Plasma leptin concentrations in obese children: changes during 4-mo periods with and without physical training[1–3]

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ABSTRACT

Background: Little is known about the effects of physical training on plasma leptin concentrations in children.

Objective: We sought to determine the effects of 4-mo periods with and without physical training on leptin in obese children and to explore the determinants of leptin at baseline and in response to physical training.

Design: Participants were 34 obese 7–11-y-old children randomly assigned to engage in physical training during either the first or second 4 mo of the 8-mo study.

Results: Total body composition, visceral adiposity, and insulin were all positively correlated with leptin at baseline ($P \leq 0.05$); however, only fat mass was retained in the final stepwise regression ($P = 0.0001$, $R^2 = 0.57$). Leptin decreased during the 4-mo periods of physical training and increased in the 4 mo after cessation of physical training ($P < 0.001$ for the time by group interaction). Decreases in leptin were greatest in children with higher pretraining leptin concentrations, those whose total mass increased least, and those whose insulin concentrations decreased most ($P \leq 0.05$); only pretraining leptin concentration ($P = 0.009$) and change in total mass ($P = 0.0002$) were retained in the final regression ($R^2 = 0.53$).

Conclusions: In obese children, leptin concentration decreased during 4 mo of physical training and increased during a subsequent 4-mo period without physical training, fat mass was highly correlated with baseline leptin, and greater reductions in leptin during 4 mo of physical training were seen in children with higher pretraining leptin and in those whose total mass increased least. *Am J Clin Nutr* 1999;69:388–94.

KEY WORDS Leptin, physical training, physical activity, exercise, obesity, children, diet, body composition, body fatness, adiposity, energy expenditure, energy balance

INTRODUCTION

The recently discovered protein product of the obese (*ob*) gene is leptin, which is secreted by adipocytes into the general circulation (1), where it helps to regulate body mass by playing a role in a feedback loop between adipocytes and the hypothalamus. For example, in *ob/ob* mice, which do not produce a functional leptin protein, administration of leptin decreases energy intake and increases energy expenditure, resulting in weight loss (2). Two studies found mutations affecting the leptin gene in obese children; these discoveries highlight the important role of leptin in this population. One study found that a deletion mutation in the leptin gene was associated with low leptin concentrations and severe obesity in 2 children who were members of a highly consanguineous family (3). Another study found that a mutation in the leptin receptor gene, resulting in a truncated receptor, was associated with early-onset obesity and perturbation of several endocrine functions (4).

In adults (5, 6) and children (7), leptin concentrations are positively correlated with total body adiposity. Moreover, energy restriction leads to lowered leptin concentrations (8), presumably stimulating appetite. Lahlou et al (7) reported that obese children had higher leptin concentrations than lean children. It would be expected that these high leptin concentrations would reduce energy intake in these children. However, the obese children had higher energy intakes than the lean children, suggesting that they may have some form of leptin resistance. With respect to regional deposition of fat, one study of children and young adults found that leptin concentrations were more closely correlated with subcutaneous abdominal adipose tissue (SAAT; $r = 0.84$) than with visceral adipose tissue (VAT; $r = 0.59$) (9).

These results suggest that in children, leptin is a marker of adiposity but does not suppress energy intake or halt fat deposition. This is suggestive of some type of leptin resistance, perhaps similar to the phenomenon of insulin resistance that occurs in obese people. This leptin resistance may be physiologic in nature, or it may result from environmental factors such as the ready availability of high-energy foods.

Studies of the effects of regular exercise in adults showed that physical training resulted in decreased leptin concentrations (10–12), although in one study this occurred in men but not in women (10) and in another study physical training lowered leptin concentrations in women but not in men (11). In children

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[2] Supported by the National Heart, Lung, and Blood Institute (HL 49549), the American Heart Association, and the Parke Davis Company.

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Received March 13, 1998.

Accepted for publication August 27, 1998.

(13), leptin concentrations were positively correlated with physical activity level after adjustment for body fat ($r = 0.26$, $P < 0.01$). No controlled studies of physical training and leptin concentrations in children have been reported.

The primary purpose of this study was to determine the effects of 4-mo periods with and without physical training on leptin concentrations in obese children. We also explored 2 subsidiary questions concerning factors that influence leptin concentrations in obese children. First, we measured cross-sectional correlations between baseline leptin concentration and variables including total body adiposity and visceral adiposity. Then we sought to determine which factors were associated with individual differences in response of leptin concentration to physical training.

SUBJECTS AND METHODS

Subjects and design

The subjects in this study were a subsample of those involved in a larger study of physical training and body composition (14). Obese 7–11-y-old children were recruited through fliers and newspaper advertisements. Interested children and parents were invited to view a videotape that illustrated the entire protocol and to sign informed consent documents in accordance with procedures of the Medical College of Georgia Human Assurance Committee. To be included, a child needed to have a triceps skinfold thickness greater than the 85th percentile (15) and could not be involved in any other weight-control or exercise program; subjects also could not have any restrictions on their physical activity.

Children underwent baseline testing and were randomly assigned, within sex and ethnicity categories, to group 1 or group 2. Testing sessions were conducted at baseline and after 4 and 8 mo of the experimental period. Group 1 engaged in physical training for the first 4-mo period and then ceased formal physical training for the next 4 mo, whereas group 2 did not engage in physical training for the first 4 mo and then engaged in physical training for the next 4 mo. Baseline leptin data were available for 34 children, 31 of whom completed 4 mo of physical training.

Measurements

Blood samples were obtained from subjects between 0800 and 0900 after a 12-h fast. It has been shown that leptin concentrations follow a diurnal pattern (16) and that this pattern seems to be related to the insulin response to meals (17). By measuring leptin in the fasting state and always at approximately the same time in the morning, we eliminated interpretation problems related to these issues. On the other hand, measuring only fasting concentrations did not permit us to look at changes in leptin reactivity over a 24-h period or in response to meals. Blood was drawn from the antecubital vein into sterile, EDTA-treated tubes. Tubes were inverted gently and stored in an ice bath until centrifuged (at $4500 \times g$ for 10 min at room temperature) to obtain plasma. Samples were frozen at -20°C until analyzed. Leptin concentrations were measured in the Physiology and Endocrinology Department of the Medical College of Georgia with a commercial radioimmunoassay according to the manufacturer's protocol (Linco Research Inc, St Louis). Because this laboratory does not perform leptin determinations on a regular basis, routine intraassay and interassay CVs for leptin measurements were not available. Each of our samples was run twice, with the mean of the 2 results used in the analyses; the intraassay CV for our samples was 7.6%. Plasma insulin and glucose concentrations were measured in the WAVE Central Biochemistry Laboratory at Emory University (Atlanta). Insulin concentrations were measured by radioimmunoassay and glucose concentrations were measured with the hexokinase method. The interassay and intraassay CVs for glucose in this laboratory were 1.6% and 1.1%, respectively, and those for insulin were 4.6% and 4.2%, respectively.

Total body composition was measured with dual-energy X-ray absorptiometry (DXA) (QDR-1000; Hologic Inc, Waltham, MA). The validity of this technique is supported by data showing good agreement between DXA values and those derived from carcass analysis of pigs (18), and its reliability is illustrated by our finding that the intraclass correlation for repeat measurements of percentage fat was 0.998 (19).

The measurements of VAT and SAAT are described in detail elsewhere (14). Briefly, VAT and SAAT were determined with a 1.5-T magnetic resonance imaging system (General Electric Medical Systems, Milwaukee). A series of 5 transverse images was acquired from the lumbar region beginning at the inferior border of the fifth lumbar vertebra and proceeding toward the head; a 2-mm gap between images was used to prevent crosstalk. To calculate volumes for VAT and SAAT, the surface area (cm^2) from each individual slice was multiplied by the slice width (1 cm) and then the individual volumes (cm^3) were summed. All images were analyzed by the same experienced observer. The intraclass correlation coefficients for repeat analyses of the same scans on separate days exceeded 0.99 (data not shown) for both VAT and SAAT.

Cardiovascular fitness was expressed as heart rate during submaximal cycling at a work rate of 49 W (300 kpm/min) on a supine ergometer (486T; Quinton, Seattle). The ergometer work rate was increased gradually until it reached 49 W, after which the child maintained that power output for 8 min. Submaximal heart rate was the average heart rate during the last 5 min, as measured with an electrocardiograph embedded in an echocardiograph (Sonos 100; Hewlett-Packard, Andover, MA).

Total daily physical activity was estimated from 7-d recalls (20). The child was asked to recall time spent sleeping and doing physical activities during the 7 d preceding the interview. The interviews were conducted before baseline testing and during the last week of each 4-mo period. Thus, the 7-d recall included the physical training for subjects participating in training during that time period. Hours spent doing hard [5–6.9 resting metabolic equivalents (METS)] and very hard (≥7 METS) activities were summed to obtain an index of vigorous physical activity. Hours spent doing moderate activity (3–4.9 METS) and vigorous activity were used in the analyses. Although the accuracy of activity recall data is limited, the changes in self-reported activity tended to agree with what would be expected based on whether the children were or were not participating in physical training during the period of recall; activity values were significantly higher during the physical training period.

Dietary assessment was designed to assist in interpretation of changes in body composition and leptin concentrations; no dietary information was provided to subjects during the intervention. We obtained 2-d recalls at baseline to familiarize the children with the procedure. Subsequent 2-d recalls were obtained after 2, 4, 6, and 8 mo, providing 4 d of diet information for each child during his or her period of physical training

and 4 d for the period without physical training. We used the NUTRITION DATA SYSTEM (Nutrition Coordinating Center, University of Minnesota, Minneapolis) to calculate total energy intake and percentage of energy derived from each macronutrient. Because of the difficulty in obtaining accurate dietary data (21), these data were interpreted with caution.

Physical training

The physical training program was offered 5 d/wk; the 40-min sessions included 20 min of exercising on machines and 20 min of playing games. Each child wore a heart rate monitor (Polar Vantage, Port Washington, NY) during every session, and the goal was to keep the heart rate above 150 beats/min. After each session, the minute-by-minute heart rate data were downloaded into a computer and displayed to the child. Details of the physical training are provided elsewhere (22).

So that we could estimate energy expenditure during the physical training sessions, each child underwent 2 multistage cycle ergometry tests during the 4-mo physical training period, from which energy expenditure could be calibrated to heart rate by regression. Then energy expenditure during the physical training sessions was estimated by using the child's average heart rate during the physical training sessions. The 3 training process variables investigated in this study were attendance, training heart rate, and energy expenditure per session.

Statistical analyses

The significance level for all tests was set at $P \leq 0.05$. All statistical analyses were performed with SAS (version 6.12; SAS Institute Inc, Cary, NC). Because we did not select the subjects to be representative of specific demographic subgroups, and because of the small numbers in our sample (10 boys, 24 girls; 19 whites, 15 blacks), we did not plan to draw any inferences about subgroup population differences. Nonetheless, we did examine such potential differences in our sample so that we could control for them in drawing conclusions about the relations of other variables to leptin concentrations. No significant sex or ethnicity effects were found. Therefore, descriptive statistics for the subgroups are not reported.

To examine which factors were associated with leptin concentrations (cross-sectional analyses), we calculated Pearson correlation coefficients for baseline leptin concentrations and variables within the following domains: demographics, total body composition, abdominal adiposity, insulin, physical activity indexes, and cardiovascular fitness. Then the variables that were significantly correlated with baseline leptin concentration were entered into stepwise regression models, with a separate model for each domain. All variables that were retained from each domain were put together in a final stepwise model. Because dietary variables were not obtained at baseline, their cross-sectional relations with leptin concentration were determined by analyzing correlations between the average leptin concentration (at 3 time points: 0, 4, and 8 mo) and the average value for the dietary variables (at 4 time points: 2, 4, 6, and 8 mo).

The primary research question was answered by analyzing changes in leptin concentration across the 3 time points with regard to physical training (baseline, 4 mo, and 8 mo). We used a mixed-model analysis of variance (ANOVA) with subject as the random factor and group and time as fixed factors. This procedure allowed unequal sample sizes at different time points, so that the maximum number of observations could be used in the analysis. Missing data at a given time point did not cause the other observations for that subject to be excluded from the analysis because the missing observations were estimated from row and column totals by using the least-squares means procedure. This procedure provides estimates of the expected values of the group means if sample sizes were equal at all time points. A significant group by time effect indicated that the 2 groups differed in how their values changed over the 3 time points.

The next research question concerned identifying the correlates of individual differences in leptin concentration changes from before to after the 4-mo physical training period. For this analysis, change scores were derived for the 31 subjects who completed 4 mo of physical training and had leptin measurements, regardless of whether they were in group 1 or group 2. The significance of the pre- to posttraining change was assessed by within-groups *t* tests. Then, with the leptin change score as the dependent variable, correlation and regression analyses were performed as described for the cross-sectional analyses, adding baseline leptin and physical training process variables as separate domains.

RESULTS

The baseline values for serum leptin concentration, the independent variables, and the bivariate correlations of the independent variables with leptin concentration are shown in **Table 1**.

TABLE 1
Baseline plasma leptin concentration and independent variables and Pearson correlations between the baseline independent variables and baseline leptin concentration in obese children[1]

	Value	*r*
Plasma leptin (μg/L)	28.6 ± 15.1	—
Demographics		
Sex	—[2]	0.14
Ethnicity	—[3]	0.26
Age (y)	9.4 ± 1.0	0.07
Body composition		
Fat mass (kg)	22.9 ± 9.4	0.75[4]
Fat-free mass (kg)	29.7 ± 6.2	0.48[4]
Total mass (kg)	52.6 ± 14.6	0.70[4]
Body fat (%)	42.5 ± 6.0	0.73[4]
VAT (cm^3)	206 ± 57	0.38[5]
SAAT (cm^3)	1204 ± 477	0.74[4]
Plasma insulin and glucose		
Insulin (pmol/L)	141.3 ± 101.2	0.46[6]
Glucose (mmol/L)	4.91 ± 0.38	0.43[7]
Insulin:glucose	0.01 ± 0.01	0.42[7]
Physical activity		
Moderate (h/wk)	4.2 ± 4.0	−0.15
Vigorous (h/wk)	2.1 ± 2.3	−0.08
Cardiovascular fitness		
Submaximal heart rate (beats/min)	120 ± 14	0.19

[1] $\bar{x}$ ± SD; n = 34 except for glucose (n = 33) and for insulin and insulin:glucose (n = 31). VAT, visceral adipose tissue; SAAT, subcutaneous abdominal adipose tissue.
[2] n = 24 girls, 10 boys.
[3] n = 19 whites, 15 blacks.
[4] P = 0.0001.
[5] P = 0.03.
[6] P = 0.008.
[7] P = 0.01.

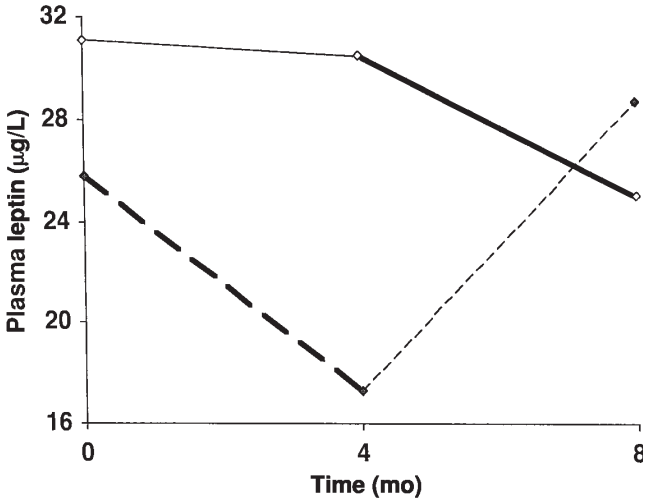

FIGURE 1. Least-squares means for plasma leptin concentrations at 3 time points in the 2 groups of obese children. Group 1 (◆) had physical training from 0 to 4 mo, group 2 (◇) had physical training from 4 to 8 mo (thicker lines denote periods of physical training). The group by time interaction was significant ($P < 0.001$, ANOVA). For group 1, n = 15, 18, and 16 at months 0, 4, and 8, respectively. For group 2, n = 19, 18, and 17 at months 0, 4, and 8, respectively.

Leptin concentration at baseline was not quite normally distributed ($P = 0.04$), but performing a log transformation did not change the results of the correlations; therefore, the results for the nontransformed data are reported. Age, ethnicity, and sex were not significantly correlated with baseline leptin concentration. Baseline leptin concentration was positively correlated with all of the body-composition variables, serum insulin concentration, serum glucose concentration, and insulin to glucose ratio. Variables related to physical activity and fitness were not significantly correlated with baseline leptin. The stepwise regression analysis produced a final model that included only fat mass ($P < 0.001$, $R^2 = 0.57$):

$$\text{Baseline leptin} = 0.55 + 1.21(\text{baseline fat mass}) \quad (1)$$

where baseline leptin is in μg/L and baseline fat mass is in kg. None of the dietary variables were significantly correlated with average leptin concentration during the 8-mo experimental period.

The pattern of change in plasma leptin concentration over the 3 time points for the 2 groups is illustrated in **Figure 1**; the group by time interaction was significant ($P < 0.001$). The residuals obtained from the mixed-model ANOVA were normally distributed ($P = 0.22$). The data indicate that in both groups, leptin concentration declined during the physical training period, and that in group 1, leptin increased rather sharply upon cessation of the physical training. To determine whether changes in leptin concentration were dependent on changes in body composition, we divided the leptin value by fat mass and repeated the ANOVA. The patterns over the 3 time points were almost identical for the 2 analyses (with and without adjustment for fat mass) and the group by time interaction with adjustment for fat mass was still highly significant ($P < 0.001$). Thus, the changes in leptin concentration were attributable to some effect of the physical training that was independent of its effect on body composition.

Changes in the variables from pre- to posttraining, along with the bivariate correlations, are shown in **Table 2**. The change in leptin from pre- to posttraining was normally distributed ($P = 0.67$). The average heart rate during physical training was 159 beats/min and the average attendance was 79% (equivalent to 4 d/wk). Thus, participation in the physical training involved a substantial amount of exercise.

The within-groups t tests indicated that leptin concentration decreased significantly from pre- to posttraining ($P = 0.0035$); the results were similar when leptin values were corrected for fat mass. Notwithstanding the significant average change for the group, it is noteworthy that there was a great deal of individual variability in the response of leptin concentration to physical training, from a decline of 32.2 μg/L to an increase of 18.9 μg/L.

The correlations showed that pretraining leptin concentration was negatively associated with change in leptin, indicating that higher pretraining concentrations were associated with larger decreases with physical training. The variables age, ethnicity, and sex were not significantly correlated with change in leptin. Of the body-composition variables, only change in total mass was significantly correlated with change in leptin; those subjects who increased least in total mass (or lost weight) tended to have the largest decreases in leptin. A similar but not quite significant trend was found for change in fat mass ($P = 0.07$). Change in insulin from pre- to posttraining, which was significant ($P < 0.05$), was also positively correlated with change in leptin; those subjects whose insulin concentrations decreased the most tended to have the largest decreases in leptin concentration. Changes in glucose and the ratio of insulin to glucose were not significantly correlated with change in leptin. Physical activity, fitness, and training process variables were not significantly correlated with change in leptin concentration. When pretraining leptin, change in total mass, and change in insulin were entered into a stepwise regression model, only pretraining leptin concentration ($P = 0.009$) and change in total mass ($P = 0.0002$) were retained in the model, with an R^2 of 0.53.

$$\text{Change in leptin} = -2.02 - 0.40(\text{pretraining leptin}) + 3.74(\text{change in total mass}) \quad (2)$$

where leptin is in μg/L and total mass is in kg.

DISCUSSION

The main finding of this study was that plasma leptin concentrations declined during the 4-mo periods of physical training and increased during the subsequent 4-mo period without physical training, even when concentrations were corrected for changes in fat mass. This is consistent with studies showing that especially long or intense single bouts of exercise reduce leptin concentrations (23, 24) and is also consistent with studies in which physical training reduced leptin concentrations in adults (10, 11, 12, 25). Thus, the changes in leptin may have reflected changes in energy balance in addition to changes in adiposity; negative energy balance resulting from physical training may reduce leptin concentrations.

The mechanism by which physical training influences leptin concentrations is still open to speculation. There is emerging evidence that insulin and glucose play roles in regulating leptin concentrations. Boden et al (26) showed that fasting leptin concentrations were positively correlated with fasting insulin and glucose concentrations in normal and obese subjects. Saad et al

TABLE 2
Mean changes with training in plasma leptin concentration and independent variables, and Pearson correlations between independent variables and change in plasma leptin in obese children[1]

	Value	Minimum	Maximum	*r*
Plasma leptin				
Δ (μg/L)	−6.7 ± 11.7[2,3]	−32.2	18.9	—
Pretraining (μg/L)	27.9 ± 18.1	3.3	95.1	−0.46[4]
Demographics				
Sex[5]	—	—	—	−0.13
Ethnicity[6]	—	—	—	0.03
Age (y)	9.3 ± 1.0			0.12
Body composition				
Δ Fat mass (kg)	0.2 ± 1.6	−2.9	4.2	0.33
Δ Fat-free mass (kg)	1.5 ± 1.1[3]	−0.1	3.8	0.21
Δ Total mass (kg)	1.8 ± 1.9[3]	−1.8	7.7	0.41[7]
Δ Body fat (%)	−1.1 ± 2.0[3]	−4.6	2.5	0.11
Plasma insulin and glucose				
Δ Insulin (pmol/L)	−17.9 ± 47.3[3]	−157.9	78.2	0.54[8]
Δ Glucose (mmol/L)	0.20 ± 0.84	−0.89	1.55	0.20
Δ Insulin:glucose	0.01 ± 0.04[3]	−0.13	0.05	0.18
Physical activity				
Δ Moderate (h/wk)	1.1 ± 3.8	−6.8	12.5	−0.25
Δ Vigorous (h/wk)	1.3 ± 2.8[3]	−5.0	6.8	−0.09
Cardiovascular fitness				
Δ Submaximal heart rate (beats/min)	0.5 ± 18.5	−36	44	0.17
Training process				
Heart rate (beats/min)	159 ± 6	146	170	−0.002
Attendance (%)	79 ± 18	40	100	0.07
Energy expenditure (kJ/session)	956 ± 228	574	1431	0.03

[1] n = 31 except for insulin and insulin:glucose (n = 28) and for submaximal heart rate (n = 29). Δ, change from pre- to posttraining.
[2] $\bar{x}$ ± SD.
[3] Significant change from pre- to posttraining, $P < 0.05$.
[4] $P = 0.009$ for correlation with Δ in leptin.
[5] n = 22 girls, 9 boys.
[6] n = 19 whites, 12 blacks.
[7] $P = 0.02$ for correlation with Δ in leptin.
[8] $P = 0.003$ for correlation with Δ in leptin.

(27) found that insulin infusions resulted in increased leptin concentrations. Furthermore, Mueller et al (28) showed that insulin-mediated leptin secretion was closely related to glucose uptake by isolated adipocytes, and that blocking glucose uptake or metabolism inhibited insulin-mediated leptin secretion. It is now recognized that physical training increases insulin sensitivity (29), and we might expect that this increased sensitivity occurs in muscle rather than adipose tissue, resulting in decreased metabolism of glucose in adipose tissue. Thus, physical training could influence fasting leptin concentrations by increasing insulin sensitivity and lowering plasma insulin concentrations, resulting in decreased glucose transport and metabolism in adipose tissue.

The cross-sectional analyses at baseline showed that various aspects of body composition (including abdominal fat), insulin, glucose, and the ratio of insulin to glucose were all significantly correlated with leptin concentrations, yet only total fat mass was retained in the final regression model. This is consistent with the theory that leptin is an adipostat, informing the body of total-body energy stores so that appropriate alterations in appetite, energy expenditure, and nutrient partitioning can occur (30). It has been suggested that in humans, leptin regulates body fat by suppressing or increasing appetite (31) rather than by acting on energy expenditure as is seen in rodents. However, notwithstanding the concept of a negative feedback loop to prevent excessive increases in fatness, the children in our study still became obese. Subtle changes in energy expenditure that are difficult to detect might have a significant long-term effect on energy balance. Moreover, there has been a societal trend toward a marked increase in childhood obesity in recent decades (32). Thus, during the process of becoming obese, the putative negative biological signal represented by elevated leptin concentrations may be overwhelmed by environmental factors that lead to continued increases in fatness.

Also, part of this process may be a state of leptin resistance, analogous to insulin resistance, wherein increasing leptin concentrations are not necessarily accompanied by increasing leptin action. Tartaglia (30) suggested that the site of such resistance may be the transfer of leptin from the blood to the cerebrospinal fluid or in the signal transduction pathway activated by the leptin receptor.

We also investigated the cross-sectional relations between dietary variables and average leptin concentration over the 8-mo experimental period, and we found that there was no relation between leptin and either energy intake or percentage of energy obtained from each macronutrient. This finding agrees with results from a cross-sectional study of adults that failed to find a significant correlation between energy intake or diet composi-

tion and leptin concentrations (33), and an intervention study showing no effect of diet composition on leptin concentrations (34). On the other hand, intervention studies investigating the effects of low-energy diets have found decreases in leptin concentrations that were independent of decreases in fat mass (35, 36). At first glance, the results from these studies seem to support the idea that it is negative energy balance rather than diet composition that influences leptin concentrations. However, all these studies looked at fasting leptin concentrations. Some studies have found that leptin concentrations at other times of the day may be influenced by insulin responses to energy intake (17, 27), suggesting that diet composition may play an important role.

When we combined the data from both groups, regardless of whether they participated in physical training during the first or second 4-mo period, there was a good deal of individual variation in change in leptin concentration, prompting us to explore determinants of this change; to our knowledge, no other published studies have looked at the issue in this way. We were not surprised to find a correlation between the change in leptin and pretraining leptin concentration, because children with higher pretraining leptin concentrations had greater potential for decreasing their leptin concentrations. It was a bit surprising that the stepwise regression procedure indicated that change in total mass, rather than change in fat mass, was the only significant determinant of change in leptin. Pretraining leptin concentrations and change in total mass accounted for 53% of the variance in change in leptin during the 4-mo physical training periods. Children who had the greatest increases in total mass had the smallest decreases in leptin, which is in keeping with the concept that having a greater mass should result in a signal to decrease appetite. In children, both fat mass and fat-free mass increase during the normal process of growth. Thus, in children, total mass may be a better indicator of change in energy stores than fat mass alone.

In summary, this study showed that in obese children *1*) leptin concentrations decreased during 4 mo of physical training and increased during a subsequent 4-mo period without physical training, *2*) total fat mass was highly correlated with baseline leptin concentration, and *3*) greater reductions in leptin during 4 mo of physical training were seen in those children who had higher pretraining leptin concentrations and in those whose total mass increased least.

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