The Effects of Changes in Body Mass and Subcutaneous Fat on the Improvement in Metabolic Risk Factors in Obese Children After Short-Term Weight Loss

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The pattern of subcutaneous fat (SAT) is related to metabolic risk factors in obese children. Because weight loss improves the risk-factor profile, we sought to determine whether changes in SAT or SAT-pattern contribute to the improvement in the risk-factor profile after 3 weeks of a low-calorie diet and physical activities. In 22 obese boys (mean age, 11.9 years) and 40 obese girls (mean age, 12 years), fat mass (by means of impedance) and fat distribution (waist and hip circumference) were assessed. The thickness of 15 different subcutaneous adipose tissue layers (SAT-layers) was measured using a Lipometer (Moeller Messtechnik, Graz, Austria). SAT and SAT-pattern (arm-SAT, trunk-SAT, leg-SAT) were calculated. Blood samples were taken for the determination of insulin, glucose, triglycerides, and cholesterol. After 3 weeks, fat mass, waist and hip circumference, SAT, arm-SAT, trunk-SAT (all $P < .0001$), and leg-SAT ($P < .01$) were reduced. Besides glucose, metabolic parameters were lowered (all $P < .001$) but changes in metabolic parameter were interrelated in boys and girls. Age- and sex-adjusted regression revealed that changes in body mass contributed to the variability in changes of insulin (adjusted R^2 = .15, P = .0015). For the change in triglycerides, changes in cholesterol together with subtle alterations in glucose and changes in leg-SAT were found to be the main determinants (adjusted R^2 = .587, $P < .0001$). The results indicate that the change in the atherogenic and metabolic risk factor profile is largely independent from the concomitant loss in SAT. The reduction in body mass explained only a small part of the variability in changes of insulin, but leg-SAT might participate in the lowering of triglycerides, especially in boys. The contribution of SAT-pattern to the risk factor profile is an issue that needs further investigation.

CHILDHOOD OBESITY is associated with an increased risk for cardiovascular disease in later life.[1,2] An unfavorable metabolic and fibrinolytic risk profile might already be present in childhood obesity.[3] Hyperinsulinemia, secondary to obesity and to an increased amount of visceral fat, contributes to the increase in cardiovascular risk.[4-6] Initial hyperinsulinemia compensates for insulin resistance, and it has been suggested that the triglyceride content of tissues sets the level of both insulin resistance and insulin production.[7]

In children, visceral fat appears to be metabolically unique, being independently associated with elevated trigylceride levels and insulin but not insulin sensitivity.[8] Exercise training improved some components of the insulin resistance syndrome,[9] and short-term weight loss is associated with an improvement in the lipid profile in obese children.[10] The reduction in fat mass,[11] subcutaneous fat,[12] or abdominal adiposity might participate in weight loss–associated changes in the atherogenic risk factor profile.[13] However, data are scarce as to whether a reduction in a specific subcutaneous fat region, ie, trunk-fat or upper/lower extremities-fat, is related to changes in insulin and trigylceride levels in obese children participating in a short-term weight loss program.

We have shown recently that there is an interrelationship between different measures of adiposity and subcutaneous fat distribution with metabolic parameters in obese children, suggesting that hemostatic and metabolic parameters work in concert, perhaps mediated by increased adiposity.[14] The present study was undertaken to elucidate whether the improvement in the metabolic and atherogenic risk factor profile is related to the reduction in subcutaneous fat and/or subcutaneous fat pattern, or related to the loss in body mass after control for an interrelationship between changes in metabolic parameters.

SUBJECTS AND METHODS

Subjects

Forty 40 obese girls (mean ± SD; age, 12 ± 1.8 years; body mass index [BMI], 26.9 ± 5.25) and 22 obese boys (age, 11.9 ± 1.7 years; BMI, 26.2 ± 5.2) were investigated. Obesity was defined as a BMI greater than the 90th percentile for age and sex. The main characteristics of the children are listed in Table 1. Children were judged as healthy by medical examination, and informed consent was given by the children and written informed consent by the parents also. The study was approved by the local ethical committee.

Weight Reduction Program

Children participated in a weight reduction program including physical activities for 3 weeks. Physical training consisted of several activities: walking, brisk jogging, biking, and playing different ball games 3 times per day. Each training session lastet approximately 1.5 hours. All training sessions were supervised by instructors and were performed according to the age of the children.

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Table 1. Baseline Values of All Estimated Parameters of Obese Children According to Sex

Parameter	Boys (n = 22)	Girls (n = 40)	*P*
Age (yr)	11.9 ± 1.7	12 ± 1.8	.77
Body mass index	26.2 ± 5.2	26.9 ± 5.25	.64
FM (kg)	30.4 ± 13	31.8 ± 12.4	.66
% FM	45.5 ± 6.1	46 ± 7.2	.79
Waist circumference (cm)	89.5 ± 13.1	87.4 ± 12.2	.53
Hip circumference (cm)	89.8 ± 11.4	95.7 ± 11.4	.054
WHR	1 ± 0.05	0.91 ± 0.07	<.0001
Serum insulin (μIU/mL)	8.1 (5.1-34.7)	10.2 (4.5-32.6)	
Log insulin	0.91 ± 0.2	1.03 ± 0.19	.39
Glucose (mmol/L)	3.6 (3.1-4.5)	3.33 (2.4-9.8)	
Log glucose	0.56 ± 0.05	0.53 ± 0.09	.005*
Triglycerides (mmol/L)	0.81 (0.36-3.31)	0.81 (0.36-1.74)	
Log triglycerides	−0.06 ± 0.23	−0.09 ± 0.17	.88*
Cholesterol (mmol/L)	5.1 ± 1.04	4.9 ± 0.97	.40
SAT (mm)	235.75 (125.5-308.8)	216.7 (101.7-276)	.16
Trunk-SAT (mm)	148.1 ± 33.6	140.9 ± 32.6	.41
Arm-SAT (mm)	25.8 ± 6.5	26 ± 6.5	.90
Leg-SAT (mm)	52.6 ± 12.6	43.6 ± 10.6	.004

*Kruskal-Wallis test.

Diet

Children were assigned to receive a mixed diet of 1,000 to 1,200 kcal/d, depending on age and degree of overweight. Energy intake consisted of approximately 50% carbohydrate, 20% protein, and 30% fat.[15] Children were offered 5 meals a day consisting of breakfast, lunch, dinner, and 2 snacks.

Laboratory Methods

Blood samples were taken after an overnight fast and determined for insulin by means of radioimmunoassay (RIA; Linco Research, St Charles, MO). Both, intra- and interassay coefficients of variation (CV) for insulin were less than 6.5% and 8.2% in our laboratory, respectively.

Glucose (mmol/L) was measured by means of the hexokinase/glucose 6-phosphate-dehydrogenase method using a commercial kit (Boehringer Mannheim, Mannheim, Germany). The intra-assay CV for the measurement of glucose was 1%.

Triglycerides (mmol/L) were measured using hydrolysis with subsequent determination of liberated glycerol by colorimetry (Boehringer Mannheim); the intra-assay CV was 1.5%.

Cholesterol (mmol/L) was measured enzymatically using cholesterol esterase and cholesterol oxidase with subsequent determination photometrically (Boehringer Mannheim). The intra-assay CV for the measurement of cholesterol was 0.8%.

Measurement of Body Composition

Measurements for fat free mass (FFM) were obtained by bioelectrical impedance (BIA; Akern-RJL 101/S, Clinton, MI) with an applied current of 0.8 mA at 50 kHz using a specific equation for a pediatric population (FFM $= 0.65 \times$ [Height^2/Impedance] $+$ [$0.68 \times$ age] $+$ 0.15).[16] Children were measured in the supine position after an overnight fast and after a 10-minute rest in the supine position.[17] Fat mass (FM) was calculated as the difference between body mass and FFM. Percentage fat mass (%FM) was expressed as the relative amount of FM for a given body mass. Repeatability of BIA measurements was performed in 32 obese girls (mean age, 12.1 ± 2.6 years; range, 5.2 to 17.1) on 2 days spaced 1 week apart. The mean differences between the 2 measurements were $-1.57 \pm 7.1\Omega$ for resistance and $-0.8 \pm 3.1\Omega$ for reactance. This resulted in a mean difference of 0.33 ± 1.2 kg for the calculated FFM and of 0.5% ± 1.9% for %FM. The CV for resistance was 2% and that for reactance 2.3%

Measurement of Waist-to-Hip Ratio

Waist and hip circumferences were measured to the nearest 0.5 cm in triplicate and the median value was taken. Waist circumference was measured halfway between the iliac crest and the rib cage. Hip circumference was measured at the maximum protuberance of the buttocks. The waist-to-hip ratio (WHR) was calculated as waist circumference (cm) divided by hip circumference (cm).

Measurement of Subcutaneous Adipose Tissue Layers

Measurements were performed by means of the optical device, Lipometer (Moeller Messtechnik, Graz, Austria), as described previously.[14,18-20] Measurement for the thickness of subcutaneous adipose tissue (SAT)-layers (mm) were performed at 15 body sites, from 1, neck, to 15, calf (Fig 1A and B) on the right side of the body in standing position.[19] The CV of SAT-layers ranges from 1.9% for SAT-layer 5, front chest, to 12.2% for SAT-layer 13, rear thigh.[20] Overall subcutaneous fatness (SAT) was calculated through linear addition of all 15 SAT-layers (Table 1). To give a proxy measure of SAT patterning, we calculated trunk-SAT (summed SAT-layers: 1 [neck], from 4 [upper back] to 10 [hip]), upper extremities-SAT (arm-SAT; summed SAT-layers: 2 [triceps], 3 [biceps]) and lower extremities-SAT (leg-SAT; summed SAT-layers: from 11[front thigh] to 15 [calf]) (Table 1).

Statistics

Initial values of insulin, glucose, and triglycerides were skewed and therefore $\log_{10}$-transformed. Analysis of variance was used to compare parameters between boys and girls where appropriate. In case of a significant difference, post hoc analysis was employed. The Kruskal-Wallis test was used if variances were not normally distributed. A 2 (sex) × 2 (time) design with repeated measurements on time was used to compare parameters before and after weight loss. Maturity levels were not assessed in children, and correlations between variables of interest were therefore adjusted for chronologic age. Because of sex differences in glucose levels, WHR, and leg-SAT (see Results), and due to the 2-fold greater number of girls than boys studied, calculations were performed for boys and girls separately.

The independence and significance of variables was tested by stepwise multiple regression analysis based on results of the bivariate correlations. The significance level of *P* values was set at 5%. Data are given as the mean and standard deviation unless otherwise indicated.

RESULTS

Baseline Values of Parameters in Boys and Girls

Significant sex differences were found for glucose, which was higher in boys than in girls (Table 1). There was a tendency ($P = .054$) for hip circumference to be higher in girls, and WHR was significantly greater in boys ($P < .0001$).

Values of measured SAT-layers are shown for boys in Fig 1A) and for girls in Fig 1B. Significantly greater values of SAT-layers 8 (lower abdomen), 13 (rear thigh), 14 (inner thigh), and 15 (calf) were found in boys. However, overall SAT, as well as trunk-SAT and arm-SAT, were not signifi-

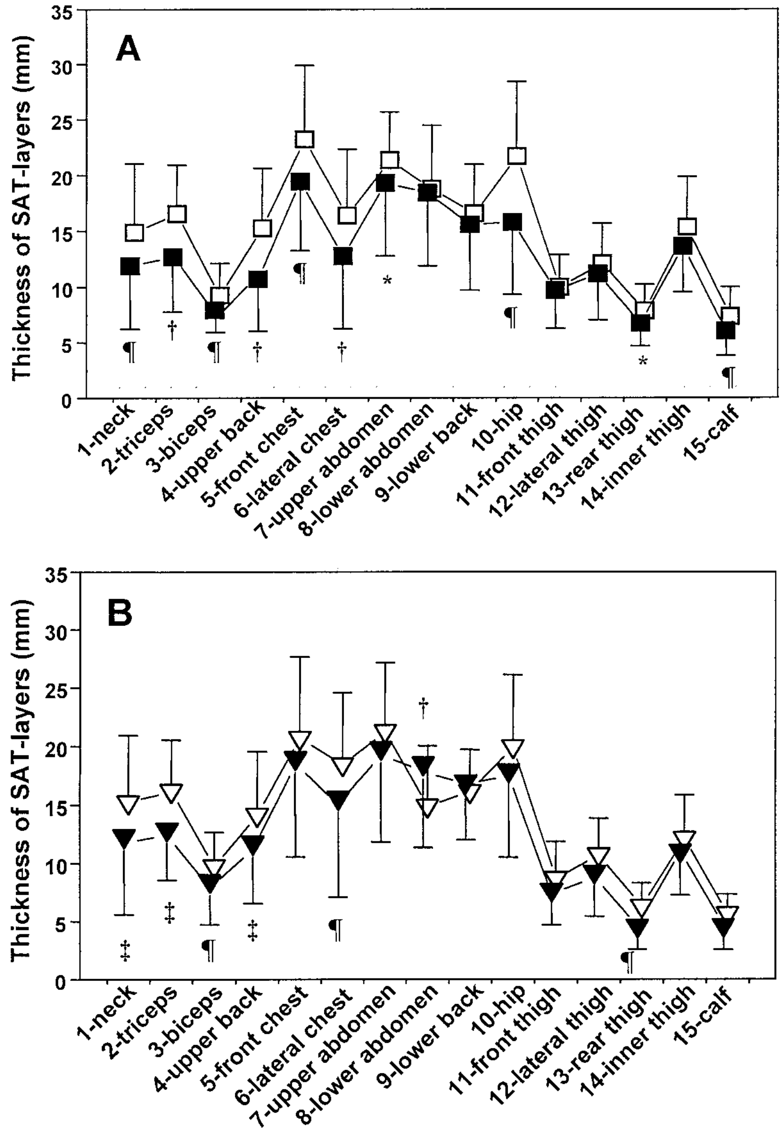

Fig 1. (A) Measurements of SAT-layers (from 1 [neck] to 15 [calf]) using the optical device Lipometer in obese boys before (□) and after weight loss (■). *P < .05; ¶P < .01; †P < .001. (B) Measurements of SAT-layers (from 1 [neck] to 15 [calf]) using the optical device Lipometer in obese girls before (△) and after weight loss (▲). Note the significant increase in SAT-layer 8, lower abdomen, after 3 weeks of diet and physical activity. ¶P < .01; †P < .001; ‡P < .0001.

cantly different between boys and girls (Table 1), but leg-SAT was greater in boys (P = .004).

The Influence of the Weight Loss Program on Estimated Parameters

Estimates of adiposity, ie, body mass, FM, %FM, SAT, and measures of fat distribution, ie, waist and hip circumference, trunk-, arm-, leg-SAT, were significantly lowered but FFM was not changed after 3 weeks (Table 2). The loss in body mass and FM (both $P < .0001$) did not significantly differ between boys and girls, but the change in %FM was greater in boys (sex × time interaction, P = .01). In addition to glucose, metabolic parameters, ie, insulin, triglycerides, and cholesterol (all $P <$ .0001), were reduced. No sex × time interaction was found for the change in insulin, trigylcerides, glucose, and cholesterol, suggesting that the effects of the intervention program on metabolic parameters were quite similar in boys and girls. There was a significant interaction (sex × time, P = .009) for the reduction in waist circumference, with the reduction being greater in girls (-9.2 ± 6 cm) than in boys (-5.5 ± 3.2 cm). The weight loss program lowered the thickness of almost all SAT-layers in boys (Fig 1A) and in girls (Fig 1B). There were significant sex × time interactions for the reduction in the following SAT-layers: 4 (upper back), P = .003; 8 (lower abdomen), P = .008; 9 (lower back), P = .04; 10 (hip), P = .026; and 15 (calf), P = .042. After 3 weeks, SAT-layer 7, lower abdomen, was not changed in girls. However, SAT-layer 8, lower abdomen, was significantly increased P = .0001 in girls (Fig 1B) but remained unchanged in boys. The increase in SAT-layer 9, lower back, was not significant in boys (P = .08) or in girls (P = .07). Although significant when grouped together (P = .029), pre- and post-weight loss values of SAT-layer 12, lateral thigh, were not significantly different in boys or in girls. SAT-layer 15, calf, was not reduced in girls (P = .43) (Fig 1B).

In general, SAT, trunk-SAT, arm-SAT (all $P < .0001$), and

Table 2. Changes in Estimated Parameters as Shown by the 2 × 2 Factorial Design

Parameters	Mean Changes (all children)	Mean Changes (boys, n = 22)	Mean Changes (girls, n = 40)
Body mass (kg)	−3.76 ± 1.22‡	−4 ± 1.4	−3.6 ± 1.1
FM (kg)	−3.6 ± 1.6‡	−4 ± 1.4	−3.3 ± 1.65
% FM (%)	−3.1 ± 2.3‡	−4.1 ± 2.7§	−2.5 ± 1.9
FFM (kg)	−0.18 ± 1.38	−0.04 ± 1.7	−0.3 ± 1.2
Waist-circumference (cm)	−7.9 ± 5.4‡	−5.5 ± 3.2	−9.2 ± 6†
Hip-circumference (cm)	−5.8 ± 2.87‡	−5.5 ± 3.2	−6 ± 2.7
Insulin (μIU/mL)	−4.1 ± 5.6‡	−3.9 ± 5.85	−4.25 ± 5.5
Glucose (mmol/L)	0.13 ± 0.87	0.18 ± 0.36	0.11 ± 1.04
Triglycerides (mmol/L)	−0.38 ± 0.34‡	−0.42 ± 0.38	−0.35 ± 0.31
Cholesterol (mmol/L)	−1.76 ± 0.85‡	−1.98 ± 0.77	−1.65 ± 0.88
SAT (mm)	−23.2 ± 36.7‡	−38.4 ± 41.55*	−14.8 ± 31.2
Trunk-SAT (mm)	−13.9 ± 27.7‡	−26.4 ± 31.5§	−7.05 ± 22.9
Arm-SAT (mm)	−4.6 ± 4.4‡	−5.3 ± 5.4	−4.2 ± 3.8
Leg-SAT (mm)	−4.7 ± 12.9§	−6.7 ± 14	−3.55 ± 12.4

NOTE. Mean ± SD values are given for all obese children and for boys and girls separately. Symbols denote level of significance for changes in parameters (‡$P < .0001$) and for the sex difference in changes of parameters (*$P < .05$, §$P < .01$, †$P < .001$).

leg-SAT ($P = .006$) were lowered. The mean reduction in SAT was more than 2-fold greater in boys (sex × time, $P = .014$) and the mean reduction in trunk-SAT was 3 times greater in boys than in girls (sex × time, $P = .007$; Table 2).

Age-Adjusted Relationship Between Changes in Estimated Parameters in Boys and Girls

Although glucose was not significantly changed (Table 2), we tested whether subtle alterations in glucose were related to changes in estimated parameters (Table 3).

In boys, changes in body mass were significantly related to changes in triglycerides ($P = .02$), cholesterol ($P = .012$), and insulin ($P = .011$). The reduction in FM was related to alterations in glucose ($P = .005$), whereas the loss in SAT was inversely related to changes in cholesterol ($P = .02$). The fall in cholesterol was also related to the fall in trigylcerides ($P = .00017$), and the fall in insulin had a significant relationship to alterations in glucose ($P = .006$).

In girls, changes in body mass ($P = .006$) and FM ($P = .02$) were related to changes in insulin.

The reduction in hip circumference ($P = .044$) and changes in triglycerides ($P = .00013$) were associated with changes in cholesterol. Changes in triglycerides were also related to changes in insulin ($P = .009$) and glucose ($P = .0005$).

Crude and Age-Adjusted Relationship Between Changes in Metabolic Parameters and Changes in Measures of Subcutaneous Fat Patterning

In boys, the reduction in trunk-SAT was inversely related to the fall in cholesterol, with the relationship becoming significant after adjustment for age ($P = .007$) (Table 4). The same inverse relationship was found between the fall in cholesterol and the reduction in arm-SAT, with the relationship remaining unchanged after controlling for age ($P = .014$). However, changes in triglycerides had a positive relationship to the reduction in leg-SAT ($P = .035$), also after controlling for age ($P = .012$). In girls, only the fall in insulin was significantly and inversely related to the the reduction in leg-SAT ($P = .038$), but the relationship was blunted after controlling for age ($P = .15$).

Multiple and Stepwise Regression Analyses

Analyses were performed for boys and girls together. Changes in insulin and triglycerides served as dependent variables in the regression models (Table 5). Parameters that were significantly related to changes in insulin and triglycerides (Tables 3 and 4) served as independent variables.

When changes in insulin served as the dependent variable, the change in body mass ($P = .0015$) was the main determinant for the variability, and the slope of the regression model was not influenced when changes in leg-SAT (Table 4) entered the model (data not shown in Table 5). Changes in cholesterol ($P < .0001$), glucose ($P = .0002$), and the reduction in leg-SAT ($P = .011$) were found to contribute to the variability of changes in triglycerides. However, sex and chronologic age were used as additional variables in all calculations, but they did not influence outcome measures.

DISCUSSION

Most baseline values were not significantly different between boys and girls. However, WHR and subcutaneous fat from the lower extremities were significantly greater in boys

Table 3. Age-Adjusted Relationship Between Changes in Metabolic Parameters and Measures of Adiposity in Obese Boys and Girls

Parameters	Δ Triglycerides	Δ Cholesterol	Δ Insulin	Δ Glucose
Boys (n = 22)				
Δ Body mass	0.48*	0.51*	0.52*	0.28
Δ FM	0.38	0.24	0.01	0.56†
Δ Waist-circumference	0.09	−0.35	−0.28	−0.01
Δ Hip-circumference	0.13	0.01	−0.05	0.34
Δ SAT	0.03	−0.48*	0.14	0.01
Δ Triglycerides	—	0.73‡	0.14	0.21
Δ Cholesterol	0.73‡	—	0.24	0.15
Δ Insulin	0.14	0.24	—	0.56†
Δ Glucose	0.21	0.15	0.56†	—
Girls (n = 40)				
Δ Body mass	0.11	−0.13	0.40†	0.13
Δ FM	0.18	0.10	0.33*	0.12
Δ Waist-circumference	0.16	0.21	0.05	−0.05
Δ Hip-circumference	0.14	0.28*	−0.04	0.16
Δ SAT	−0.10	−0.04	−0.15	−0.08
Δ Triglycerides	—	0.55‡	0.38†	0.50‡
Δ Cholesterol	0.50‡	—	0.11	0.05
Δ Insulin	0.38†	0.11	—	0.22
Δ Glucose	0.50‡	0.05	0.22	—

*$P < .05$.
†$P < .01$.
‡$P < .001$.

Table 4. Crude and (Age-Adjusted Relationship) Between Changes in Different Subcutaneous Fat Depots and Metabolic Parameters in Obese Boys and Girls

	Δ Triglycerides	Δ Cholesterol	Δ Insulin	Δ Glucose
Boys (n = 22)				
Δ Trunk-SAT	−0.15 (−0.12)	−0.29 (−0.55†)	0.23 (0.14)	0.19 (0.08)
Δ Arm-SAT	−0.27 (−0.16)	−0.52* (−0.50*)	−0.18 (−0.13)	−0.19 (0.0)
Δ Leg-SAT	0.42* (0.51*)	0.03 (−0.01)	0.19 (0.19)	−0.15 (−0.195)
Girls (n = 40)				
Δ Trunk-SAT	−0.06 (−0.20)	0.06 (−0.07)	−0.14 (−0.1)	0.03 (−0.01)
Δ Arm-SAT	0.12 (0.07)	0.07 (0.08)	−0.13 (−0.07)	0.1 (0.05)
Δ Leg-SAT	0.02 (0.1)	−0.01 (−0.0)	−0.29* (−0.17)	−0.2 (−0.195)

*$P < .05$.
†$P < .01$.

(Table 1). Glucose was elevated in boys despite very similar insulin levels in boys and girls. In 3 girls, glucose levels exceeded 4 mmol/L, and 1 girl had a fasting glucose of 9.82 mmol/L. Subsequent testing by means of an oral glucose tolerance test and the follow-up of HbA_{1c} values excluded the possibility of type 2 diabetes. Therefore, data of these girls were not excluded from the calculations.

At baseline, almost all parameters were not significantly different between boys and girls (Table 1). However, the greater value of leg-SAT in obese boys suggests that they have more subcutaneous fat stored at the legs than girls.[21] This could be due to the age-related redistribution of body fat in girls,[22] and because of hormonal differences and (or) obesity-related metabolic alterations that could influence body fat distribution.[23]

The weight loss program lowered adiposity, but not FFM (Table 2). The maintenance of FFM is in accordance with others showing that after 10 weeks of a weight loss program including diet and exercise, FFM was maintained among boys and girls.[24] Besides glucose, metabolic parameters were lowered and this effect was quite similar in boys and girls (Table 2). However, changes in waist circumference were greater in girls. Waist circumference was shown to perform well in identifying children with high trunk fat as measured with dual-energy x-ray absorptiometry (DEXA)[25] and changes in waist circumference due to weight loss were shown to be useful to estimate changes in visceral fat in adults.[26] Waist circumference comprises intraabdominal fat, subcutaneous fat, and lean tissue, but SAT-layers from the abdominal region were unchanged after weight loss (Fig 1A and 1B). This indicates that weight loss is associated with a greater decrease in visceral fat and, perhaps, abdominal lean tissue in obese girls. In contrast to girls, the weight reduction program was associated with a greater loss in subcutaneous fat and with a greater reduction in trunk-SAT in obese boys (Table 2). The lipolytic response of

Table 5. Multiple Regression Analysis With Changes in Insulin and Changes in Triglycerides as Dependent Variables

Dependent Variable	Multiple Regression Model				Stepwise Regression Model			
	Independent Variables	β	95% CI	P	Independent Variables	β	95% CI	P
Δ Insulin	Sex	1.29	±2.9	.32	Δ Body mass	1.99	±1.195	.0015
	Age	0.51	±0.82	.52	Intercept: 3.28			
	Δ Triglycerides	2.87	±4.54	.08	Adjusted R^2 = 0.15; P = .00015			
	Δ Glucose	0.65	±1.72	.77				
	Δ Body mass	1.95	±1.25	.0017				
Δ Triglycerides	Sex	0.009	±0.134	.89	Δ Cholesterol	0.246	±0.071	<.0001
1st model	Age	−0.006	±0.04	.75	Δ Glucose	0.0136	±0.07	.0002
	Δ Cholesterol	0.241	±0.075	<.0001	Intercept: 0.038			
	Δ Insulin	0.004	±0.012	.49	Adjusted R^2 = 0.54; $P < .0001$			
	Δ Glucose	0.126	±0.073	.001				
	Δ Body mass	0.04	±0.061	.19				
2nd model	Sex	0.041	±0.13	.52	Δ Cholesterol	0.245	±0.068	<.0001
	Age	0.003	±0.037	.86	Δ Glucose	0.0136	±0.066	.00012
	Δ Cholesterol	0.238	±0.072	<.0001	Δ Lower extremities-SAT	0.006	0.0045	.015
	Δ Insulin	0.006	±0.012	.32	Intercept: 0.068			
	Δ Glucose	0.12	±0.07	.0011	Adjusted R^2 = 0.587; $P < .0001$			
	Δ Body mass	0.03	±0.059	.30				
	Δ Lower extremities-SAT	0.006	0.0048	.015				

NOTE. The P level of significance, the regression coefficient (β), and the 95% confidence interval (95% CI) for each independent variable are shown. The adjusted R^2 is given for each model of the stepwise regression.

different adipose tissue depots is sex-dependent[27,28] and men mobilize more intra-abdominal fat than women, whereas women lose more subcutaneous fat after weight loss.[29] As can be seen in Fig 1, obese boys and girls lost subcutaneous fat predominantly at the upper trunk and at the arms, whereas in obese females (18 to 22 years of age), weight loss during energy restriction was associated with a greater reduction in internal fat compared with subcutaneous fat.[30] In obese children (7 to 11 years of age), a 4-month period of controlled physical training was associated with a significant decline in FM, %FM, and subcutaneous abdominal fat.[31] The differences between the above-cited studies and ours might be due not only to the different methodologies used to measure subcutaneous and visceral fat,[31] but could also depend on the subject's age as well as on the mode (diet *v* training) and time of intervention.

In boys, the loss in body mass was related to changes in the metabolic and lipid profile, and the reduction in FM accounted for the lowering of fasting glucose. However, the improvement in risk factors can also occur independent of changes in adiposity because mild-intensity exercise training in obese boys (13.3 ± 1.4 years) was shown to be associated with an improved metabolic and lipid profile without changes in body mass and %FM.[32]

We found a relationship between changes in cholesterol and trigylcerides supporting previous work of an interrelationship between metabolic parameters.[14] The changes in triglycerides were related to changes in leg-SAT (Table 4), which also might reflect the relationship between the loss in body mass and changes in leg-SAT (data not shown). Hence, those boys who showed the greatest reduction in body mass also had the greatest reduction in leg-SAT and triglycerides. Surprisingly, there was a negative relationship between changes in SAT and changes in SAT-pattern with the fall in cholesterol (Tables 3 and 4). Whereas cholesterol was reduced in all boys, SAT was not lowered in 3 of the 22 boys; in 2 of the boys, arm-SAT and trunk-SAT were not reduced. Given this small number of boys whose subcutaneous fat was not reduced, but who were responsible for the negative relationship, it is nexcessary to state that such an inverse relationship should be considered with caution. On the other hand, if an inverse relationship exists in response to weight loss, then it can be hypothesized that a greater fall in cholesterol can occur in the absence of changes in SAT and upper body SAT patterning. If so, then it is unlikely that subcutaneous central fat is an independent risk factor[33] in childhood obesity.

In girls, the loss in body mass and FM was related to the lowering in fasting insulin (Table 3). Although all of the girls showed a reduction in waist circumference, there was no significant relationship between changes in waist circumference and improvements in the metabolic and lipid profiles. In addition, changes in SAT and SAT-pattern failed to show a significant relationship (Tables 3 and 4), suggesting that the lowering of lipids and insulin can occur independent of the loss in subcutaneous fat and, probably, visceral fat. However, it was shown that in obese girls participating in a weight loss program for 6 weeks, those with abdominal obesity (WHR $>$ 0.88) exhibited more beneficial changes in the atherogenic risk factor profile than those with gluteal-femoral obesity, partly because of a greater weight loss.[13] Thus, the loss in body mass represents a general reduction in adiposity, which might have contributed to the lowering of risk factors in that study[13] and ours.

In girls, the small and inverse relationship between changes in insulin and changes in leg-SAT (Table 4) did not remain significant after controlling for age. Training and diet improve glucose tolerance and tissue sensitivity to insulin,[34,35] but whether the lowering of the metabolic parameters is the first event in the improvement or secondary to the reduction in adiposity cannot be answered from the present study.

Although of minor magnitude, the main influence of the loss in body mass on changes in insulin was confirmed by the regression analysis (Table 5) in which age and sex did not significantly influence outcome measures. Regarding the fall in triglycerides, the fall in cholesterol, subtle alterations in glucose, and the reduction in leg-SAT were found to explain most of the variance. Therefore, the short-term dynamic regulation of insulin and trigylcerides might differ with respect to the underlying mechanism(s). However, changes in cholesterol, trigylcerides, insulin, and glucose were interrelated (Table 3), which might have contributed to the findings of the stepwise regression. Although we can conclude from the present findings that the common basis for the maintenance of a lowered risk profile is the change in body mass (or adiposity), it is conjecture to conclude that the reduction in adiposity and the changes in metabolic parameters work synergistically. This is also because of some potential for overstating relationships given the high number of statistical tests performed in that study, which makes it difficult to consider all of the findings as meaningful.

Moreover, the small number of children included in the weight loss program is a limitation, and especially the results obtained in the group of obese boys need to be considered with caution. Ongoing studies comprising a sufficient number of boys (and also girls) are warranted to extend our findings for a general conclusion in an obese pediatric population.

In summary, a short-term diet and sports intervention program reduced adiposity and risk factors in obese children. The loss in body mass was the only significant parameter to explain some of the variance in changes of insulin. The reduction in total SAT and that in trunk-SAT were not related to the changes in metabolic parameters which contributed to the improvement in the risk profile itself. Given the finding that the reduction in leg-SAT contributed to the fall in triglycerides, the role of SAT-pattern is an issue that needs further investigation.

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