

Response of Severely Obese Children and Adolescents to Behavioral Treatment

Pernilla Danielsson, RN, PhD; Jan Kowalski, BA; Örjan Ekblom, PhD; Claude Marcus, MD, PhD

Objectives: To investigate whether the degree of obesity predicts the efficacy of long-term behavioral treatment and to explore any interaction with age.

Design: A 3-year longitudinal observational study. Obese children were divided into 3 age groups (6-9, 10-13, and 14-16 years) and also into 2 groups (moderately obese, with a body mass index [BMI]–standard deviation [SD] score [or *z* score] of 1.6 to <3.5, and severely obese, with a BMI-SD score of ≥ 3.5).

Setting: National Childhood Obesity Center, Stockholm, Sweden.

Participants: Children 6 to 16 years of age who started treatment between 1998 and 2006.

Intervention: Behavioral treatment of obesity.

Main Outcome Measure: Change in BMI-SD score during 3 years of treatment; a reduction in BMI-SD score of 0.5 units or more was defined as clinically significant.

Results: A total of 643 children (49% female children)

met the inclusion criteria. Among the youngest moderately obese children, 44% had a clinically significant reduction in BMI-SD score (mean reduction, -0.4 [95% CI, -0.55 to -0.32]). Treatment was less effective for the older moderately obese children. Twenty percent of children who were 10 to 13 years of age and 8% of children who were 14 to 16 years of age had a reduction in BMI-SD score of 0.5 units or more; 58% of the severely obese young children showed a clinically significant reduction in BMI-SD score (mean reduction, -0.7 [95% CI, -0.80 to -0.54]). The severely obese adolescents showed no change in mean BMI-SD score after 3 years, and 2% experienced clinically significant weight loss. Age was found to be a predictor of a reduction in BMI-SD score (odds ratio, 0.68 units per year [95% CI, 0.60-0.77 units per year]).

Conclusions: Behavioral treatment was successful for severely obese children but had almost no effect on severely obese adolescents.

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Author Affiliations: National Childhood Obesity Center, Departments of Pediatrics and of Clinical Science, Intervention, and Technology, Karolinska University Hospital, Karolinska Institutet (Drs Danielsson, Ekblom, and Marcus and Mr Kowalski), and Astrand Laboratory of Work Physiology, Swedish School of Sport and Health Sciences (Dr Ekblom), Stockholm, Sweden.

CHILDHOOD OBESITY IS A MAJOR problem worldwide, and it is important to optimize treatment to reduce future health hazards and increase the quality of life for these children. The most common form of evidence-based treatment consists of behavioral interventions focused on eating habits and physical activity.¹ Although behavioral treatment has been shown to have positive effects on the degree of obesity in many children,^{1,2} it is still unclear whether there are subgroups with different responses.

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In recent studies,²⁻⁷ we and others have shown that age at the start of treatment appears to be of major importance for the

success of the treatment. For adolescents, we found that a decreased body mass index (BMI)–standard deviation (SD) score was observed only during the first treatment year and that no effect could be statistically demonstrated for treatment in years 2 and 3.

In a 1-year multimodal intervention, Nowicka et al⁸ found that the degree of obesity may affect treatment outcome. Adolescents with a BMI-SD score of less than 3.5 showed a significant decrease in this measure (ie, degree of obesity) during 1 year of treatment, whereas adolescents with a BMI-SD score of 3.5 or greater showed no decrease.⁸ This is an alarming observation because the degree of childhood obesity is known to be a risk factor for adult obesity.⁹ The aim of the present study was to investigate differences in the efficacy of obesity treatment based on the

degree of obesity and the age of the child at the start of treatment.

METHODS

Our study is a longitudinal study of 966 patients 6 to 16 years of age who were referred to and accepted for treatment at the National Childhood Obesity Center, Stockholm, Sweden, between January 1998 and December 2006. All patients had at least 1 visit to the clinic in accordance with the inclusion criteria. At the end of the study period, they had had the opportunity to be in treatment for 3 years. Follow-up was terminated after 3 years of treatment or at the time of loss to follow-up, whichever came first. Only patients with primary obesity undergoing behavioral treatment were included ($n=643$). Patients were excluded ($n=323$) if they were receiving other obesity treatments (such as a low-calorie diet or a very-low-calorie diet), if they were receiving pharmacological and/or surgical treatment, or if they received a diagnosis related to the development of obesity (such as obesity-related syndromes, obesity surgery within the central nervous system, myelomeningocele, or various types of mental and psychological disorders). This is an extension of the recently published cohort study by Danielsson et al.⁷

The National Childhood Obesity Center is a nationwide referral center for children with severe obesity. Treatment is multimodal and consists of very-low-calorie diets, pharmacological treatment using orlistat and/or sibutramine hydrochloride, and surgical treatment¹⁰⁻¹³; behavioral treatment is always a part of the treatment as well. The behavioral treatment was described previously⁷ and follows generally accepted guidelines.¹⁴⁻¹⁷ The purpose of the behavioral treatment is to help patients, with the support of their parents, to adopt healthier eating habits, to become more physically active, and to reduce the time spent in sedentary activities. The guiding principle is that the treatment should be intensified if it failed. Therefore, the frequency of weight checks varied from weekly to once a year, and there was no association between the frequency of visits and the results of treatment.⁷ Obesity is a chronic disease, and therefore patients should remain in treatment for at least 5 years regardless of the results.

The present study is based on data extracted from the BORIS database, which includes data from the first visit and subsequent visits to the National Childhood Obesity Center and comprises background and demographic characteristics (ie, sex, pubertal status, age at onset of obesity, development of weight over time, parental weight status, socioeconomic status [parental occupation] and BMI-SD score).¹⁸ At all visits, trained nurses assessed the height (with the Ulmer stadiometer) and body mass (with the Vetek TI-1200) of children wearing underwear and a lightweight shirt or blouse.

To be able to classify the degree of obesity and to compare weight data between children of different ages and sexes, a BMI standardized age- and sex-dependent deviation score (the BMI-SD score) or BMI z score is used. The BMI-SD score is based on a Swedish population of children born between 1973 and 1975.¹⁸ The BMI-SD score was calculated using the BORIS database. The children were divided into 3 age groups, defined by age at the start of behavioral treatment. The age groups formed were 6 to 9.9 years (prepubertal), 10 to 13.9 years (pubertal), and 14 to 16.9 years (late pubertal or postpubertal). Pubertal status (according to Tanner and Whitehouse¹⁹) was assessed by a pediatrician and used as a covariate in the final statistical model.

The children were further divided into 2 groups, depending on the degree of obesity, as moderately obese (BMI-SD score of 1.6 to <3.5) and severely obese (BMI-SD score of ≥ 3.5) ac-

ording to Karlberg et al.¹⁸ We defined a clinically significant weight loss as 0.5 units or more, which is within the range where positive effects on cardiometabolic risk markers can be found in children.²⁰⁻²³ A BMI-SD score of 3.5 or greater was classified as severely obese,⁸ which corresponds to a BMI (calculated as weight in kilograms divided by height in meters squared) of 35 to 36 in 18-year-old boys and girls.

Age at onset of obesity was derived from growth charts as the age at which the BMI exceeded the BMI that forecasts an adult BMI of greater than 30.²⁴ Age at onset of obesity was underreported; 24% of the children had missing data in the BORIS database. However, there were no differences between children with missing data and the rest of the cohort (data not shown). The children were divided into 3 groups (younger than 3 years, 3.1-6 years, and older than 6 years) based on age at onset.

Parental BMI data in the BORIS database are based on the weight and height data reported by the parents at the first clinical visit. The parents are classified as overweight or obese according to the international standards²⁵: normal weight (BMI = 18-24.9), overweight (BMI = 25-29.9), or obese (BMI = 30).

Socioeconomic status was defined in terms of parental occupation or education. This was coded, based on official Swedish socioeconomic categories and the Swedish standard classification of occupations provided by Statistics Sweden, into 3 categories: (1) at least 1 parent with an academic degree, (2) at least 1 parent with a post-upper secondary school education, and (3) others (unemployed, early/disability retired, long-term sick-listed, students, and housewives).^{8,20-22}

STATISTICAL ANALYSES

The primary statistical analyses in our study were performed using the analysis of covariance with regard to the change in BMI-SD score at follow-up years 1, 2, and 3, including the BMI-SD score at the first visit (as a covariate in the model) and degree of obesity, age at start of treatment, age at onset of obesity, sex, Tanner pubertal stage, parental weight status, and socioeconomic status (as fixed factors in the model). The interaction between age at start of treatment and BMI-SD score greater or less than 3.5 was also investigated.

The secondary statistical analyses were performed using logistic regression for the purpose of discriminant analyses. The first model was used to explore the best cutoff levels to identify children at high risk for developing severe obesity at 14 to 16 years of age. Data from children who were 3, 5, and 7 years of age were used to estimate cutoff levels. Predicted values from the results of the logistic regression modeling were compared with observed values to estimate the sensitivity (ie, children correctly predicted to develop severe obesity) and the specificity (ie, children correctly predicted not to develop severe obesity). The second model was used to explore the odds for a decrease in BMI-SD score of at least 0.5 units or at least 1.0 units, respectively, by age at start of treatment.

ANALYSIS OF POPULATIONS

Two populations were defined. First, the completers population was defined as all children who were completely assessed for BMI-SD scores from the first visit through the 3-year follow-up visits (ie, observed cases). Second, the full-analysis population was defined as all children who had a first visit. The full-analysis population was used to perform a sensitivity analysis of the completers population. In the full-analysis population, missing data for patients lost to follow-up were replaced using (1) the last observation carried forward (LOCF) method and (2) the baseline observation carried forward method. After 3

Table. Descriptive Statistics of Baseline Characteristics of Children, Stratified by Age Group and BMI SDS at Inclusion^a

Characteristic	6-9 y		10-13 y		14-16 y		Total	
	BMI SDS \geq 3.5	BMI SDS < 3.5	BMI SDS \geq 3.5	BMI SDS < 3.5	BMI SDS \geq 3.5	BMI SDS < 3.5	BMI SDS \geq 3.5	BMI SDS < 3.5
Children, No.	91	54	98	194	82	124	271	372
Age, mean (SD), y	8.2 (1.1)	8.9 (0.8)	11.7 (1.1)	12.2 (1.0)	15.6 (0.9)	15.1 (0.8)	11.7 (3.1)	12.7 (2.2)
Sex, No.								
Male	60	13	67	98	25	67	152	178
Female	31	41	31	96	57	57	119	194
Tanner score, No. (%)								
1	68 (75)	40 (74)	23 (23)	39 (20)	0 (0)	1 (1)	91 (34)	80 (22)
2	3 (3)	4 (7)	17 (17)	42 (22)	0 (0)	3 (2)	20 (7)	49 (13)
3	3 (3)	1 (2)	20 (20)	30 (15)	5 (6)	14 (11)	28 (10)	45 (12)
4	1 (1)	0 (0)	7 (7)	24 (12)	11 (13)	22 (18)	19 (7)	46 (12)
5	0 (0)	0 (0)	10 (10)	12 (6)	43 (52)	45 (36)	53 (20)	57 (15)
Missing	16 (18)	9 (17)	21 (21)	47 (24)	23 (28)	39 (31)	60 (22)	95 (26)
Weight, mean (range), kg	59 (37-104)	50 (28-74)	91 (49-156)	78 (41-114)	121 (88-191)	95 (48-129)	89 (37-191)	80 (28-129)
BMI, mean (SD)	31 (4.3)	26 (2.7)	36 (4.7)	31 (3.5)	42 (4.4)	33 (2.6)	36 (6.3)	31 (3.8)
BMI SDS, mean (SD)	4.28 (0.56)	3.11 (0.37)	3.76 (0.2)	3.02 (0.4)	3.86 (0.3)	3.02 (0.3)	3.96 (0.4)	3.04 (0.4)
Age at onset of obesity, No. (%)								
<3 y	45 (49)	16 (30)	32 (33)	26 (13)	23 (28)	9 (7)	100 (37)	51 (14)
3-6 y	30 (33)	23 (43)	39 (40)	77 (40)	26 (32)	39 (31)	95 (35)	139 (37)
>7 y	0 (0)	3 (6)	5 (5)	42 (22)	11 (13)	48 (39)	16 (6)	93 (25)
Missing	16 (18)	12 (22)	22 (22)	49 (25)	22 (27)	28 (23)	60 (22)	89 (24)
BMI of father, No. (%)								
<25	14 (15)	13 (24)	14 (14)	37 (19)	9 (11)	30 (24)	37 (14)	80 (22)
\geq 25	33 (36)	21 (39)	34 (35)	76 (39)	25 (30)	38 (31)	92 (34)	135 (36)
\geq 30	25 (27)	7 (13)	31 (32)	34 (18)	24 (29)	25 (20)	80 (30)	66 (18)
Not reported	19 (21)	13 (24)	19 (19)	47 (24)	24 (29)	31 (25)	62 (23)	91 (24)
BMI of mother, No. (%)								
<25	25 (27)	18 (33)	19 (19)	58 (30)	12 (15)	31 (25)	56 (21)	107 (29)
\geq 25	28 (31)	19 (35)	25 (26)	54 (28)	19 (23)	36 (29)	72 (27)	109 (29)
\geq 30	29 (32)	8 (15)	37 (38)	34 (18)	35 (43)	34 (27)	101 (37)	90 (24)
Not reported	9 (10)	9 (17)	17 (17)	47 (22)	16 (20)	23 (19)	42 (15)	66 (18)
SES, No. (%)								
Academic degree	12 (13)	13 (24)	21 (21)	32 (16)	17 (21)	26 (21)	50 (18)	71 (19)
Upper secondary education	20 (22)	7 (13)	11 (11)	45 (23)	14 (17)	26 (21)	45 (17)	78 (21)
Others	38 (42)	22 (41)	47 (48)	66 (34)	29 (35)	50 (40)	114 (42)	138 (37)
Not reported	21 (23)	12 (22)	19 (19)	51 (26)	22 (27)	22 (18)	62 (23)	85 (23)

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); SDS, standard deviation score; SES, socioeconomic status.

^aMean (SD) values are used for continuous variables, and numbers (%) are used for categorical variables.

year of treatment, 44% of the initial children remained in treatment. The frequency of dropouts did not significantly differ between the moderate and severely obesity groups. For the age group of 6 to 9 years, approximately 32% of the children were lost to follow-up; for the age group of 10 to 13 years, approximately 52% were lost to follow-up; and for the age group of 14 to 16 years, approximately 78% were lost to follow-up.

Analyses were performed using Statistica 9.0 (Statsoft Inc). All tests used were 2-sided, and $P < .05$ was regarded as statistically significant. Odds ratios (ORs) and mean differences in BMI-SD scores are presented with 95% CIs. All analyses were regarded as exploratory. No correction for multiple testing was made.

RESULTS

A total of 643 children (313 female children and 330 male children) met the inclusion criteria for our study and had their first visit to the National Childhood Obesity Center between January 1998 and December 2006. There were 54 children in the youngest age group (6-9 years), 194

children in the middle age group (10-13 years), and 124 children in the adolescent age group (14-16 years) who were moderately obese. There were 91 children in the youngest age group, 98 children in the middle age group, and 82 children in the adolescent age group who were severely obese.

The sex distribution varied with age and degree of obesity (**Table**). Among children with a BMI-SD score of less than 3.5, there was a low percentage of boys in the youngest age group (6-9 years), an approximately even distribution in the middle age group (10-13 years), and a majority of boys in the adolescent age group (14-16 years). Of 271 children with a BMI-SD score of 3.5 or greater, 152 (56%) were boys and 119 (44%) were girls. In the age groups of 6 to 9 years and 10 to 13 years, 66% (60 of 91) and 68% (67 of 98), respectively, were boys. In the age group of 14 to 16 years, only 30% (25 of 82) were boys. The prevalence of overweight and obese parents was 53% among the fathers and 54% among the moth-

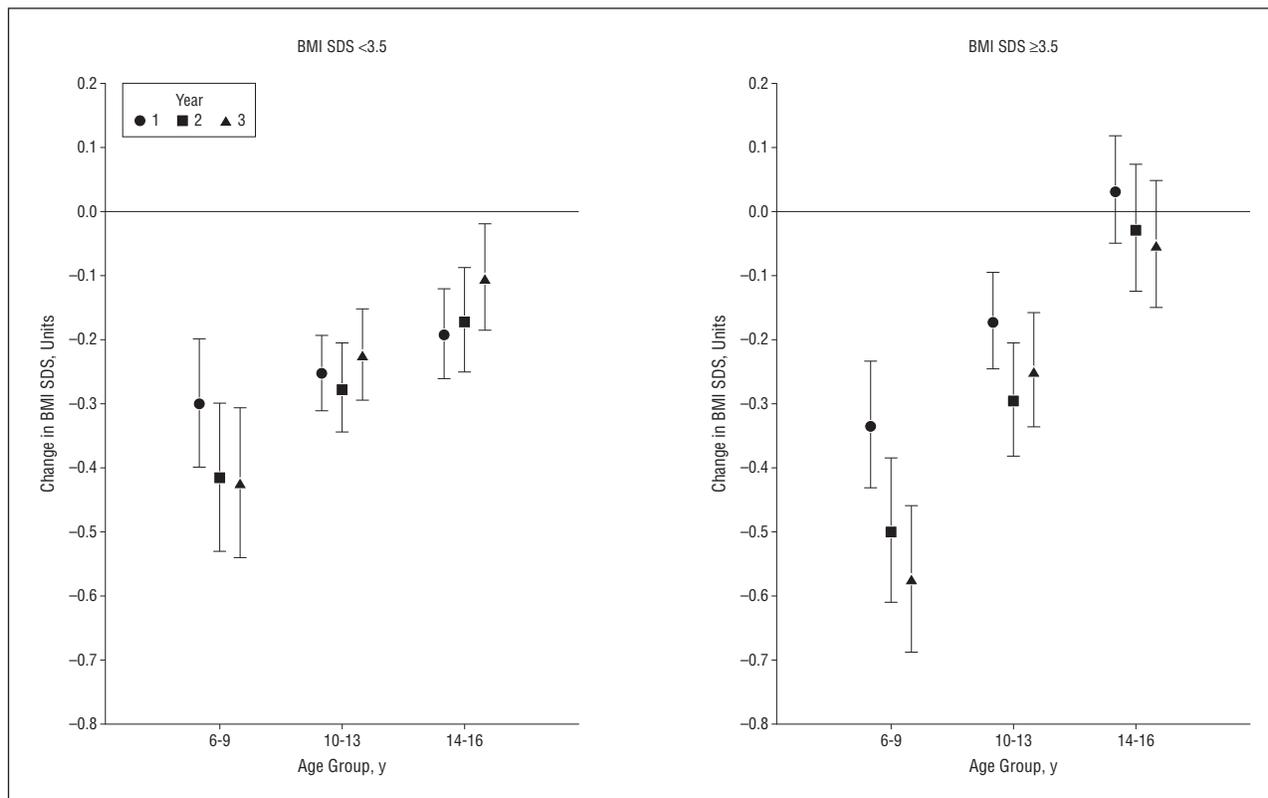


Figure 1. Mean change in body mass index (BMI) standard deviation score (SDS) as an effect of age at start of treatment in children with either a BMI SDS of less than 3.5 or a BMI SDS of 3.5 or greater. Mean changes in BMI SDSs during years 1, 2, and 3 are shown. Values are adjusted for differences in BMI SDSs at the start of treatment. The error bars indicate 95% CI.

ers in the group of moderately obese children. Sixty-four percent of both fathers and mothers were overweight or obese in the group of severely obese children. The proportion of children with parents in the third socioeconomic status (unemployed, early/disability retired, long-term sick-listed, students, and housewives) was 37% for the moderately obese children and 42% for the severely ones.

The primary aim of our study was to investigate whether the BMI-SD score at the first visit had any impact on the treatment outcome. Multivariate analysis and analysis of covariance, using the baseline observation carried forward method for missing data, revealed that age and BMI-SD score at inclusion interacted ($P = .049$) as predictors of treatment effect, and therefore further analyses between age group and BMI-SD score were performed. A post hoc test showed that, among children with moderate obesity (ie, a BMI-SD score of < 3.5), the youngest age group had a good treatment effect (**Figure 1**); 44% of these children had achieved a clinically significant 0.5-unit reduction after 3 years of treatment. Post hoc analyses showed that treatment efficacy was less pronounced in the older age groups (Figure 1): 20% of moderately obese adolescents 10 to 13 years of age and 8% of moderately obese adolescents 14 to 16 years of age had experienced clinically significant weight loss. The severely obese young children (ie, a BMI-SD score of ≥ 3.5) showed a very good treatment effect (Figure 1), and 58% had a reduction in BMI-SD score of at least 0.5 units after 3 years; 22% of severely obese children who were 10 to 13 years of age had a reduction of at least 0.5 units

after 3 years of treatment. The severely obese adolescents showed no change in BMI-SD score at all after 1, 2, or 3 years (Figure 1), and 2% had experienced clinically significant weight loss after 3 years. The data from sensitivity analysis using the completers population were similar concerning interaction effect and differences in treatment efficacy ($P = .04$).

Following the multivariate analysis of covariance, post hoc analysis was performed, and in the middle age group (10-13 years), it was found that the severely obese boys showed a significantly greater mean decrease in BMI-SD score after 3 years (-0.5 [95% CI, -0.64 to -0.36]) than did the severely obese girls (-0.1 [95% CI, -0.35 to 0.11]) ($P < .001$) when the missing data were replaced using the LOCF method. Sensitivity analysis, using the completers population, showed that the pattern was similar when analyzing completers only, but the differences did not reach statistical significance. Sex differences were not observed in any other age group.

Using multivariate analysis, we examined whether the effect of parental BMI status on treatment efficacy differs between moderately and severely obese children. The severely obese children with normal-weight mothers showed a larger mean decrease in BMI-SD score (-0.6 [95% CI, -0.79 to -0.37]) than did the severely obese children with obese mothers (-0.3 [95% CI, -0.46 to -0.24]) ($P = .04$). Subgroup analysis revealed that the same trend was observed in all age groups. We could not detect any relationship between the father's weight status and the change in BMI-SD score during treatment.

In multivariate analysis, the treatment results were found to be related to age at onset of obesity. However, when controlling for age at the start of treatment, we found that this relationship was attenuated ($P = .25$). Furthermore, in multivariate analysis, biological age (defined by Tanner stages) was tested but was found not to be related to treatment outcome when controlling for age at onset and age at the start of treatment. In multivariate analysis, there was no difference in socioeconomic status detected between the age groups with regard to change in BMI-SD score.

Finally, in univariate exploratory analysis, we calculated the odds for children to achieve a decrease of at least 0.5 units in the BMI-SD score from baseline to year 3 (Figure 2). Using the LOCF method for replacement of missing data, we found that age was a significant predictor of a reduction in BMI-SD score (OR, 0.68 [95% CI, 0.60-0.77] per year; $P < .001$); that is, for every year younger, this corresponds to an OR of 1.47 (47%) for a decrease of 0.5 units at year 3. Sensitivity analyses using children with complete assessments showed similar results (OR, 0.68 [95% CI, 0.59-0.75]; $P = .001$).

The corresponding OR for age for predicting a decrease of 1.0 units or more during 3 years of treatment was 0.81 (95% CI, 0.74-0.89) per year ($P = .001$) when using the LOCF method for replacement of missing data and 0.90 (95% CI, 0.79-1.02) per year ($P = .10$) when using the complete case population (Figure 2). In the group of severely obese adolescents, 92% were obese at the age of 7 years, and 51% were severely obese at the age of 7 years. In the group of moderately obese adolescents, 46% were obese at the age of 7 years, and 8% were severely obese at the age of 7 years.

We have estimated the cutoff levels for identifying children at high risk for developing severe obesity at 14 to 16 years. The data on BMI-SD scores from children 3, 5, and 7 years of age were used to estimate these cutoff levels and to discriminate between severe and nonsevere (moderate) obesity. Discrimination was estimated using logistic regression, and ORs for developing severe obesity at 14 to 16 years were calculated. The results of subgroup analyses showed that 3-year-old children with a BMI-SD score greater than 2.5 (15% of all the children) had an OR of 1.6 (95% CI, 1.22-2.11) ($P < .001$) for developing severe obesity (BMI-SD score of ≥ 3.5). Five-year-old children with a BMI-SD score of greater than 3.04 (36% of all the children) had an increased risk (OR, 2.2 [95% CI, 1.57-3.08]; $P < .001$) of developing severe obesity at 14 to 16 years of age. Seven-year-olds with a BMI-SD score greater than 3.51 (51% of all the children) had an increased risk of developing severe obesity (OR, 2.72 [95% CI, 1.75-4.22]; $P < .001$). Sensitivity for discriminating severe obesity was 37%, 52%, and 49% for 3-year-old children, 5-year-old children, and 7-year-old children, respectively, and the corresponding specificity was 89%, 83%, and 88%, respectively.

COMMENT

The results show that the degree of obesity was an important predictor of treatment outcome and that treatment outcome varied by age. The adolescents who were

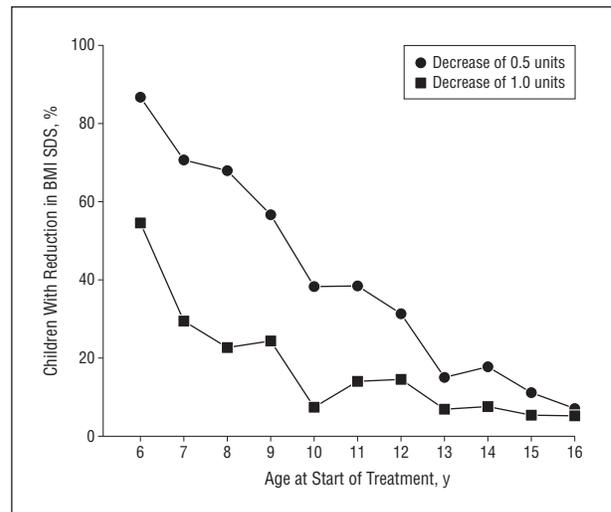


Figure 2. Percentage of children achieving a reduction of 0.5 and 1.0 units in body mass index (BMI) standard deviation score (SDS) after 3 years of behavioral treatment. Analyses were performed using the last observation carried forward (LOCF) method. Missing data were replaced using the LOCF method. There were 22 children who were 6 years of age, 17 children who were 7 years of age, 44 children who were 8 years of age, 62 children who were 9 years of age, 55 children who were 10 years of age, 70 children who were 11 years of age, 93 children who were 12 years of age, 74 children who were 13 years of age, 78 children who were 14 years of age, 72 children who were 15 years of age, and 56 children who were 16 years of age.

14 to 16 years of age showed no reduction in BMI-SD score at all after 1, 2, or 3 years of behavioral treatment. In contrast, the effect of behavioral treatment initiated between 6 and 9 years of age appeared to be more effective among severely obese children than among the moderately obese ones. Recently published data³⁻⁷ provide strong support for starting treatment at an early age.

In our study, we were able to demonstrate that when using the LOCF population, severely obese boys had a significantly larger decrease in BMI-SD scores than severely obese girls, although this was not found in the complete case population. This difference was not seen in any other age group and may indicate that, for the severely obese boys, puberty may contribute to a more beneficial weight development. This is in line with the findings of Sabin et al,⁴ who reported a tendency for boys at a mean age of 11.7 years to achieve better treatment results.

In our study, we also found an association between treatment effect and maternal BMI. The severely obese children with normal-weight mothers had a better outcome than those with obese mothers. This finding is in line with the findings of Reinehr et al³ and Sabin et al,^{3,4} but not with our previous study.⁷

In our study, treatment efficacy was proposed to be related to age at onset of obesity. One potential confounder may be the age at start of treatment. Our study showed that the correlation between age at onset of obesity and treatment efficacy disappears when controlling for age at the start of treatment. The mechanism behind this finding is unknown, but the time span during which the child suffers from untreated obesity is shorter, and it is hypothesized that the shorter the time spent as an obese individual, the better the treatment results.

The strength of our study is the length of the treatment period in combination with a relatively large num-

ber of patients. A limitation is that the treatment was not identical for all children, but for the aims of our study, this is of minor importance. In our study, we identified sex differences in the group distribution that may also be a possible confounder. This is a single-center study, and the generalizability is therefore uncertain. However, to the best of our knowledge, there are no long-term studies showing good results of behavioral treatment in severely obese adolescents.

Behavioral treatment was successful when initiated early in life for both moderately and severely obese children. In contrast, behavioral treatment had no effect at all on adolescents with severe obesity. Nearly all severely obese adolescents were already obese or severely obese at 7 years of age. Thus, early treatment may be one way to reduce treatment failures during adolescence. If these results are generalizable for the severely obese adolescents, new treatment modalities such as gastric banding²⁶ or gastric bypass^{13,27} need to be developed and tested. We question whether it is reasonable from an ethical standpoint to initiate a treatment that has such a poor outcome and that may result in reduced self-esteem.²⁸

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Correspondence: Pernilla Danielsson, RN, PhD, Department of Pediatrics, Karolinska University Hospital, Karolinska Institutet, B62, SE-141 86 Stockholm, Sweden (pernilla.danielsson@karolinska.se).

Author Contributions: *Study concept and design:* Danielsson and Marcus. *Acquisition of data:* Danielsson and Marcus. *Analysis and interpretation of data:* Danielsson, Kowalski, Ekblom, and Marcus. *Drafting of the manuscript:* Danielsson and Ekblom. *Critical revision of the manuscript for important intellectual content:* Danielsson, Ekblom, and Marcus. *Statistical analysis:* Kowalski and Ekblom. *Obtained funding:* Danielsson and Marcus. *Administrative, technical, and material support:* Danielsson and Marcus. *Study supervision:* Ekblom and Marcus.

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