
Mothers of adolescents		
Age (y)	45.4 ± 0.20 [997]	45.3 ± 0.20 [996]
Height (cm)	163.0 ± 0.20 [998]	163.0 ± 0.20 [989]
Weight (kg)	62.0 ± 0.30 [990]	62.3 ± 0.40 [988]
BMI (kg/m^2)	23.3 ± 0.10 [986]	23.5 ± 0.10 [984]
Fathers of adolescents		
Height (cm)	178.6 ± 0.27 [741]	178.8 ± 0.27 [724]
Weight (kg)	77.4 ± 0.40 [687]	78.7 ± 0.44 [674]
BMI (kg/m^2)	24.3 ± 0.11 [686]	24.5 ± 0.12 [671]
Total family income scale[2]	4.7 ± 0.07 [912]	4.6 ± 0.07 [912]

[1] $\bar{x}$ ± SE; *n* in brackets.
[2] Total income scale in 1975 dollars: 1, <$2500; 2, $2500–4999; 3, $5000–5999; 4, $6000–6999; 5, $7000–7999; 6, $8000–8999; 7, $9000–9999; 8, $10 000–12 499; 9, $12 500–14 999; 10, ≥$15 000.

1963 and had participated in the CHDS developmental examinations at birth. A total of 2020 children participated in the Adolescent Study. Both teenagers and their mothers were invited to participate and a subsample of the fathers also participated. From this data set, a full set of measurements was available for 1993 white subjects (997 males and 996 females) who were evaluated at birth and again at the age of either 15, 16, or 17 y.

Study measurements

The measurements available for the 1993 subjects studied included gestational age at birth (in weeks; derived from the date of the last menstrual period), birth weight (for live-born infants only) and age, height, weight, upper arm circumference, and triceps skinfold thickness at the time of the Adolescent Study. In addition, measurements of age, height, weight, and triceps skinfold thickness of the mothers of the adolescents were available, as were measurements of height and weight of the fathers. The mothers' measurements were obtained at the time of the Adolescent Study. The fathers' measurements were recorded during the first study of the first cohort of newborns (referred to as 5-y-olds) and were matched on basis of identification number. The subjects were measured standing fully erect and without shoes. Measurements of stature were recorded in completed inches and sixteenths of an inch, whereas weight was measured in pounds and quarter pounds. The English measurements were then converted into metric units. Triceps skinfold thickness was measured at the midpoint of the upper arm and was expressed in mm. Body mass index (BMI) was calculated as weight in kg divided by height squared in m.

Indexes of prenatal growth

On the basis of birth weight and gestational age, the adolescents were classified into 3 categories: *1*) small for gestational age, *2*) appropriate for gestational age, and *3*) large for gestational age. These categories corresponded, respectively, to birth weights below the 10th, between the 10th and the 90th, and above the 90th percentiles of birth weight by gestational age standards (22).

Indexes of parental body size and body composition

Age-specific percentiles of BMI and triceps skinfold thickness of the mothers were calculated. Then, on the basis of this information, the mothers were classified *1*) as having low or high BMIs and *2*) as being lean or fat depending on whether their BMI or triceps skinfold thickness measurements were less than or greater than the 50th percentile for either of these variables. Similarly, the fathers were classified as having low or high BMIs.

Statistical analysis

The group comparisons were made with reference to the actual measurements and to *z* score values. The *z* scores were derived by computation as follows:

$$z \text{ Score} = (\text{individual value} - \text{mean for the age and sex of the subject}) / \text{SD for the age and sex of the subject} \quad (1)$$

Three types of *z* scores were obtained.

1) Newborn *z* scores: For this purpose, gestational-age- and sex-specific means and SDs of birth weight were calculated and the newborn *z* scores for birth weight were calculated with reference to these values.
2) Adolescent *z* scores: For this purpose, age- and sex-specific means and SDs of BMI and triceps skinfold thickness were calculated for all the adolescents. Then, the corresponding sex- and age-specific *z* scores were calculated with reference to these values.
3) Parental *z* scores: For this purpose, age-specific means and SDs of BMI were calculated for the mothers and fathers and age-specific means and SDs of triceps skinfold thicknesses were calculated for the mothers of the adolescents.

With use of the individual *z* scores, multiple analysis of variance was used to determine significant differences in the anthropometric dimensions of the adolescents across the 3 birth weight categories and the 2 subgroups of maternal body composition. Associations or differences were considered to be statistically significant if *P* values were <0.05.

The relation between the BMI of the adolescents and their birth weight, the BMI of their parents, and per capita family income was assessed by multiple regression analysis. The stepwise elimination procedure was used to establish the optimal model. Regression equations are presented with *r* values, and any variable with a *P* value <0.05 for the last determinant added are presented. The statistical program STATVIEW SPSS (SPSS Inc, Chicago) was used for the analyses.

RESULTS

The general characteristics of the sample are given in **Table 1**. The mean values for birth weight, body size, and body composition of both males and females were similar to the mean values expected for US white populations of the same age and sex (23). The BMI and triceps skinfold thicknesses of the adolescents arranged by their birth weight category and the BMI category of their mothers are compared in **Table 2**. Differences in birth weight were not associated with significant differences in the

TABLE 2
Comparison of measurements of BMI and triceps skinfold thickness of the adolescents according to whether their birth weight was small for gestational age (SGA), appropriate for gestational age (AGA), or large for gestational age (LGA) and whether their mother's BMI was either high or low[1]

Adolescent birth weight category	Adolescent BMI			Adolescent skinfold thickness		
	Low BMI	High BMI	P^2	Low BMI	High BMI	P^2
	kg/m²			*mm*		
Males						
SGA	21.0 ± 0.4 [60]	22.9 ± 0.8 [33]	<0.01	10.2 ± 0.8	12.4 ± 1.8	<0.05
AGA	21.2 ± 0.1 [390]	22.7 ± 0.2 [395]	<0.01	10.7 ± 0.3	12.6 ± 0.4	<0.05
LGA	21.1 ± 0.5 [31]	23.0 ± 0.5 [58]	<0.01	11.8 ± 1.3	13.2 ± 1.2	<0.05
P	NS	NS		NS	NS	
Females						
SGA	20.4 ± 0.3 [55]	23.1 ± 1.0 [32]	<0.01	17.4 ± 1.0	23.3 ± 2.3	<0.05
AGA	21.2 ± 0.1 [416]	22.6 ± 0.3 [377]	<0.01	19.2 ± 0.4	21.3 ± 0.5	<0.05
LGA	21.3 ± 0.4 [29]	23.9 ± 0.6 [55]	<0.01	19.9 ± 1.6	24.5 ± 1.5	<0.05
P	NS	NS		NS	NS	

[1] $\bar{x}$ ± SE; *n* in brackets.
[2] The statistical significance of the differences was based on the individual *z* scores.

BMI or triceps skinfold thicknesses of the adolescents. On the other hand, across each of the birth weight categories there were significant differences in BMI and triceps skinfold thicknesses between the parental categories: high maternal BMI was associated with significantly higher adolescent BMI and triceps skinfold thickness than was low maternal BMI. As illustrated in **Figure 1**, when the mother's or father's BMI was low, the *z* scores for BMI during adolescence for all 3 birth weight categories were below the mean. On the other hand, if the BMI of the mother or the father was high, the newborns, irrespective of their birth weight categories, grew to have higher BMIs than did their counterparts born to mothers with low BMIs. As shown in **Figure 2**, when the mothers were lean (ie, when the mothers had low triceps skinfold thicknesses), the *z* scores for triceps skinfold thickness during adolescence for all 3 birth weight categories were below the mean. On the other hand, when the mothers were fat (ie, when the mothers had high triceps skinfold thicknesses), the newborns, irrespective of their birth weight categories, grew to be fatter adolescents than did their counterparts born to lean mothers.

The incidences of newborns becoming fat adolescents are compared in **Table 3**. When the mother was fat (defined by having a high BMI), the risk of becoming fat increased <2 times among those infants who were small or adequate for gestational age. These data also show that among those who were large for

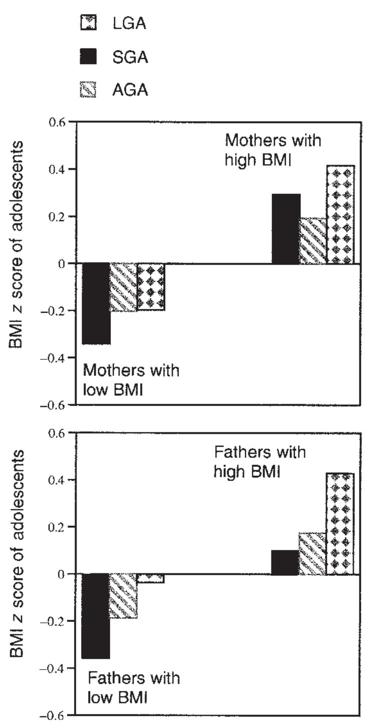

FIGURE 1. Comparison of adolescent BMI (in kg/m²) by birth weight category (LGA, large for gestational age; SGA, small for gestational age; and AGA, appropriate for gestational age) and BMI of the parents. When either the mother's or the father's BMI was low, the *z* scores for the BMIs of the adolescents, irrespective of birth weight category, were below the mean. On the other hand, when the parent's BMI was high, the BMI of the adolescents was above the mean. In particular, the LGA newborns grew up to be fatter adolescents than did their counterparts born to mothers of low BMI.

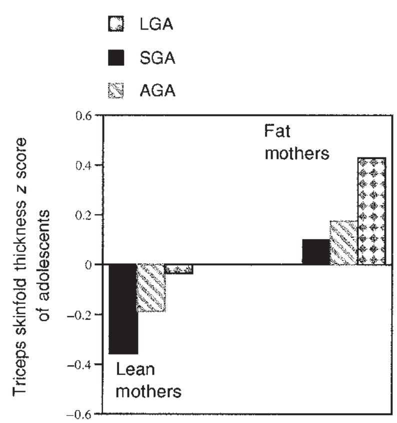

FIGURE 2. Comparison of adolescent triceps skinfold thickness by birth weight category (LGA, large for gestational age; SGA, small for gestational age; and AGA, appropriate for gestational age) and mother's body composition. When the mothers were lean, the *z* scores for triceps skinfold thickness during adolescence for all 3 birth weight categories were below the mean. On the other hand, if the mother was fat, the newborns grew to be fatter adolescents than did their counterparts born to lean mothers, irrespective of birth weight categories.

TABLE 3
Comparison of the incidence and relative risk (RR) of becoming a fat adolescent according to birth weight category and maternal BMI

Adolescent birth weight category	Maternal BMI category	Adolescent BMI category	Incidence	RR[1]
			%	
Small for gestational age	High	Fat	7.3	1.9
Small for gestational age	Low	Fat	3.9	—
Adequate for gestational age	High	Fat	7.0	2.2
Adequate for gestational age	Low	Fat	3.2	—
Large for gestational age	High	Fat	13.1	5.7
Large for gestational age	Low	Fat	2.3	—

[1] RR for high compared with low maternal BMI.

gestational age, the risk for becoming fat adolescents increased nearly 5.7 times compared with the risk for those whose mothers were lean (defined by having a low BMI).

As shown in **Table 4**, in both boys and girls, the BMIs of the mother and the father were significant predictors of the adolescents' BMIs. Birth weight and per capita family income were not significant predictors.

DISCUSSION

Previous studies showed that heavy newborns tend to become fat children (2–9) and that fat children tend to become fat adults (10–13). Similarly, several studies linked low birth weight to increased central adiposity in adolescence, as measured by the ratio of triceps to subscapular skinfold thickness (14), and to central obesity in adult life, as measured by the waist-hip ratio (15). However, in all these studies the influence of parental body composition on the development of obesity was not evaluated. The present study sought to determine whether adolescent fatness differed among those whose parents were either lean or obese. The present results show that BMI and triceps skinfold thicknesses differed significantly among adolescents with either lean or obese parents. The main predictor of BMI in this cohort of adolescents was parental BMI. Birth weight and per capita family income were not significant predictors of adolescent fatness.

These findings agree with those reported by other investigators. Longitudinal studies in infants (16) and children (17) showed that parental body composition is an important predisposing factor in the development of obesity in children. Similarly, in a retrospective study, the probability of obesity in young adulthood was examined in relation to the presence or absence of obesity at various times throughout childhood and the presence or absence of obesity in the child's parents (18). That study showed that obese children without obese parents were at low risk of obesity in adulthood. The effect of parental obesity on the risk of obesity in adulthood was most pronounced among obese and nonobese children aged < 10 y. The risk of adult obesity was significantly greater if either parent was obese.

The present findings indicate that the tracking effect of birth weight and body composition during adolescence is mediated by parental body composition. In other words, heavy newborns (assumed to be fat newborns) do not necessarily become fat adolescents unless the mother or father is also overweight. Comparisons of the incidence of obesity during adolescence indicate that heavy newborns are 5.7 times more likely to become fat adolescents if their mothers or fathers are also fat than when their parents are lean. Previous studies of prepubertal children of obese and nonobese parents found that the major determinants of change in fat mass adjusted for fat-free mass were sex (fat gain was greater in girls), fatness at baseline, and parental fatness (24). In addition, studies of premenarcheal girls found that fathers' total or percentage body fat was predictive of long-term changes in total and percentage body fat (25). It is important to determine the mechanism whereby parental fatness contributes to the increased risk of obesity in offspring. It is possible that the mechanism is related to differences in the components of energy expenditure between overweight and nonoverweight parents, which is some cases appear to have a familial component. In conclusion, the present findings indicate that the tracking of high birth weight to adolescence depends on the body composition of the parents such that heavy newborns become fat adolescents only if either the mother or father is also fat.

I thank Stanley M Garn for his valuable suggestions.

TABLE 4
Multiple linear regression equations for predicting BMI of adolescent boys and girls derived from stepwise regressions[1]

Variable	Equations	*r*	*P*
Boys, BMI (n = 967)	0.002 + 0.289 z mother's BMI	0.27	0.001
Boys, BMI (n = 674)	0.009 + 0.239 z father's BMI	0.23	0.001
Boys, BMI (n = 655)	0.014 + 0.296 z mother's BMI + 0.190 z father's BMI	0.36	0.001
Girls, BMI (n = 964)	0.001 + 0.308 z mother's BMI	0.32	0.001
Girls, BMI (n = 659)	0.009 + 0.210 z father's BMI	0.22	0.001
Girls, BMI (n = 647)	– 0.062 + 0.266 z mother's BMI + 0.165 z father's BMI	0.34	0.001
Combined, BMI (n = 1931)	0.002 + 0.299 z father's BMI	0.29	0.001
Combined, BMI (n = 1333)	– 0.031 + 0.221 z father's BMI	0.22	0.001
Combined, BMI (n = 1302)	– 0.024 + 0.281 z mother's BMI + 0.174 z father's BMI	0.35	0.001

[1] Predictors under consideration were birth weight, BMI of mother, BMI of father, and per capita family income in 1975 dollars.

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