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Improvement of Early Vascular Changes and Cardiovascular Risk Factors in Obese Children After a Six-Month Exercise Program

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OBJECTIVES The present study aimed to assess the effect of a 6-month exercise program in obese children on flow-mediated vasodilation (FMD) carotid intima-media thickness (IMT) and cardiovascular risk factors (RF).

BACKGROUND Childhood obesity contributes to adult obesity and subsequent cardiovascular disease. Physical inactivity is a major RF for obesity, endothelial dysfunction, and elevated carotid IMT, culminating in early atherosclerotic disease.

METHODS Sixty-seven obese subjects (age 14.7 ± 2.2 years) were randomly assigned to 6 months' exercise or non-exercise protocol. We examined the influence of exercises (1 h, 3 times/week) on FMD, IMT, and cardiovascular risk profile.

RESULTS Compared with lean control subjects, obese children demonstrated at baseline significantly impaired FMD (4.09 ± 1.76% vs. 10.65 ± 1.95%, $p < 0.001$), increased IMT (0.48 ± 0.08 mm vs. 0.37 ± 0.05 mm, $p < 0.001$), and a number of obesity-related cardiovascular RF. Significant improvements were observed in the exercise group for IMT (0.44 ± 0.08 mm, $p = 0.012$, −6.3%) and FMD (7.71 ± 2.53%, $p < 0.001$, +127%). This improvement correlated with reduced RF, such as body mass index standard deviation scores, body fat mass, waist/hip ratio, ambulatory systolic blood pressure, fasting insulin, triglycerides, low-density lipoprotein/high-density lipoprotein ratio, and low-degree inflammation (C-reactive protein, fibrinogen).

CONCLUSIONS The present study documented increased IMT, impaired endothelial function, and various elevated cardiovascular RF in young obese subjects. Regular exercise over 6 months restores endothelial function and improves carotid IMT associated with an improved cardiovascular risk profile in obese children. (J Am Coll Cardiol 2006;48:1865–70) © 2006 by the American College of Cardiology Foundation

Child and adolescent obesity strongly relates to early atherosclerosis and obesity-related cardiovascular disease (1). Physical inactivity is instrumental in the development of atherosclerotic cardiovascular disease (2) and might well intermediate between obesity, inflammation, insulin resistance, and early atherosclerosis (3). Greater physical activity reduces cardiovascular risk (4) and is beneficial to weight management, prevention of obesity, and insulin resistance in adults and children (5).

It is universally accepted that disturbed endothelial cell biology, variably including activation, injury, damage, and dysfunction (6), is part of the early pathogenesis of atherosclerosis (7).

Ultrasound evaluation of brachial artery flow-mediated vasodilation (FMD) and carotid artery intima-medial thickening (IMT) is increasingly used for pediatric cardiovascular risk assessment (8) and might present a novel strategy for primary prevention and early therapy. In children, impaired FMD is known to prevail in conditions predisposing atherosclerosis, including familial hypercholesterolemia, type I diabetes, and morbid obesity (9–11). The analysis of short-term exercise studies in a wide population range with endothelial dysfunction showed improvements in vascular function with exercise, with or without concomitant reduced weight and cardiovascular RF (12–14).

Intima-medial thickening in obese children is a focus of ongoing debate. A study of severely obese children produced no evidence of significant differences in carotid IMT, compared with control subjects (11). Results from a larger study, however, demonstrate increased carotid IMT in obese children and potential influence from long-term exercise (15).

In the current study, we sought to determine the effects of 6 months' physical activity in obese children and adolescents on FMD, IMT, and obesity-related cardiovascular disease RF.

METHODS

Study design. Ninety-six obese children (47 boys and 49 girls, age 14.2 ± 1.9, range 11–16 years) were consecutively recruited when they presented to an established university outpatient department of pediatric endocrinology and cardiology. Obesity was defined as body mass index (BMI) in excess of the 97th percentile for the German pediatric population (16).

The control group consisted of 35 children (17 boys and 18 girls, age 14.7 ± 2.2, range 12–16 years) without appreciable cardiovascular RF and was selected from children presenting at the same institution for the diagnostic work-up of dizziness

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Abbreviations and Acronyms

BMI = body mass index
BP = blood pressure
CRP = C-reactive protein
FMD = flow mediated vasodilation
HDL = high-density lipoprotein
IL = interleukin
IMT = intima-media thickness
LDL = low-density lipoprotein
NO = nitric oxide
RF = risk factor(s)

and minor orthostatic complaints. Children with structural or functional cardiovascular abnormalities were excluded.

At baseline, all patients underwent identical 2-day screening with a multiple RF approach. We ensured group comparability by matching for major baseline characteristics, including family history of atherosclerotic disease, age, gender, and Tanner stages.

The study complied with the Declaration of Helsinki. The study plan was approved by the local ethics committee, and written informed consent was obtained from the parents. Study participation was voluntary; subjects were free to withdraw at any time.

Subjects were randomly assigned to 6 months' exercise or to 6 months' non-exercise. Exclusion criteria were medication of any type; smoking, active participation in any exercise activity ≥30 min more than once/week; participation in organized diet programs; and diabetes, heart, renal, or liver disease.

For all subjects with obesity, the screening protocol was repeated at 6 monthly intervals. The lean control subjects were studied only at baseline.

Of 50 subjects who started the program, only 33 (17 boys and 16 girls, age 13.7 ± 2.1 years), participated sufficiently for inclusion in the second screening protocol. Exclusion criteria were participation in organized exercises less than twice/week, a break in activities for longer than 2 weeks, and total discontinuance of the program. Of 46 subjects of the obese control group, 34 (17 boys and 17 girls, age 14.1 ± 2.4 years) could be recruited for a second risk profile evaluation.

Measurement of risk factors. Anamnestic and anthropometric data were reviewed during 2 days' hospital stay. Body fat mass was assessed by bioelectrical impedance (Data Input Inc., Frankfurt, Germany), expressed as percentage of body weight. A venous blood sample was collected after overnight fasting. Insulin resistance was calculated by homeostasis model assessment (17).

Resting blood pressure (BP) was measured at all extremities by an automatic oscillometric cuff device (Dinamap, Critikon Inc., Tampa, Florida). The 24-h ambulatory BP was measured on the right arm (Space Labs Inc., Issaquah, Washington). The BP data were automatically recorded every 15 min from 8:00 AM to 8:00 PM (daytime BP) and every 30 min from 8:00 PM to 8:00 AM (nighttime BP). The BP studies were excluded from analysis if measurements were invalid or lacking for more than 2 h.

The spiroergometric equipment Oxycon Alpha (Jaeger, Würzburg, Germany) evaluated exercise parameters. All children underwent cycling exercises with a modified Bruce protocol with continuously raised loads; they exercised to exhaustion. Blood pressure was measured during exercise every minute, and the groups were compared at 2 W/kg load. Echocardiography and vascular measurements were taken with a Hewlett-Packard Sonos system (Sonos 5500, Philips Int., Andover, Massachusetts). Left ventricular measurements were derived from 2-dimensional guided M-mode tracings, as recommended by the American Society of Echocardiography (18). Left ventricular mass (LVMMI) was calculated by Devereux-modified American Society of Echocardiography cube equation (19) and indexed to body surface area.

Vascular measurements. Flow-mediated vasodilation and IMT were conducted as previously described (20) at baseline and after 6 months. Endothelium-dependent responses of the right radial artery were measured for each patient subject to International Brachial Artery Reactivity Task Force guidelines (21). A trained, certified pediatrician analyzed FMD and IMT. Intraobserver variability expressed as median absolute difference in the measurements of FMD was 1.03 ± 0.28%. Results of measuring the arterial diameter were highly reproducible with a mean difference of 0.034 ± 0.076. The IMT–intraobserver and IMT–interobserver variability (mean bias) was 0.2% and 1.2%, respectively.

Intervention protocol. Exercises were conducted 3 times/week: on Mondays, swimming and aqua aerobic training (60 min); Wednesdays, sports games (90 min); and Fridays, walking (60 min), supervised by qualified coaches and physiotherapists. Exercises were progressively intensified as individually tolerated. Control subjects did not participate in structured exercises and were instructed to maintain current levels of physical activity. Physical activity was recorded in a 1-week activity protocol, completed by subjects of both groups. There was one consultation with a nutritionist to enhance knowledge about healthy nutrition for children and adolescents for subjects of both groups. Calorie intake was measured at the beginning and after 6 months with a 1-week nutrition protocol and calculated with the Nutriscience Prodi 5.1 expert program (Hausach, Germany). There was no change in calorie intake or diet plan in both groups.

Statistical methods. Data were stored and analyzed with the SPSS statistical package 12.0 (SPSS Inc., Chicago, Illinois). Descriptive statistics were computed for variables of interest and included mean values and SDs of continuous variables and absolute and relative frequencies of categorical factors.

Testing for differences of continuous variables between the study groups was accomplished by the 1-way analysis of variance (ANOVA) or the Kruskal-Wallis 1-way ANOVA, ranked as appropriate. Test selection was based on evaluating the variables for normal distribution, employing the Kolmogorov-Smirnov test. Post hoc comparisons were made after an ANOVA resulted in a significant test. We then

Table 1. Anthropometric and Laboratory Parameters at Baseline and After Intervention (Lean, Intervention, and Obese Control Group)

Variable	Intervention (n = 33)			Obese Control Subjects (n = 34)			Lean (n = 35)
	Baseline	After 6 Months	p Value	Baseline	After 6 Months	p Value	Baseline
BMI (kg/m^2)	29.8 ± 5.93	27.2 ± 4.80	<0.001	31.0 ± 4.42	31.3 ± 4.21	0.517	18.6 ± 2.02*
BMI SDS	2.33 ± 0.55	1.90 ± 0.69	<0.001	2.58 ± 0.71	2.44 ± 0.47	0.198	−0.081 ± 0.84*
Body fat mass (%)	35.9 ± 6.99	34.9 ± 9.71	0.064	37.2 ± 7.9	37.2 ± 8.8	0.555	16.7 ± 7.63*
Waist/hip ratio	0.93 ± 0.12	0.87 ± 0.09	0.012	0.94 ± 0.10	0.94 ± 0.10	0.077	0.86 ± 0.06*
Insulin (pmol/l)	13.8 ± 5.20	11.16 ± 4.61	0.008	15.9 ± 6.47	14.6 ± 7.65	0.774	6.55 ± 1.99*
Insulin resistance	3.94 ± 1.75	3.12 ± 1.38	0.034 (W)	4.44 ± 1.71	4.93 ± 3.16	0.926 (W)	1.76 ± 0.63* (KW)
HbAlc	5.3 ± 0.54	5.3 ± 0.38	0.717	5.5 ± 0.45	5.2 ± 0.46	0.072	4.9 ± 0.10 ns
Triglycerides (mmol/l)	1.41 ± 1.14	1.04 ± 0.48	0.016	1.14 ± 0.79	1.06 ± 0.51	0.688	0.69 ± 0.29*
LDL	2.71 ± 0.70	2.57 ± 0.66	0.025	2.9 ± 0.83	3.01 ± 0.79	0.653	2.26 ± 0.54†
HDL (mmol/l)	1.10 ± 0.25	1.09 ± 0.24	0.787	1.20. ± 0.41	1.11. ± 0.31	0.254	1.34 ± 0.26†
LDL/HDL ratio	2.71 ± 0.68	2.58 ± 0.93	0.187	2.71 ± 0.81	2.92 ± 1.05	0.196	1.78 ± 0.37*
Fibrinogen (g/l)	3.57 ± 0.75	3.24 ± 0.61	0.012	3.55 ± 0.82	3.54 ± 0.99	0.975	2.10 ± 0.74*
CRP (mg/l)	4.84 ± 6.31	2.05 ± 2.44	0.013 (W)	4.61 ± .54	3.36 ± 4.76	0.472 (W)	1.24 ± 0.44* (KW)

Comparisons of baseline data between obese groups and lean control subjects by 1-way analysis of variance (ANOVA) or Kruskal-Wallis 1-way ANOVA by ranks (KW), *p < 0.001; †p < 0.05. Comparisons of data at baseline and after 6 months by paired *t* test or Wilcoxon signed rank test (W). Data presented as mean ± SD.

BMI = body mass index; BMI-SDS = BMI standard deviation scores; CRP = C-reactive protein; Hb = hemoglobin; HDL = high-density lipoprotein cholesterol; LDL = low-density lipoprotein cholesterol.

applied the least significant difference (LSD) or Mann-Whitney *U* test with a lower critical significance probability (Bonferroni correction). Within the groups, all comparisons were made between 2 moments by using the paired *t* test or Wilcoxon signed rank test depending on the results of Kolmogorov-Smirnov tests for differences. Pearson correlation coefficients were calculated to evaluate relationships between some variables. All p values resulted from 2-sided statistical tests and $p \leq 0.05$ was considered to be significant.

RESULTS

Assessment of risk profile at baseline. The groups of obese intervention, obese control, and lean children differ significantly in numbers of RF, including BMI, body fat mass, BP, laboratory parameters (insulin, insulin resistance, triglycerides, high-density lipoprotein [HDL] cholesterol, low-density lipoprotein [LDL]/HDL ratio, fibrinogen, and C-reactive protein [CRP]), echocardiographic measurements, and physical fitness at baseline (Tables 1 and 2). Post hoc comparisons demonstrated that, compared with lean children, both groups of obese children differed significantly. By contrast, there were no significant differences among the 3 groups for additional laboratory measures, including the concentrations of total cholesterol, lipoprotein(a), homocysteine, and apolipoproteins A1, A2, and B (data not shown).

Vascular measurements at baseline. The 3 groups differ significantly in FMD (Table 2). Post hoc comparison showed that both groups of obese children presented significantly reduced FMD compared with lean children. Time-to-maximum dilation was between 40 and 80 sec after cuff release. Maximum FMD did not correlate with time-to-maximum dilation (r = 0.07), and the 2 obese groups did not differ significantly in time-to-maximum dilation. The IMT measurements were adequate for all children in the segments of the common carotid artery and carotid bifurcation. In these segments, differences were significant for near and far walls between obese and control children ($p < 0.001$).

Effect of intervention. Tables 1 and 2 show the data after 6 months in the intervention group and in obese control subjects. Anthropometric measurements revealed significant decreases in BMI, body mass index standard deviation

Table 2. Blood Pressure, Physical Fitness, and Echocardiographic Measurements at Baseline and After Intervention

Variable	Intervention (n = 33)			Obese Control Subjects (n = 34)			Lean (n = 35)
	Baseline	After 6 Months	p Value	Baseline	After 6 Months	p Value	Baseline
sBP (mm Hg)	128 ± 15.7	120 ± 13.3	0.048	133 ± 14.1	133 ± 19.6	0.589	113 ± 10.7*
sBP ex. (mm Hg)	161.6 ± 26.1	157.9 ± 25.9	0.200	166.9 ± 40.1	182.2 ± 20.9	0.056	143 ± 12.7†
Amb BBs	117.1 ± 7.1	113.1 ± 7.7	0.036	121 ± 9.4	121.0 ± 8.6	0.486	114.1 ± 5.6‡
Amb BBd	68.3 ± 5.8	68.3 ± 5.9	0.201	68.1 ± 7.3	68.5 ± 6.7	0.544	68.7 ± 5.8
Wmax (W/kg)	2.14 ± 0.37	2.46 ± 0.62	<0.001	2.11 ± 0.46	2.14 ± 0.48	0.936	3.11 ± 0.57*
% of norm	64.9 ± 14.3	76.9 ± 20.9	<0.001	66.3 ± 18.5	66.6 ± 18.5	0.374	95.4 ± 13.6*
LVMMI (g/m^2)	97.5 ± 26.9	84.2 ± 23.8	0.377	90.6 ± 23.6	91.3 ± 24.5	0.895	77.7 ± 15.3‡
LA (cm)	3.13 ± 0.46	3.2 ± 0.45	0.194	3.38 ± 0.44	3.54 ± 0.43	0.203	2.73 ± 0.34*

Comparisons of baseline data between obese groups and lean control subjects by 1-way analysis of variance. Comparisons of data at baseline and after 6 months by paired *t* test. Data presented as mean ± SD. *p < 0.001; †p < 0.01; ‡p < 0.05.

Amb BBs/d = mean systolic/diastolic ambulatory blood pressure; LA = size of left atrium; LVMMI = left ventricular mass index; sBP = systolic blood pressure at initial physical examination; sBP ex. = exercise systolic blood pressure at 2 W/kg; Wmax = maximal W/kg at exercise; % of norm = maximal W/kg in percent of normal values.

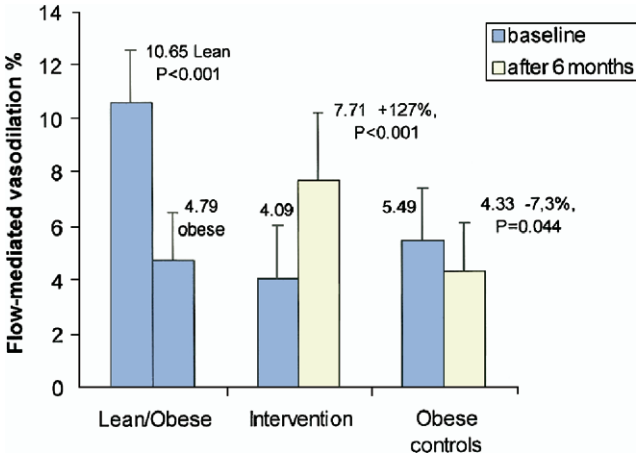

Figure 1. Flow mediated vasodilation at baseline of the intervention and obese control groups and lean control subjects and data after 6-month intervention or non-intervention. Comparisons of baseline data between the obese groups and lean control subjects by 1-way analysis of variance. Comparisons of data at baseline and after 6 months by paired *t* test. Data presented as mean ± SD.

scores (BMI-SDS), body fat mass, and waist/hip ratio in the intervention group. There were no statistically relevant changes of these parameters in the obese control group. In contrast to the control group, the intervention group showed a significant benefit in laboratory risk parameters, such as fasting insulin, insulin resistance, triglycerides, LDL/HDL ratio, fibrinogen, and CRP. Relative changes also differed significantly compared with the obese subjects without intervention (data not shown). Intervention produced a significant decrease in systolic mean ambulatory BP and an increase in physical fitness data (maximum work capacity [Wmax]). Systolic BP during exercise and left ventricular mass did not change significantly in the intervention group, but relative changes differed significantly compared with control subjects, because of increases in these parameters in the control subjects (systolic BP: −1.8 ± 15.6% vs. +7.0 ± 13.1%, $p < 0.05$; left ventricular mass −1.36 ± 39.9% vs. +4.3 ± 35.9%, $p < 0.05$).

After 6 months, FMD increased significantly (4.09 ± 1.76% vs. 7.71 ± 2.53%, $p < 0.001$) (Fig. 1). Compared with the obese control group, a significant difference in relative changes in FMD (intervention +127 ± 171% vs. control group −7.3 ± 61.7%, $p < 0.001$) was shown.

The IMT improved significantly in all measured segments of the carotid artery after intervention but not in the control group (Table 3). Relative differences between the 2 groups for maximum IMT of common carotid artery (−8.4 ± 15.8% vs. +0.5 ± 12.8%, $p = 0.01$) and carotid bifurcation (−10.9 ± 17.1% vs. +1.5 ± 20.9%, $p = 0.015$) were significant. The relative changes in FMD were tested in relation to the relative changes in other risk parameters. Risk parameter changes possibly relating to FMD were BMI ($r = -0.355$, $p = 0.004$), waist/hip ratio ($r = -0.397$, $p = 0.002$), body fat ($r = -0.320$, $p = 0.025$), fasting insulin ($r = -0.371$, $p = 0.005$), and hours of weekly sports activities ($r = -0.537$, $p < 0.001$).

DISCUSSION

The present study shows that obesity in children and adolescents associates with early signs of atherosclerosis and some obesity-related cardiovascular RF. More important is the finding that 6 months' physical exercise in obese adolescents significantly improved endothelium-dependent vasodilation of the radial artery and IMT of the carotid artery. This improvement mirrors a significant reduction of body weight, waist/hip ratio, BP, insulin resistance, triglycerides, LDL/HDL ratio, fibrinogen, and CRP and a significant rise in physical fitness.

Flow-mediated dilation is endothelium-dependent and largely nitric oxide (NO)-dependent, and impaired FMD is considered a key event of atherosclerotic disease (22). Exercise programs improve FMD in adults with cardiac failure (23), coronary artery disease (24), and diabetes (25). This improvement is not restricted to vessels of the exercising musculature (23) and probably occurs in the absence of changes in traditional RF (13,14). This effect, therefore, is probably due to the generalized impact of hemodynamic variables acting through vessel wall shear stress (26), upregulation of NO-synthase gene expression, (22,27), and bioavailability of NO. Other hormonal and inflammatory effects and enhanced endothelial progenitor cells during exercise could help to improve endothelial integrity (28).

Regarding the endothelial function, the study did not differentiate between the effects of exercise versus associated weight reduction. Improved endothelium-dependent vasodilation was reported after 8 weeks' exercise of obese children and

Table 3. Carotid IMT at Baseline and After Intervention in Lean, Intervention, and Obese Control Subjects

Variable	Intervention (n = 33)			Obese Control Subjects (n = 34)			Lean (n = 35)
	Baseline	After 6 Months	p Value	Baseline	After 6 Months	p Value	Baseline
IMT (mm)							
CCA mean	0.48 ± 0.08	0.44 ± 0.08	0.012	0.47 ± 0.06	0.45 ± 0.06	0.240	0.37 ± 0.05*
CCA max	0.53 ± 0.08	0.48 ± 0.08	0.002	0.51 ± 0.07	0.50 ± 0.06	0.979	0.41 ± 0.06*
CB mean	0.53 ± 0.06	0.46 ± 0.08	0.001	0.51 ± 0.06	0.47 ± 0.05	0.347	0.39 ± 0.03*
CB max	0.58 ± 0.07	0.51 ± 0.09	<0.001	0.56 ± 0.07	0.57 ± 0.06	0.941	0.44 ± 0.04*

Comparisons of baseline data between obese groups and lean control subjects by 1-way analysis of variance *$p < 0.001$. Comparisons of data at baseline and after 6 months by paired *t* test. Data presented as mean ± SD.

CB = carotid bifurcation; CCA = common carotid artery; FMD = flow-mediated vasodilation; IMT = intima-media thickness; max = maximum measurement; mean = mean of 10 measurements of left and right side.

adults that did not include a weight-reducing component (13,14,29), suggesting that exercise might well impact the vasculature condition immediately and beneficially. In contrast, 2 previous studies evaluated the effect of weight reduction with and without exercise on vessel wall properties in obese adults (30,31).

Weight loss alone through weight-reducing gastroplasty was associated with the reduced progression rate of carotid IMT after 4 years but no reduction of IMT (32). Elevated IMT in the early stages of atherosclerosis is interpreted as a thickening of the intima layer and, to some extent, as hypertrophy of the media layer in adaptive response to changes in transmural pressure shear stress and lumen diameter (33). In randomized controlled trials in adults, mean maximum IMT has been proposed as primary means for studying the efficacy of interventions (34). The study confirmed this suggestion with the measurements of maximum IMT showing the most impressive reduction after intervention. In contrast with intervention studies in adults, where changes in progression rates of IMT are used as a marker reflecting cardiovascular risk, data of this study show directly reduced carotid IMT in young subjects. In the current study, the main predictors of improved FMD seem to be a percentage reduction in body weight, body fat mass, waist/hip ratio, and fasting insulin and increased physical activity. In Type 2 diabetic rats, exercise achieved better results for the endothelial function than food reduction alone, although both interventions significantly suppressed plasma levels of insulin, glucose, and cholesterol; reduced abdominal fat accumulation; and improved insulin sensitivity comparably (35).

Recent studies reported increased inflammatory markers (CRP, interleukin [IL]-6, fibrinogen) in overweight children and a positive association of these proinflammatory factors with BMI, body fat mass, BP, and insulin resistance (homeostasis model assessment) (36–38). Inflammation, indicated by elevated CRP and fibrinogen concentrations, might affect the arteries of obese children by disturbing the endothelial function and promoting IMT, supporting the hypothesis that inflammation is important to the pathogenesis of early atherosclerosis (39,40). It has been suggested that IL-6 released by adipose tissue stimulates the hepatic production of acute phase proteins such as CRP and fibrinogen (41). Initial weight loss during exercise is suggested to occur mainly from the viscera (14). This also would positively affect the release of proinflammatory factors and could explain improved vascular status.

In contrast to the results of the present study, Kelly et al. (13) could not correlate improvements in fasting insulin with changes in inflammatory markers after exercise. In their 8 weeks' exercise program, there was no change in body fat mass, such as is probably required to stimulate improvement in the CRP profile. Data of the current study showed a significant reduction in systolic BP and left ventricular mass after the intervention, compared with obese control subjects. The remaining issue is whether elevated BP is a cause or effect of endothelial dysfunction. Enhanced arterial stiffness affects the ability of the large arteries to cushion cardiac output, even during exercise. Impaired vascular response and higher blood volume in obese children influence BP regulation and might affect elevation of left ventricular mass and size of left atrium, which are also known to be RF for cardiovascular outcome. It is, therefore, an important determinant factor for the vascular load on the heart and is vital to future cardiovascular profiles.

Elevated levels of triglycerides are well-known RF, mostly combined with increased LDL/HDL ratio and very low-density lipoprotien (VLDL) in RF studies in adults (42), and part of the metabolic syndrome. Triglyceride levels and LDL/HDL ratio were significantly higher in the obese groups than in lean control subjects and were significantly reduced after exercise, suggesting overall reduction in RF for cardiovascular disease in response to intervention.

This study lasted 6 months; however, the length of time required to produce sustained and stable changes after intervention to improve vascular status (FMD, IMT) remains unknown. Previous studies showed that improvement of the endothelial function was reversible within 8 weeks after cessation of training in adults and adolescents (13,15). It is likely, therefore, that exercise needs to be continuous to maintain its benefits for vascular status and risk profiles. We conclude that a 6-month program of enhanced physical exercise improves the endothelial function of the radial artery, reduces IMT of the carotid artery, and has a positive effect on BP and cardiovascular risk profile.

These findings also show that similar programs not only diminish the risk of developing obesity-related cardiovascular RF but also hamper progression of early cardiovascular disease itself. This is important, given the need to identify non-pharmacological interventions for improving vascular statuses in young individuals.

Future studies will be required to assess responses relating to the degree of obesity and intensity and duration of intervention. The long-term impact of exercises on weight control, vascular status, and RF also requires further study, even after termination of such programs.

Study limitations. Consideration has to be given to a certain influence of the high discontinuation rate in both groups (intervention and non-intervention) on the results after 6 months. Low motivation and perseverance might be an intrinsic problem in influencing life-style in obese children. This fact should be taken into account in future studies.

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