Correlates of individual differences in body-composition changes resulting from physical training in obese children[1–3]

Paule Barbeau, Bernard Gutin, Mark Litaker, Scott Owens, Sharon Riggs, and Tomoki Okuyama

ABSTRACT
Background: No studies have been reported in children that assess correlates of body-composition changes in response to a physical training intervention.
Objective: The hypothesis studied was that variation in diet and physical activity would explain a significant portion of the interindividual variation in the response of body composition to physical training.
Design: The participants were 71 obese children aged 7–11 y (22 boys, 49 girls; 31 whites, 40 blacks). Body composition was measured by dual-energy X-ray absorptiometry, physical activity by a 7-d recall interview, and diet by two, 2-d recalls. The children underwent 4 mo of physical training.
Results: The mean attendance was 4 d/wk, the mean (±SD) heart rate for the 40-min sessions was 157 ± 7 beats/min, and the mean energy expenditure was 946 ± 201 kJ/session. On average, the percentage body fat decreased significantly in the total group, and total mass, fat-free soft tissue, bone mineral content, and bone mineral density increased, but there was a good deal of individual variability. Multiple regression models indicated that in general, more frequent attendance, being a boy, lower energy intake, and more vigorous activity were associated with healthier body-composition changes with physical training. Ethnicity was not retained as a correlate of the change of any component of body composition.
Conclusions: In obese children, age, vigorous activity, diet, and baseline percentage body fat together accounted for 25% of the variance in the change in percentage body fat with physical training. *Am J Clin Nutr* 1999;69:705–11.

KEY WORDS Body composition, physical training, children, obesity, correlates, diet, physical activity, interindividual variability

INTRODUCTION

The possible correlates of body composition are many and varied. Included are unmodifiable factors such as age, sex, and ethnicity, as well as modifiable factors such as total energy intake, diet composition, and level of physical activity. Understanding the correlates can guide intervention efforts designed to enhance body composition.

One approach is to perform cross-sectional analyses between hypothesized correlates and individual differences in body-composition measures, from which we infer that over some period of time before the measurements the correlates contributed to the individual differences in body composition. For example, Tucker et al (1) found that dietary fat intake was positively related to adiposity in 9–11-y olds, suggesting that ingestion of high amounts of dietary fat leads to increased adiposity; therefore, we hypothesized that reducing fat intake will lead to reduced adiposity.

Another approach is to investigate, in a noninterventional manner, factors that are associated with changes in body composition over some period of time. For example, Moore et al (2) found that preschoolers who were inactive, as measured with a Caltrac movement sensor, were 3.8 times as likely as active children to have an increasing triceps-skinfold-thickness slope over an average of 2.5 y of follow-up.

A third approach is to study individual differences in body-composition changes that result from an intervention program designed to alter body composition, thereby producing relatively large changes (and perhaps variability in changes) over relatively short periods of time. For example, when exposed to physical training, obese children would be expected to reduce their body fatness. However, children may vary in how they respond to the physical training, with some decreasing their free-living activity, increasing their energy intake, or both, such that the physical training may actually lead to a paradoxical increase in adiposity. In any case, there is often a good deal of variation in how people respond to a given intervention.

Because little is known about the correlates of individual differences in response to physical training, we used this third approach by subjecting obese children to a controlled physical training program over a 4-mo period and then determining which factors were associated with individual differences in the resulting changes in body composition. Factors investigated included subject characteristics (eg, age, ethnicity, and sex), free-living diet, and physical activity during the 4-mo period, and individual differences in the physical training process (intensity and

[1] From the Georgia Prevention Institute, Department of Pediatrics, and the Office of Biostatistics, Medical College of Georgia, Augusta.
[2] Supported by the National Heart, Lung, and Blood Institute (HL 49549).
[3] Address reprint requests to P Barbeau, Medical College of Georgia, Georgia Prevention Institute (HS1640), Augusta, GA 30912–3710. E-mail: pbarbeau@mail.mcg.edu.
Received March 2, 1998.
Accepted for publication October 20, 1998.

frequency). The hypothesis of this study was that differences in diet, time spent in physical activity, and physical training modalities would explain a significant portion of the interindividual variation in the response of body composition to physical training. To our knowledge, no studies have been reported in children that used this approach to assess correlates of body composition.

SUBJECTS AND METHODS

Subjects

Obese children 7–11 y of age were recruited from schools near our institute. Interested children attended an information session accompanied by their parents and signed informed consent forms in accordance with the procedures of the Human Assurance Committee before starting the study. Inclusion criteria were a triceps skinfold thickness above the 85th percentile for sex, age, and ethnicity (3), not being involved in any other weight-control or exercise program, and having no restrictions on physical activity. The original group comprised 78 individuals. Because of dropouts and missing data, data for only 71 subjects were retained in the analyses. Their mean (±SD) age was 9.7 ± 1.0 y before the start of training and the group had 22 boys, 49 girls, 31 whites, and 40 blacks.

The children were randomly assigned, within their sex and ethnicity, to group 1 or group 2. Testing was done at baseline, after 4 mo, and after 8 mo (except for diet, *see* below). Group 1 trained during the first 4 mo, then discontinued the physical training; group 2 underwent the training intervention during the second 4-mo period, receiving no intervention during the first 4 mo. The overall pattern of body-composition changes over the 8-mo period is reported elsewhere (4). For the purposes of this study, data were pooled from the 2 groups to study the individual differences in response to the physical training intervention.

Body composition

Total body composition, including total body mass, fat mass, fat-free soft tissue, percentage body fat, bone mineral density, and bone mineral content, was assessed with dual-energy X-ray absorptiometry (DXA) (QDR-1000 version 6.20A; Hologic, Waltham, MA) before and after the 4-mo physical training program. DXA has been shown to be reliable when measuring body composition in children, yielding intraclass correlations for repeat measurements of percentage body fat of 0.998 (5). Furthermore, the validity of the DXA measurement was assessed by comparing it with total mass obtained by using a scale (data not shown). The correlations between the 2 measures were very high: before physical training (r = 0.95), after physical training (r = 0.99), and for the change with physical training (r = 0.99). To provide insight into DXA measurement error over time, we looked at the correlation between body-composition measures at month 0 and month 4 (nonexercise period) in group 2. The changes in body composition occurring during these 4 mo reflect variation in body-composition changes due to growth as well as measurement error over time. The correlations between the month 0 and month 4 measures were 0.99 for total mass, bone mineral content, and bone mineral density; 0.98 for fat-free soft tissue and fat mass; and 0.91 for percentage body fat (P = 0.0001). Thus, the error between the 2 measures was very small, even though it included real change as well as the measurement error. These values agree with those of Figueroa-Colon et al (6), who found correlations of 0.96 (for fat-free mass and fat mass) and 0.91 (for percentage body fat) between measures taken 6 wk apart in prepubertal girls by using Lunar DXA. Therefore, it is unlikely that measurement error over time was a problem in this study.

Physical activity

Hours spent doing moderate-to-very hard physical activity were estimated from 7-d recalls (7). The pretraining measurement was for a 7-d period before physical training and the posttraining measurement included the last week of physical training. An interviewer questioned each child to reconstruct time spent sleeping and doing physical activities during the 7 previous days. Moderate activities were defined as "similar to how you feel when you are walking at a normal pace," very hard activities as "similar to how you feel when you are running," and hard activities as "those activities that are between walking and running." From these definitions we calculated vigorous activity, which comprised hours spent doing hard and very hard activity. Analyses were performed by using the change in each of these from before to after training because it is logical that the change in activity from before to during the intervention period might be expected to lead to a change in body composition. In addition, we examined the variability present in absolute amounts of moderate and vigorous activity during the physical training period itself to see whether it would predict variability in body-composition changes.

Energy intake and diet composition

Dietary variables were assessed by using 2-d recalls. At the baseline test session, a 1-d recall was used to orient the child to the procedure. After 2 and 4 mo of physical training, the children were scheduled for test sessions and given forms on which they were to record everything they ate for the 2 d before the session; this information was used during the diet interviews to assist in the recalls. The dietary data were analyzed by using the Nutrition Data System (NDS) of the Nutrition Coordinating Center at the University of Minnesota, Minneapolis. From these data we calculated the average daily energy intake (in kJ); the average percentage of daily energy intake from carbohydrates, fat, and protein; as well as daily calcium intake.

Training process

Training sessions were offered 5 d/wk and the children were asked to attend a minimum of 3 d/wk. Each session lasted 40 min: 20 min were spent exercising on machines (eg, treadmill, stationary cycle, and trampoline) and the remaining 20 min playing games (eg, basketball, dodge ball, and tag). Each child wore a heart rate monitor (Polar Vantage, Port Washington, NY) during each session and was encouraged to maintain a heart rate ≥150 beats/min. After each session, the minute-by-minute heart rate data were downloaded into a computer and displayed to the child. Incentives were offered for attendance ($1 for each exercise session attended) and points were awarded for each session during which the target heart rate was maintained, the accumulation of which led to prizes.

Our intention was to minimize individual variability in physical training process variables to assess the experimental effect of the physical training on body composition. However, some individual variability did occur and we included 2 training process variables in the correlates: average heart rate during a training session and average attendance as a percentage of total sessions offered.

TABLE 1
Change in body composition from before to after physical training, and physical activity, diet, and training process variables[1]

Variable	Before training	After training	Change with physical training
Height (cm)	143.5 ± 8.7	146.3 ± 8.5	2.7 ± 1.2 (−0.2 to 5.5)
Relative BMI	1.05 ± 0.24	1.06 ± 0.25	0.73 ± 8.26 (−18.3 to 19.1)
Body composition			
Total mass (kg)	59.2 ± 18.5	61.0 ± 19.1	1.8 ± 2.5[2] (−7.8 to 7.7)
Fat mass (kg)	27.0 ± 11.7	26.8 ± 11.7	−0.19 ± 2.6 (−8.7 to 5.2)
Fat-free soft tissue (kg)	30.7 ± 7.5	32.6 ± 8.0	1.9 ± 1.4[2] (−0.2 to 6.0)
Bone mineral content (kg)	1.4 ± 0.3	1.5 ± 0.3	0.09 ± 0.07[2] (−0.3 to 0.2)
Bone mineral density (g/cm^2)	0.90 ± 0.08	0.92 ± 0.08	0.02 ± 0.02[2] (−0.1 to 0.1)
Percentage body fat (%)	44.4 ± 6.5	42.8 ± 6.5	−1.6 ± 2.9[2] (−11.7 to 3.0)
Physical activity			
Moderate (h/wk)	3.1 ± 2.8	3.6 ± 2.8	0.5 ± 3.3 (−8.8 to12.5)
Vigorous (h/wk)	2.3 ± 2.4	3.7 ± 3.2	1.4 ± 3.1 (−6.5 to 8.8)
Diet[3]			
Energy intake (kJ/d)	—	7284 ± 1674	—
Fat (% of energy)	—	35.0 ± 5.7	—
Protein (% of energy)	—	14.3 ± 2.2	—
Carbohydrate (% of energy)	—	52.0 ± 6.3	—
Calcium (mg/d)	—	773 ± 286	—
Training process[4]			
Heart rate (beats/min)	—	157 ± 7	—
Attendance (% of sessions)	—	80 ± 16	—

[1] $\bar{x}$ ± SD; range in parentheses. *n* = 71 obese children aged 9.7 ± 1.0 y before training.
[2] Significant change with training, *P* ≤ 0.0001. After training was the week after the end of physical training, except for the physical activity data, which included the last 7 d of physical training, and the diet data, which included ≥2 d of physical training.
[3] During training.
[4] For the entire 4-mo training period.

Statistical analyses

The dependent variables were the change scores in the body-composition measures from before to after physical training. There were no obvious extreme values from the examination of univariate analyses. Pearson intercorrelations between the body-composition measures were calculated by using SAS software (version 6.12; SAS Institute Inc, Cary, NC). The correlation between changes in fat-free soft tissue and fat-free mass was high (*r* = 0.999); therefore, we would expect the results to be similar for these 2 variables. Because fat-free soft tissue and bone mineral content make up fat-free mass, analyses are presented for these components rather than for fat-free mass. Changes in fat mass and percentage body fat were also highly correlated (*r* = 0.92), but because the latter is a ratio and thus may provide additional information, results for both indexes are presented. The other correlations were more modest, so all variables except fat-free mass were kept for further analyses. Paired *t* tests were performed by using SPSS/PC 7.5 (SPSS Inc, Chicago) to determine whether the change in the dependent variables from before to after training was significant.

Stepwise multiple regressions were used to identify the correlates of the individual differences in body composition. These analyses were performed by using the SAS regression procedure, keeping the default cutoff *P* value for inclusion in the model at 0.15. In stage 1, stepwise regressions were performed separately for *1*) ethnicity, sex, and age; *2*) baseline value of the dependent variable; *3*) physical activity–related variables; *4*) diet-related variables; and *5*) training process–related variables. In stage 2, a stepwise regression was run that included all the main effects retained by the models in stage 1. In stage 3, two-way interactions of all main effects retained in stage 2 were added to the model and the relevant main effects were forced into the model. We evaluated the stability of the final models by eliminating extreme values (as indicated in the figures), and rerunning the final model regressions. These extreme values were first identified by examining the interaction plots, and were confirmed by looking at their studentized residuals, which ranged from 2 to 3.6.

RESULTS

The values before training and after training and the change values for the independent and dependent variables studied are presented in **Table 1**. Note that the change scores for the body-composition outcome variables were quite variable. For example, although the mean 1.6% reduction in percentage fat for the group was significant, the change in percentage fat ranged from an 11.7% decrease to a 3% increase. The only outcome variable that did not change significantly with physical training was fat mass.

The first stepwise regression analyses were done separately for each domain. The influence of each independent variable within the domain was adjusted for each other independent variable within that domain.

Descriptive factors

When ethnicity and sex were controlled for, older children had a larger increase in fat-free soft tissue (*r* = 0.32, *P* = 0.006), bone mineral content (*r* = 0.18, *P* = 0.13), and bone mineral density (*r* = 0.23, *P* = 0.06), as well as a larger decrease in percentage body fat ($r = -0.21$, $P = 0.07$) than younger children. Compared with white individuals, blacks had a smaller increase in bone mineral density ($r = -0.19$, $P = 0.08$). Boys had a greater decrease in fat mass ($r = -0.20$, $P = 0.09$) than girls, whereas girls had a greater increase in bone mineral content ($r = 0.15$, $P = 0.09$) and bone mineral density ($r = 0.10$, $P = 0.12$) than boys.

Baseline values

Baseline values for total mass and fat-free soft tissue were related to larger increases in total mass ($r = 0.18$, $P = 0.12$) and fat-free soft tissue ($r = -0.32$, $P = 0.006$), respectively, whereas higher baseline values of percentage body fat were associated with a greater decrease in percentage fat ($r = -0.21$, $P = 0.08$). The baseline values for the other body-composition indexes were not significantly associated with change scores when adjusted for the other variables in the model.

Physical activity

Time spent doing moderate physical activity was not retained in any of the models, but children who spent more time doing vigorous physical activity had greater decreases in fat mass ($r = -0.10$, $P = 0.13$) and percentage body fat ($r = -0.13$, $P = 0.06$). The change from before to after in the amount of time doing moderate and vigorous physical activity was not retained in the model for any of the outcome variables.

Diet

A larger total energy intake was related to a larger increase in total mass ($r = 0.12$, $P = 0.10$) and fat mass ($r = 0.14$, $P = 0.01$), whereas a larger protein intake was related to a larger increase in total mass ($r = 0.28$, $P = 0.02$), fat mass ($r = 0.29$, $P = 0.05$), and percentage body fat ($r = 0.22$, $P = 0.05$). Dietary fat and carbohydrate intake were not related to any outcome variable, whereas a greater dietary calcium intake was related to a smaller decrease in percentage body fat ($r = 0.24$, $P = 0.04$).

Training process

A higher training heart rate was associated with smaller increases in fat-free soft tissue ($r = -0.24$, $P = 0.04$) but greater increases in bone mineral density ($r = 0.19$, $P = 0.10$). Better attendance at training sessions was related to a smaller increase in total mass ($r = -0.22$, $P = 0.07$).

The final models, in which all domains were integrated, are presented in **Table 2**. Greater increases in total mass were independently associated with lower attendance, higher energy intake, and higher protein intake, which together accounted for 18% of the variance. Larger decreases in fat mass were independently associated with lower protein and energy intakes and with male sex. Together these accounted for 21% of the variance in fat mass changes. There was also an interaction between sex and protein intake (**Figure 1**), which became nonsignificant when the extreme values were eliminated.

Larger increases in fat-free soft tissue were associated with being older and a lower training heart rate. This model accounted for 16% of the variance in fat-free soft tissue change. The interaction between heart rate and age, which became nonsignificant after the extreme value was eliminated, is shown in **Figure 2**.

Larger increases in bone mineral content were independently associated with female sex and being older, which together accounted for 7% of the variance. Larger increases in bone mineral density were independently associated with being older, female sex, and a higher training heart rate. Together these variables accounted for 12% of the variance in bone mineral density change. The putative interaction between sex and training heart rate before the elimination of extreme values is shown in **Figure 3**.

A larger decrease in percentage body fat was independently associated with being older, a low protein and calcium intake, and a greater amount of time spent doing vigorous activities. The interactions between baseline percentage body fat and protein intake and between vigorous activity and calcium intake, respectively, are depicted in **Figures 4** and **5**. Both became nonsignificant when the extreme values were eliminated from the model.

TABLE 2
Partial correlation coefficients (r) and coefficients of determination (R^2) for the final regression models pooling unmodifiable independent variables, physical activity, training process, and diet correlates[1]

Dependent and independent variables	Partial r	P	Model R^2
ΔTotal mass ($n = 71$)	—	—	0.18
Attendance	−0.23	0.04	
Energy intake	0.22	0.05	
Protein intake	0.28	0.02	
ΔFat mass ($n = 68$)	—	—	0.21
Sex[2]	0.27	0.01	
Energy intake	0.22	0.05	
Protein intake	0.29	0.01	
ΔFat-free soft tissue ($n = 70$)	—	—	0.16
Age	0.32	0.01	
Heart Rate	−0.23	0.04	
ΔBone mineral content ($n = 71$)	—	—	0.07
Sex	0.20	0.09	
Age	0.18	0.13	
ΔBone mineral density ($n = 69$)	—	—	0.12
Age	0.23	0.06	
Sex	0.17	0.13	
Heart rate	0.20	0.08	
ΔPercentage fat ($n = 67$)	—	—	0.25
Age	−0.23	0.05	
Vigorous activity	−0.17	0.11	
Protein intake	0.23	0.04	
Calcium intake	0.24	0.04	
Percentage fat at baseline	−0.24	0.03	

[1] The multiple regression analyses to obtain the final models were run without the outliers. *See* the text for descriptions of each variable.
[2] Boys = 1, girls = 2.

DISCUSSION

This study let us observe lifestyle factors that might influence the change in body composition over time, and by providing a stimulus, namely physical training, we hoped to accentuate individual variation to better isolate the correlates of the change in body composition. Because the subjects were children, we expected to see increases in some aspects of body mass associated with growth. Our main interest was in seeing whether baseline values, physical activity, diet, and physical training, when controlled for the confounding effects of sex, ethnicity, and age, would affect the children's increase in body mass during the 4-mo physical training period. We also wanted to see how that mass would be distributed within the fat and fat-free body compartments.

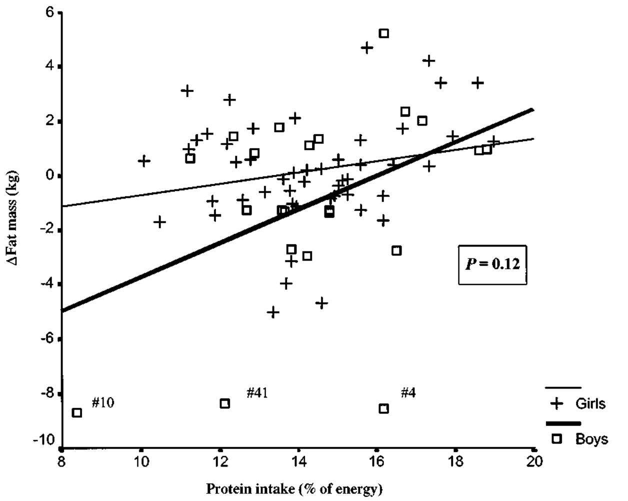

FIGURE 1. Relation between protein intake and the change in fat mass with training in boys and girls. The lines depict the interaction before the extreme values were taken out of the model. Individuals who were subsequently eliminated from the final model are identified by subject number.

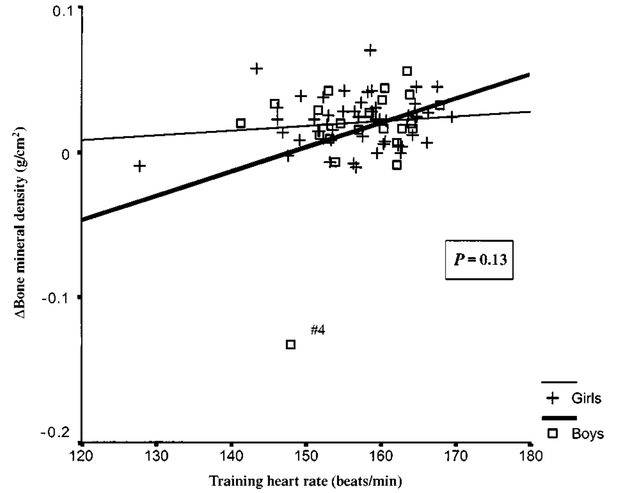

FIGURE 3. Relation between training heart rate and the change in bone mineral density with training in boys and girls. The lines depict the interaction before the extreme values were taken out of the model. Individuals who were subsequently eliminated from the final model are identified by subject number.

Total mass increased less in children who attended physical training sessions more often. This agrees with a longitudinal study that showed that 3–5-y-old children who were more active were less likely to increase their body fat (as measured by triceps skinfold thickness) than were their less active counterparts (2). In addition, a cross-sectional study showed that habitual physical activity was associated with a higher percentage fat-free mass and a lower percentage fat mass in 10-y olds (8). However, it was not clear whether this effect was due in part to dietary factors, because the children who were more active also increased their energy intake by increasing their carbohydrate intake and reducing their percentage dietary fat. In our study, neither fat nor carbohydrate intake were retained in the regression models as correlates of change in total mass. However, children who had a smaller total energy intake and protein intake also had smaller increases in total mass. Thus, a combination of higher physical activity and lower energy intake seems to help obese children to slow down the increase in total mass.

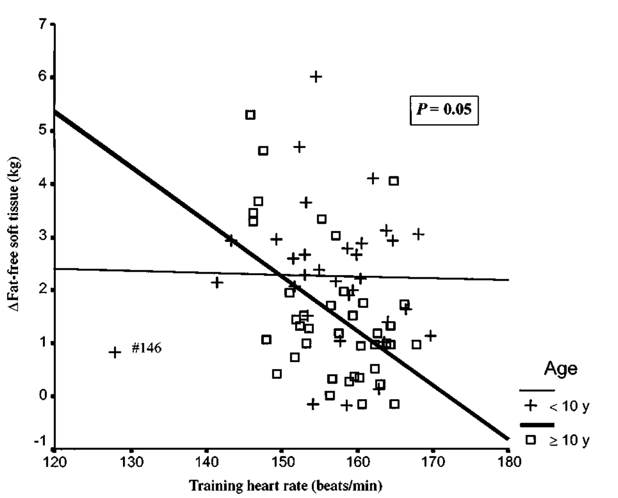

FIGURE 2. Relation between training heart rate and the change in fat-free soft tissue with training in younger and older children. The cutoff age of 10 y represents the mean age of the group at baseline. The lines depict the interaction before the extreme values were taken out of the model. The individual who was subsequently eliminated from the final model is identified by subject number.

Larger decreases in fat mass were seen in children who had a lower total energy intake and in boys than in girls. A lower protein intake also resulted in a greater decrease in fat mass. This finding agrees with the data of Rolland-Cachera et al (9), who suggested that high protein intake may increase the risk of obesity on the basis of their results showing that a high body mass index at age 8 y was associated with a high protein intake at age 2 y. The mechanism by which protein intake can affect adiposity is not clear, but Rolland-Cachera et al suggested that a high protein intake can increase insulin-like growth factor I, which in turn triggers adipocyte multiplication. Although their hypothesis was formulated to explain the development of obesity in early childhood, the same mechanism may also be at work in later childhood, whereby higher than normal concentrations of insulin-like growth factor I are produced by a high-protein diet. The fact that fat intake was not retained as a correlate conflicts with the results of studies (1, 10) that found it to be positively related to adiposity in 9–10-y olds. Differences between our study and those of previous ones that might account for the discrepant findings include the fact that we studied changes in body composition over a relatively short period of time, during which the children participated in physical training, whereas other studies used nonintervention designs. We studied only obese children whereas others studied children with a wide range of body-composition values.

Older children had a greater decrease in percentage body fat. One possible explanation for this is that the older children had more fat mass (≥10 y: 29.9 ± 14.3 kg; <10 y: 24.8 ± 8.8 kg) at baseline, and therefore had more to lose than younger children. However, they did not lose significantly more fat mass than younger children; rather, they experienced greater increases in fat-free mass (≥10 y: 2.2 ± 1.1 kg; <10 y: 1.7 ± 1.5 kg). Higher

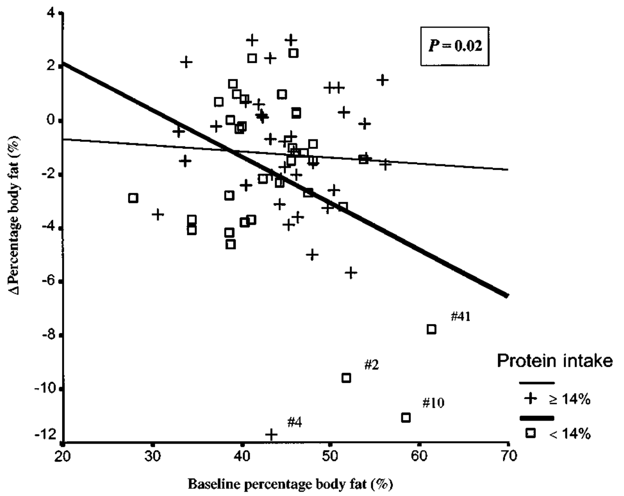

FIGURE 4. Relation between percentage body fat at baseline and the change in percentage body fat with training in children who consumed a greater or smaller percentage of protein. The cutoff protein intake of 14% of energy represents the average consumption of the group during physical training. The lines depict the interaction before the extreme values were taken out of the model. Individuals who were subsequently eliminated from the final model are identified by subject number.

baseline percentage fat values were associated with greater decreases in percentage fat, and it was particularly noteworthy that 2 of the individuals who had the greatest decrease in percentage fat also had some of the highest percentages of body fat at baseline. This seems to indicate that children who have a high percentage of fat are able to decrease this percentage with physical training and are not resistant to fat loss. Children who consumed less protein had greater decreases in percentage fat, which is consistent with the results of Rolland-Cachera et al (9) described above. Children who consumed less calcium also had

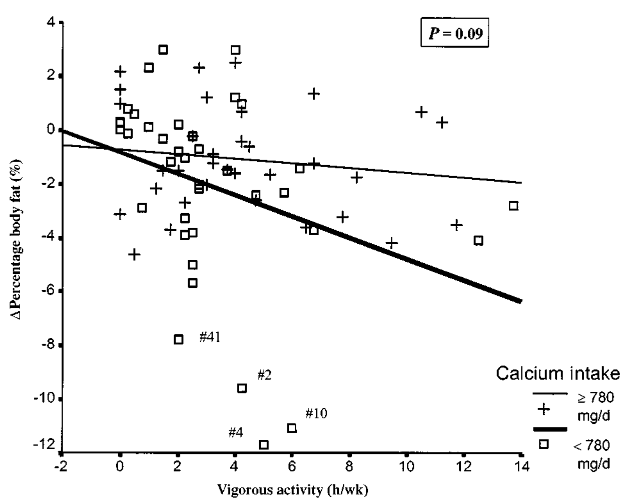

FIGURE 5. Relation between vigorous activity and the change in percentage body fat with training in children who consumed more or less calcium per day. The cutoff calcium intake of 780 mg represents the average daily consumption for the group. The lines depict the interaction before the extreme values were taken out of the model. Individuals who were subsequently eliminated from the final model are identified by subject number.

greater decreases in percentage fat. Takaya et al (11) showed that intracellular free calcium (Ca^{2+}) concentrations are higher in obese adolescents. However, the mechanisms by which calcium intake might affect intracellular Ca^{2+} concentrations or by which a high intracellular Ca^{2+} concentration acts on obesity and the regulation of body composition are not known. Also, children who spent more time doing vigorous physical activity per week experienced a greater decrease in percentage fat, probably because of the increased energy expenditure. Thus, the change in percentage fat with 4 mo of training was affected by both dietary and physical activity variables.

Older children had greater increases in fat-free soft tissue, probably related to normal growth. It is unclear why children who trained at a higher heart rate had a smaller increase in fat-free soft tissue. To our knowledge, there are no studies in the literature that looked at the effect of training intensity on body-composition changes in children.

Older children had a greater increase in bone mineral content than younger children and girls had a greater increase than boys. Older children also had greater increases in bone mineral density than younger children, as did girls compared with boys. Training at a higher heart rate also resulted in a greater increase in bone mineral density. These results differ from those of Nelson et al (12), who measured bone mineral content in a group of girls and boys at age 9 y and again at age 10 y. They found no differences in bone mineral content or bone mineral density between the girls and boys at either time point, implying that the rate of change during that year was similar in the 2 groups. However, Nelson et al's study did not target obese children, and although it was longitudinal, did not include a physical training intervention.

Ethnicity was not kept as a correlate in any of the final body-composition models. There are no other published studies that looked at the effect of ethnicity on the change in body composition with training in children, only cross-sectional studies comparing blacks and whites, and the results of such studies are conflicting. Kaplan et al (13) found no significant differences between black and white 5–12-y olds for weight, fat-free mass, fat mass, and percentage body fat. Other studies found bone mineral content and bone mineral density to be consistently greater in blacks than in whites in different age groups ranging from 3 to 18 y of age (12, 14, 15). It may be that the differences found in these latter studies reflect not biological differences, but cultural differences between blacks and whites, ie, their diets. We did not find evidence that white and black children respond differently to a physical training stimulus.

Although our preliminary models found some interactions in addition to the main effects, some of the values were extreme and perhaps unduly influential; when these were omitted from the data set the interactions were no longer significant. Thus, we have chosen to be parsimonious by drawing conclusions only from the main effects. However, the extreme values were physiologically reasonable and did not appear to be due to methodologic error. Furthermore, closer examination of these values showed that they belonged to the same subset of individuals (identified in the figures). Therefore, we can conclude that these individuals did not fit the same statistical models as the other subjects, and may share some other quality that is not present in the other subjects. Thus, our final models are probably not applicable to ≈10% of the population.

The proportions of the variance in body-composition changes explained by the models are modest. This study showed that in obese children, age, sex, vigorous activity, diet, and physical training together accounted for a maximum of 25% of the variance in the change of body composition with training, whether it be total mass, fat mass, or fat-free mass. The results suggest that in obese children who are engaged in physical training, diet may be an important correlate of fat loss, but that the intensity of training is associated with increased bone mineral density and smaller increases in fat-free soft tissue. Other potential correlates of changes in body composition, which were not studied here, include such factors as resting metabolic rate, the thermic effect of food, and lipid partitioning, as well as genetic factors that influence determinative mechanisms.

REFERENCES

1. Tucker LA, Seljaas GT, Hager RL. Body-fat percentage of children varies according to their diet composition. J Am Diet Assoc 1997;97:981–6.
2. Moore LL, Nguyen UDT, Rothman KJ, Cupples LA, Ellison RC. Preschool physical activity level and change in body fatness in young children. Am J Epidemiol 1995;142:982–8.
3. Must A, Dallal G, Dietz W. Reference data for obesity: 85th and 95th percentiles of body mass index (wt/ht^2) and triceps skinfold thickness. Am J Clin Nutr 1991;53:839–46.
4. Gutin B, Owens. Role of exercise intervention in improving body fat distribution and risk profile in children. Am J Hum Biol. 1999;11:237–47.
5. Gutin B, Litaker M, Islam S, Manos T, Smith C, Treiber F. Body-composition measurement in 9–11-y-old children by dual-energy X-ray absorptiometry, skinfold-thickness measurements, and bioimpedance analysis. Am J Clin Nutr 1996;63:287–92.
6. Figueroa-Colon R, Mayo MS, Treuth MS, Aldridge RA, Weinsier RL. Reproducibility of dual-energy x-ray absorptiometry measurements in prepubertal girls. Obes Res 1998;6:262–7.
7. Sallis JF, Buono MJ, Roby JJ, Micale FG, Nelson JA. Seven-day recall and other physical activity self-reports in children and adolescents. Med Sci Sports 1993;25:99–108.
8. Deheeger M, Rolland-Cachera MF, Fontvieille AM. Physical activity and body composition in 10 year old French children: linkages with nutritional intake? Int J Obes Relat Metab Disord 1997;21:372–9.
9. Rolland-Cachera MF, Deheeger M, Akrout M, Bellisle F. Influence of macronutrients on adiposity development: a follow up study of nutrition and growth from 10 months to 8 years of age. Int J Obes Relat Metab Disord 1995;19:573–8.
10. Maffeis C, Pinelli L, Schutz Y. Fat intake and adiposity in 8 to 11-year-old obese children. Int J Obes Relat Metab Disord 1996;20:170–4.
11. Takaya J, Iwamoto Y, Higashino H, Kino M, Kobayashi T, Kobayashi Y. Altered intracellular calcium and phorbol 12,13-dibutyrate binding to intact platelets in young obese subjects. J Lab Clin Med 1997;129:245–50.
12. Nelson DA, Simpson PM, Johnson CC, Barondess DA, Kleerekoper M. The accumulation of whole-body skeletal mass in third-grade and fourth-grade children—effects of age, gender, ethnicity, and body composition. Bone 1997;20:73–8.
13. Kaplan AS, Zemel BS, Stallings VA. Differences in resting energy expenditure in prepubertal black children and white children. J Pediatr 1996;129:621–3.
14. Ellis KJ, Abrams SA, Wong WW. Body composition of a young, multiethnic female population. Am J Clin Nutr 1997;65:724–31.
15. Boot AM, Bouquet J, de Ridder MA, Krenning EP, de Muinck Keizer-Schrama SM. Determinants of body composition measured by dual-energy X-ray absorptiometry in Dutch children and adolescents. Am J Clin Nutr 1997;66:232–8.