

Long-term follow-up of cardiovascular disease risk factors in children after an obesity intervention^{1,2}

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ABSTRACT

Background: Data concerning the long-term improvement of cardiovascular disease (CVD) risk factors after an obesity intervention in children are limited.

Objective: We studied changes in weight status and CVD risk factors in children in an intervention program and evaluated whether these changes were sustained 1 y after the end of the intervention.

Design: We analyzed changes in the SD score (SDS) of body mass index [BMI; in kg/m² (SDS-BMI)], blood pressure (BP), lipids, and homeostasis model assessment index of insulin resistance (HOMA-IR) over the course of 2 y in 240 obese (BMI > 97th percentile) children aged 6–14 y (\bar{x} age: 10.4 y; \bar{x} BMI: 26.9). Of these 240 children, 203 participated in a 1-y intervention program of physical exercise, nutrition education, and behavior therapy. We compared these children with 37 obese children who underwent no intervention and with 12 normal-weight children of the same age and sex.

Results: Obese children had significantly ($P < 0.05$) higher BP, HOMA-IR, and insulin, triacylglycerol, and LDL-cholesterol concentrations and lower HDL-cholesterol concentrations than did normal-weight children. Twenty-nine children dropped out of the intervention. Only in the 126 children who reduced their SDS-BMI did BP (8% and 12% decreases in systolic and diastolic BP, respectively), lipids (12% and 5% decreases in triacylglycerol and LDL cholesterol, respectively; 7% increase in HDL cholesterol), insulin (13% decrease), and HOMA-IR (17% decrease) improve significantly ($P < 0.05$). Reduction in SDS-BMI and all benefits regarding CVD risk factors were sustained 1 y after the end of the intervention in the children whose SDS-BMI decreased.

Conclusions: Long-term multidisciplinary intervention led to a reduction in SDS-BMI in most of the obese children 1 y after the end of the intervention. Reduction in SDS-BMI was accompanied by an improvement in CVD risk factors. *Am J Clin Nutr* 2006;84:490–6.

KEY WORDS Blood pressure, triacylglycerol, LDL cholesterol, HDL cholesterol, glucose, insulin, weight loss, follow-up obesity, outpatient intervention program, children, blood pressure, lipids

INTRODUCTION

The increasing prevalence of obesity in childhood and adolescence poses an ever-widening problem (1). Obese children tend to become obese adults (1). Some obese children and adolescents go on to display a characteristic profile of hypertension, low HDL-cholesterol concentrations, high LDL-cholesterol and

triacylglycerol concentrations, and insulin resistance (metabolic syndrome) (2, 3). Such a metabolic, or atherogenic, profile may create favorable conditions for atherogenic cardiovascular disease (CVD), as shown by greater intima-media thickness in affected obese children (4).

The appropriate approach to reducing the obesity-related health risk is to lose weight and to change body composition. Only a few studies show that a reduction in BMI in childhood leads to an improvement in the atherogenic risk-factor profile (5–10). The data on whether these benefits regarding the CVD risk factors are sustained after the intervention are limited. Therefore, we analyzed the changes in weight status and in the atherogenic risk-factor profile of obese children participating in a 1-y outpatient -term intervention program 1 y after the end of intervention. We compared these data with those for normal-weight children and those for obese children who did not undergo the intervention.

SUBJECTS AND METHODS

We examined 203 obese children aged 6–14 y who were attending an outpatient long-term intervention program over the course of 2 y. The children had to prove their motivation by filling out a questionnaire concerning their eating and exercise habits (11) and by participating in local exercise groups for overweight children for ≥ 8 wk (12). The control group comprised 37 obese children who met these criteria but whose families lived too far away to travel regularly to our obesity clinic. We did not analyze children who had other reasons for not participating in the intervention or children who failed to meet our motivation criteria. In addition, we analyzed 12 normal-weight children for whom the age and sex distribution was the same.

The Obeldicks intervention program (named for a popular European comic figure) was based on physical exercise, nutrition education, and behavioral therapy, including the individual psychological care of the child and his or her family (11–13). The

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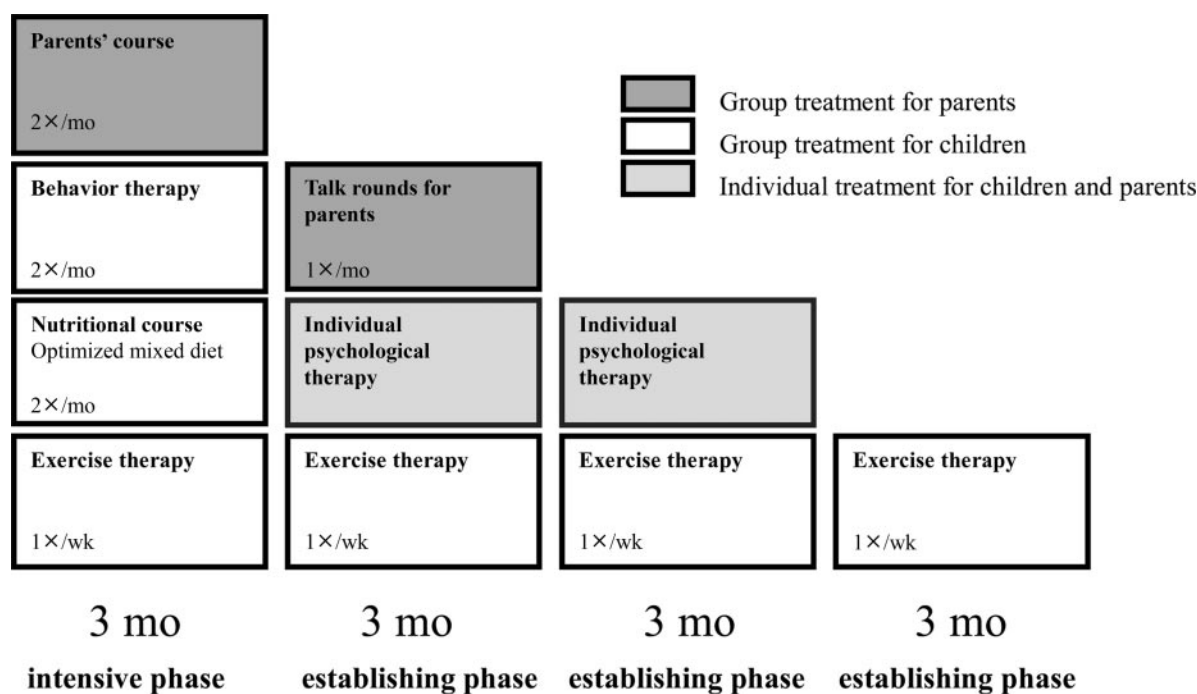


FIGURE 1. Structure of the Obeldicks outpatient training program.

aims were to reduce overweight and to improve the CVD risk factor profile by lifestyle modification. An interdisciplinary team of pediatricians, dietitians, psychologists, and exercise physiologists was responsible for the training. The children were divided into groups according to their sex and age. The 1-y training program was divided into 3 phases (Figure 1). In the intensive phase (3 mo), the children took part in the nutritional course and in the eating-behavior course in 6 group sessions, each lasting for 1.5 h. At the same time, the parents were invited to attend 6 parents' evenings. In the establishing phase (6 mo), individual psychological family therapy was provided (30 min/mo). In the follow-up phase of the program (3 mo), further individual care was possible if necessary. The exercise therapy took place 1 time/wk throughout the year and consisted of ballgames, jogging, trampoline jumping, and instructions in physical exercise as part of everyday life, as well as a reduction in the amount of time spent watching television.

The nutritional course was based on the prevention concept of the optimized mixed diet; the scientific recommendations were translated into food-based dietary guidelines with consideration of the dietary habits of children and families in Germany (14). In contrast to the present-day diet of children in Germany, which includes 38% of energy intake as fat, 13% of energy as proteins, and 49% of energy as carbohydrates (14% as sugar and 35% as other carbohydrates; 15), the optimized mixed diet was reduced in both fat and sugar and contained 30% of energy as fat, 15% of energy as proteins, and 55% of energy as carbohydrates (5% as sugar and 50% as other carbohydrates). The children followed a "traffic-light system" when selecting their food (15, 16). In this system, the foods and drinks available in Germany were separated according to their fat and sugar contents into red, orange, and green categories: red meant "stop," orange meant "consider the amount," and green meant "OK when hungry or thirsty." The traffic-light system and the intervention program were described

in detail elsewhere (11–13). Three-day weighed dietary records showed a reduction in the mean (\pm SD) energy content of 1459 ± 379 kcal/d before intervention to 1250 ± 299 kcal/d at the end of intervention and a reduction in the proportion of energy from fat from $36.3 \pm 5.0\%$ to $30.4 \pm 7.1\%$ (17).

Children with endocrine disorders, familial hyperlipidemia, or syndromal obesity were excluded from the study. Obesity was defined as a BMI above the 97th percentile; children with such a BMI are likely to have BMI values of ≥ 30 at the age of 18 y, according to population-specific data (18). Height was measured to the nearest centimeter by using a rigid stadiometer. While the subjects were unclothed, weight was measured to the nearest 0.1 kg by using a calibrated balance scale. The degree of overweight was quantified by using Cole's least-square means method, which normalized the BMI skewed distribution and expressed BMI as an SD score (SDS-BMI; 19). Reference data for German children were used (18). Because BMI is sex- and age-dependent in childhood, reduction in overweight was defined by a reduction in SDS-BMI.

The following variables were measured in the fasting state in serum by using commercially available test kits: triacylglycerol (Roche Diagnostics, Mannheim, Germany), HDL and LDL cholesterol (Ortho Clinical Diagnostics, Neckargemuend, Germany), glucose (Boehringer, Mannheim, Germany) and insulin (Abbott, Wiesbaden, Germany). Intraassay and interassay CVs of these variables were $< 5\%$. The children and their parents had been carefully instructed to fast for ≥ 10 h. Homeostasis model assessment was used to detect the degree of insulin resistance [(HOMA-IR) 20]. The resistance can be assessed from the fasting glucose and insulin concentrations by using the following formula:

$$\text{Resistance} = [\text{insulin (mU/L)} \times \text{glucose (mmol/L)}] / 22.5 \quad (1)$$

TABLE 1
Cardiovascular disease risk factors in obese and normal-weight children¹

	Obese children (n = 240)	Normal-weight children (n = 12)	P ²
Age (y)	10.4 (10.2, 10.5) ³	10.5 (9.0, 11.9)	0.863
Girls (%)	46.7 (40.2, 53.2)	50.0 (21.1, 78.9)	0.821
BMI (kg/m ²)	26.9 (26.3, 27.4)	17.9 (16.7, 19.2)	<0.001
SDS-BMI	2.4 (2.3, 2.4)	0.2 (-0.2, 0.5)	<0.001
Systolic blood pressure (mm Hg)	120.2 (118.3, 122.1)	106.1 (99.5, 112.6)	<0.001
Diastolic blood pressure (mm Hg)	62.9 (61.5, 64.2)	55.4 (51.2, 59.7)	0.003
LDL cholesterol (mg/dL)	117.6 (112.8, 122.4)	86.8 (77.5, 96.2)	<0.001
HDL cholesterol (mg/dL)	47.4 (46.2, 48.6)	58.6 (47.9, 69.3)	0.023
Triacylglycerol (mg/dL)	126.1 (115.7, 136.5)	85.5 (66.9, 104.1)	0.020
Glucose (mg/dL)	89.4 (88.5, 90.2)	87.6 (85.1, 90.1)	0.265
Insulin (mU/L)	18.3 (16.7, 19.8)	9.4 (6.2, 12.6)	<0.001
HOMA-IR	4.0 (3.6, 4.4)	2.0 (1.3, 2.7)	<0.001

¹ SDS-BMI, SD score of BMI; HOMA-IR, homeostasis model assessment of insulin resistance.

² Chi-square test, *t* test, or Mann-Whitney *U* test as appropriate.

³ \bar{x} ; 95% CI in parentheses (all such values).

Blood pressure was measured by using a validated protocol (21). Systolic and diastolic blood pressures were measured twice by using a calibrated sphygmomanometer at the right arm after the subject rested for 10 min in the supine position; the 2 measurements were averaged. The cuff size, which was based on the length and circumference of the upper arm, was chosen to be as large as possible without having the elbow skin crease obstruct the stethoscope (21). Weight status, lipids, glucose, and insulin were measured at baseline, at end of the 1-y intervention, and 1 y after the end of intervention (ie, 2 y after baseline) in the obese children.

All analyses comparing the intervention and control groups were performed by following the intention-to-treat approach with respect to the 29 dropouts. Confidence limits for means and proportions were calculated on that basis of the *t*-distribution or binomial distribution as appropriate. Differences between obese and normal-weight children were tested by using chi-square, *t*, or Mann-Whitney *U* tests as appropriate. Analysis of variance for repeated measurements (RM-ANOVA) and Bonferroni correction for multiple outcomes were used to examine differences between time points in obese children who did and did not undergo the intervention. If the time \times intervention interaction was significant, RM-ANOVA models were calculated with stratification by intervention or control group. If the sphericity assumption was violated [$P < 0.05$, Mauchly's test of sphericity (22)], the Huynh-Feldt correction was used for estimating *P* values. Analogue models were calculated for the effect of overweight reduction on BMI and SDS-BMI in treated children. The overall effect of SDS-BMI reduction in obese children with treatment was adjusted for the child's age in a doubly multivariate RM-ANOVA with outcome and time point as repeated measurements. *P* values were reported as stratified by SDS-BMI reduction groups because of a significant time \times SDS-BMI reduction interaction. Significance was set at $P < 0.05$. All calculations were carried out with the use of WINSTAT for EXCEL and SAS statistical software (version 9.1; SAS Institute Inc, Cary, NC).

Written informed consent was obtained from all subjects and their parents. The local ethics committee of the University of Witten/Herdecke approved the study.

RESULTS

The 240 obese children (203 participants and 37 children who did not undergo the intervention) had significantly higher blood pressures, insulin resistance index (by HOMA-IR), and insulin, triacylglycerol, and LDL-cholesterol concentrations, whereas HDL-cholesterol concentrations were significantly lower than those in the 12 normal-weight children (Table 1). At baseline, the obese children in the intervention and control groups did not differ significantly with respect to age ($P = 0.496$), sex ($P = 0.817$), or degree of overweight, ie, SDS-BMI ($P = 0.127$; Table 2). Moreover, they did not differ at baseline with respect to systolic ($P = 0.992$) or diastolic ($P = 0.486$) blood pressure or glucose ($P = 0.516$), insulin ($P = 0.234$), triacylglycerol ($P = 0.443$), HDL- ($P = 0.956$) or LDL- ($P = 0.765$) cholesterol concentrations, or HOMA-IR ($P = 0.233$).

Twenty-nine (14%) of the 203 children participating in the intervention program dropped out. They did not differ significantly from the children completing the intervention program in age ($P = 0.409$), sex ($P = 0.863$), or degree of overweight (SDS-BMI, $P = 0.366$). They also did not differ significantly at baseline in systolic ($P = 0.173$) and diastolic ($P = 0.498$) blood pressure or in glucose ($P = 0.334$), insulin ($P = 0.884$), triacylglycerol ($P = 0.748$), HDL- ($P = 0.929$) or LDL- ($P = 0.613$) cholesterol concentrations, or HOMA-IR ($P = 0.783$). None of the remaining 174 obese children dropped out in the follow-up period.

The changes in blood pressure, triacylglycerol, HDL and LDL cholesterol, glucose, insulin, and HOMA-IR at the end of intervention and 1 y after the end of intervention are shown in Table 2. The reduction in SDS-BMI achieved in the intervention period was sustained 1 y after the end of intervention, whereas there was no change in SDS-BMI over the course of 2 y in the children who did not undergo the intervention (see Table 2).

Of the 174 children completing the intervention program, SDS-BMI decreased in 126 (72%), whereas 48 had no reduction in SDS-BMI during the intervention program (Table 3). The successful and unsuccessful children did not differ significantly in their sex distribution ($P = 0.256$) or degree of baseline overweight ($P = 0.196$). At baseline, the children whose SDS-BMI

TABLE 2

Weight status and cardiovascular disease risk factors in obese children with and without a 1-y intervention¹

	Baseline ²	1 Y later	2 Y later	<i>P</i>		
				Intervention × time interaction ³	Time effect ⁴	Intervention effect ⁵
<i>n</i>						
Intervention ⁶	203	174	174			
No intervention ⁷	37	37	37			
BMI (kg/m ²)						
Intervention	27.0 (26.4, 27.6) ⁸	27.1 (26.4, 27.6)	28.2 (27.4, 29.0)	0.013	<0.001	—
No intervention	26.1 (25.2, 27.8)	28.1 (27.0, 29.20)	29.0 (28.0, 30.8)		<0.001	
SDS-BMI						
Intervention	2.4 (2.3, 2.4)	2.1 (2.1, 2.2)	2.1 (2.1, 2.2)	0.007	<0.001	—
No intervention	2.3 (2.2, 2.4)	2.3 (2.1, 2.4)	2.3 (2.1, 2.4)		0.872	
SBP (mm Hg)						
Intervention	120.3 (118.3, 122.4)	116.0 (113.9, 118.0)	117.1 (115.1, 119.2)	0.002	<0.001	—
No intervention	119.4 (114.9, 123.8)	124.7 (119.0, 130.5)	123.0 (117.6, 128.3)		0.191	
DBP (mm Hg)						
Intervention	63.2 (61.7, 64.8)	60.0 (58.6, 61.4)	61.7 (60.3, 63.1)	0.467	<0.001	0.517
No intervention	60.8 (57.6, 64.1)	59.6 (56.6, 62.7)	61.8 (58.6, 65.0)			
LDL cholesterol (mg/dL)						
Intervention	117.4 (112.1, 122.6)	113.0 (108.0, 117.9)	112.9 (107.6, 118.1)	0.059	0.440	0.079
No intervention	118.8 (106.0, 131.7)	129.4 (115.3, 143.5)	125.0 (109.3, 140.6)			
HDL cholesterol (mg/dL)						
Intervention	47.5 (46.2, 48.8)	49.0 (47.6, 50.4)	49.5 (48.1, 50.9)	0.368	0.013	0.416
No intervention	46.7 (44.1, 49.3)	48.9 (44.7, 53.0)	46.9 (43.4, 50.4)			
Triacylglycerol (mg/dL)						
Intervention	126.2 (115.4, 137.0)	119.9 (109.5, 130.2)	116.3 (106.5, 126.1)	0.803	0.121	0.825
No intervention	125.4 (91.3, 159.4)	121.3 (101.6, 141.0)	123.2 (104.6, 141.8)			
Glucose (mg/dL)						
Intervention	89.5 (88.5, 90.4)	88.9 (88.0, 89.8)	88.3 (87.4, 89.2)	0.328	0.040	0.940
No intervention	88.9 (86.8, 91.0)	89.9 (87.8, 92.1)	87.6 (85.8, 89.5)			
Insulin (mU/L)						
Intervention	18.4 (16.7, 20.1)	17.3 (15.4, 19.1)	17.9 (16.1, 19.7)	0.008	0.181	—
No intervention	17.3 (13.1, 21.5)	20.6 (16.2, 25.0)	21.2 (17.6, 24.8)		0.054	
HOMA-IR						
Intervention	4.1 (3.7, 4.5)	3.8 (3.4, 4.2)	4.0 (3.6, 4.4)	0.012	0.205	—
No intervention	3.7 (2.8, 4.6)	4.6 (3.5, 5.7)	4.6 (3.8, 5.3)		0.052	

¹ SDS-BMI, SD score of BMI; SBP, systolic blood pressure; DBP, diastolic blood pressure; HOMA-IR, homeostasis model assessment. *P* values were derived from stratified ANOVA for repeated measures (baseline and 1 y and 2 y later), after adjustment for multiple testing (Bonferroni) and nonsphericity if appropriate.

² No significant differences between intervention and nonintervention groups at baseline for all variables displayed in the table.

³ All significant interaction terms could already be observed at the end of intervention (1 y later).

⁴ If the time × intervention interaction was significant, stratified *P* values for time effect were reported.

⁵ *P* value was not reported if time × intervention interaction was significant.

⁶ Girls were 54%, 53%, and 53% of the cohort at baseline, 1 y later, and 2 y later, respectively.

⁷ Girls were 51% of the cohort at all three times.

⁸ \bar{x} ; 95% CI in parentheses (intention-to-treat analysis) (all such values).

did not decrease in the intervention period were significantly ($P < 0.001$) older (\bar{x} age: 11.5 y; 95% CI: 10.9, 12.1 y) than were the children whose SDS-BMI decreased (9.9 y; 9.5, 10.3 y).

In an ANOVA for repeated measurements (baseline and 2 y later) after adjustment for age, the significant reduction achieved in SDS-BMI was sustained 1 y after the end of intervention (ie, 2 y after baseline) in the children with reduction of SDS-BMI in the intervention period (Table 3). The multivariate RM-ANOVA (baseline, 1 y later, and 2 y later) to assess the effect of SDS-BMI reduction on CVD risk factors was adjusted for age in all treated children; this yielded a significant time × SDS-BMI reduction

interaction ($P < 0.001$). Therefore, the effect of SDS-BMI reduction on CVD risk factors was calculated in multivariate RM-ANOVA models stratified by SDS-BMI change. In children with SDS-BMI reduction, baseline mean CVD risk factors improved significantly at the end of intervention after adjustment for age ($P = 0.041$): HDL cholesterol increased by 7%, and systolic blood pressure decreased by 8%, diastolic blood pressure by 12%, triacylglycerol by 12%, LDL cholesterol by 5%, insulin by 13%, and HOMA-IR by 17%. These improvements in CVD risk factors were sustained 1 y after the end of intervention (Figure 2). Compared with the control group, the children with SDS-BMI

TABLE 3

Weight status in obese children according to their success in a 1-y intervention¹

	Baseline ²	1 Y later	2 Y later	<i>P</i> ³	
				Time × overweight-reduction interaction	Time effect ⁴
BMI (kg/m ²)					
Reduction in overweight (<i>n</i> = 126)	26.4 (25.8, 27.1) ⁵	25.8 (24.8, 26.7)	26.9 (26.1, 27.6)	<0.001	0.042
No reduction in overweight (<i>n</i> = 48)	28.3 (26.8, 29.7)	30.5 (28.9, 32.0)	32.4 (30.2, 34.5)		<0.001
SDS-BMI					
Reduction in overweight (<i>n</i> = 126)	2.4 (2.3, 2.5)	2.0 (1.9, 2.0)	2.0 (1.9, 2.1)	<0.001	<0.001
No reduction in overweight (<i>n</i> = 48)	2.3 (2.2, 2.5)	2.5 (2.3, 2.6)	2.5 (2.3, 2.7)		<0.001

¹ SDS-BMI, SD score of BMI.² No significant differences between intervention and nonintervention groups at baseline for all variables displayed in the table.³ ANOVA for repeated measures (baseline and 2 y later) after adjustment for multiple testing (Bonferroni) and nonsphericity if appropriate.⁴ Stratified analysis due to significant time × overweight-reduction interaction.⁵ \bar{x} ; 95% CI in parentheses (all such values).

reduction had 8% lower systolic and 3% lower diastolic blood pressure, 19% lower triacylglycerol, 9% lower LDL cholesterol, 29% lower insulin, and 28% lower HOMA-IR, and 8% higher HDL-cholesterol concentrations at the end of follow-up.

In contrast to these findings, we did not observe a significant improvement in CVD risk factors in the children without SDS-BMI reduction in the intervention group ($P = 0.277$). In all children without SDS-BMI reduction (both intervention and control groups), CVD risk factors did not change significantly ($P = 0.118$) at the end of intervention (ie, at 1 y) and 1 y after end

of intervention (ie, at 2 y) according to a multivariate RM-ANOVA after adjustment for age (Figure 2).

DISCUSSION

In the current study, we showed the effect of a 1-y multidisciplinary outpatient intervention program on CVD risk factors in obese children not only at the end of intervention but also at follow-up 1 y later. At baseline, as compared with the normal-weight children, the obese children had significantly higher

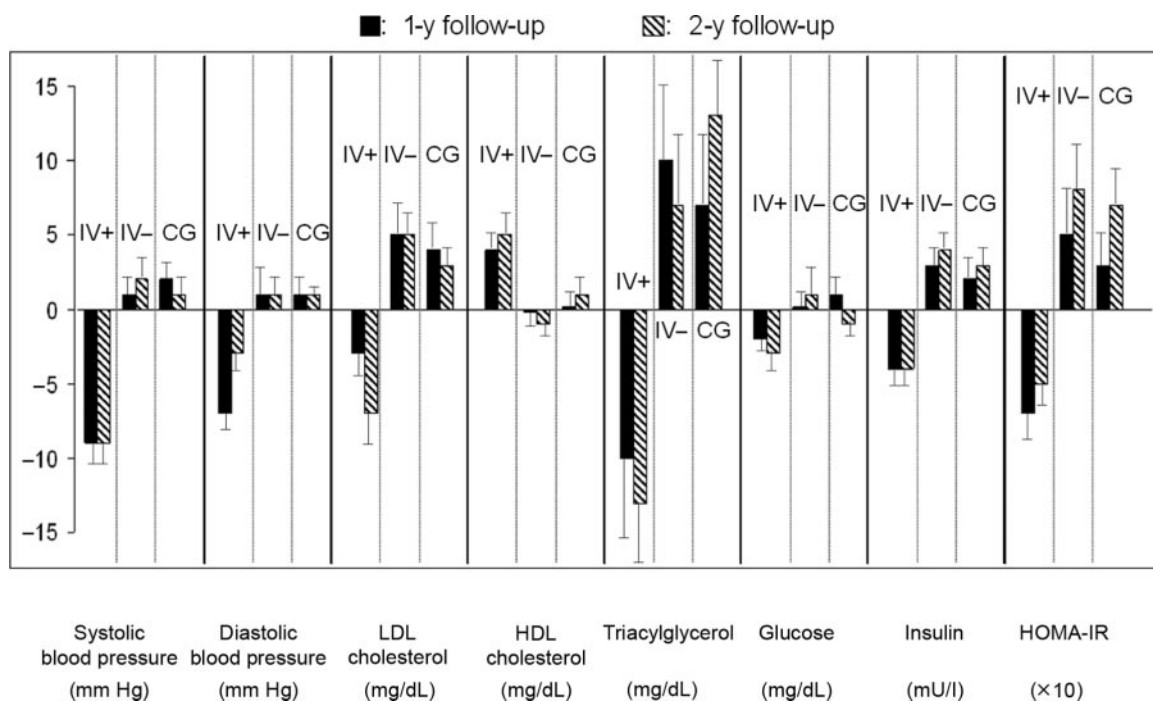


FIGURE 2. Mean (\pm SEM) changes in cardiovascular disease risk factors from baseline over the course of 2 y in 126 children with reduction in the SD score (SDS) of BMI (SDS-BMI) in a 1-y intervention program (IV+), in 48 children without reduction of SDS-BMI in a 1-y intervention program (IV-), and in 37 children who did not participate in the intervention (CG, control group). HOMA-IR, homeostasis model assessment index of insulin resistance. A significant interaction between SDS-BMI reduction and cardiovascular disease risk factors was observed ($P < 0.001$) in a multivariate repeated-measures ANOVA after adjustment for age. In children with reduction of SDS-BMI (IV+), all cardiovascular disease risk factors were significantly improved ($P = 0.041$, multivariate repeated-measures ANOVA), whereas cardiovascular disease risk factors did not change significantly ($P = 0.118$) in children without reduction in SDS-BMI (both IV- and CG).

blood pressures, HOMA-IR, and insulin, triacylglycerol and LDL-cholesterol concentrations, whereas HDL-cholesterol concentrations were significantly lower. These findings are in accordance with other studies (2, 6). The Obeldicks intervention program led to a reduction in overweight in most of the obese participants. The reduction of SDS-BMI was accompanied by an improvement in blood pressure and triacylglycerol, insulin, and HDL- and LDL-cholesterol concentrations, as well as in HOMA-IR. These results are in line with earlier studies in children showing that a reduction in BMI leads to an improvement in CVD risk factors (5–10). Most important, our study showed that the improvement in CVD risk factors was sustained in a 1-y follow-up period in children who reduced their SDS-BMI in the intervention period. In addition, the achieved reduction in SDS-BMI was sustained in the follow-up period.

In contrast to this, the children without SDS-BMI reduction in the intervention period increased in overweight in the follow-up period. The CVD risk factor profiles of those children and of the children who did not undergo the intervention did not improve during follow-up.


Our findings of improved CVD risk factors over the course of 2 y in obese children with SDS-BMI reduction contrast with findings of the only study in obese children with a follow-up period of 5 y, which found no reduction in triacylglycerol and insulin concentrations (6). The small sample size of 20 children and the small amount of overweight reduction in that study probably explain the difference between its results and those of the current study.

The improvement in CVD risk factors in the obese children in the current study has a clinical effect, because insulin resistance, with its clinical features hypertriacylglycerolemia, low HDL cholesterol, and hyperinsulinemia, predominately determines the morbidity and mortality of obesity (1, 23). The influence of these CVD risk factors on vascular changes is already detectable in childhood as shown by measurements of intima-media thickness (4). The mean reduction in LDL cholesterol and triacylglycerol and the increase in HDL cholesterol in the current study were comparable to the effect of medical therapy such as simvastatin in children with familial hypercholesterolemia (24, 25). The mean reduction in systolic and diastolic blood pressures that was due to SDS-BMI reduction was similar to the effects of medical therapies such as captopril in adults (26, 27). In summary, the improvements in the lipid profile and blood pressure were clinically just as significant as those that may be achieved with pharmacologic treatment, but that intervention does not carry concern about possible adverse effects.

The observed changes in the atherogenic risk-factor profile in our sample represented the effects of a reduced caloric and fat intake and increased physical activity, which have been shown in an earlier study by the participants in the Obeldicks intervention program (17). Because physical exercise, behavior therapy, and nutrition education were performed together in the intervention group, we cannot distinguish the effect of each one on the CVD risk factors. Furthermore, the effects of dieting and increased physical activity probably strengthened each other. Physical activity and reduced-calorie and -fat diets improve dyslipidemia, blood pressure, and insulin resistance (28–30). HDL-cholesterol concentrations decrease during the period of dieting but tend to rise some months later when the degree of overweight has stabilized at a reduced level (30, 31).

Our findings showed that reduction of overweight in an intervention program was a predictive factor for an improvement in CVD risk factors. Only the children with SDS-BMI reduction improved their CVD risk factor profiles. The children in the intervention program without overweight reduction did not show this improvement.

Our study has some potentially important limitations. First, BMI percentiles were used to classify overweight, and, whereas BMI is a good measure for overweight, it has limitations as an indirect measure of fat mass. In addition, CVD risk factors are more closely related to fat distribution than to degree of overweight (32). However, reference data on fat distribution were not available for German children. Second, the insulin resistance index is only an assessment of insulin resistance; insulin-clamp studies are the gold standard for analyzing insulin resistance, but they are difficult to perform in field studies (33). Third, the dropouts did not differ with respect to anthropometric markers or CVD risk factors and were considered in the intention-to-treat approach analysis. Fourth, this study was not randomized. Therefore, we cannot exclude different degrees of motivation for behavioral changes in the participants of the intervention program and in the control group. However, the children in the intervention and control groups did not differ in anthropometric markers or CVD risk factors. Furthermore, a significant effect of motivation on CVD risk factors seems unlikely.

In summary, long-term multidisciplinary intervention led to a reduction in SDS-BMI in most of the participants, which was associated with a clinically significant improvement in CVD risk factors. The changes in SDS-BMI and, most important, the changes in CVD risk factors were sustained 1 y after the end of intervention. 

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TR and WA contributed to the study design; TR, GS, and WA contributed to the data analysis; AMT performed the statistical analysis; and all authors contributed to the manuscript preparation. None of the authors had a personal or financial conflict of interest.

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