Stability of Relative Weight Category and Cardiometabolic Risk Factors among Moderately and Severely Obese Middle School Youth

Marsha D. Marcus¹, Gary D. Foster² and Laure El ghormli³

Objective: To examine the stability of severe pediatric obesity relative to moderate obesity and associated changes in cardiometabolic risk from the beginning of 6th to the end of 8th grade.

Methods: Participants in HEALTHY, a multi-site, cluster randomized school-based study designed to mitigate risk for type 2 diabetes, completed standardized assessments of height, weight, glucose, insulin, lipids, and blood pressure at the beginning of 6th grade and the end of 8th grade. Youth were classified as moderately obese (100-119% of the 95th percentile of BMI for age and gender) or severely obese (≥120% of the 95th percentile of BMI for age and gender). Generalized linear mixed models (GLMM) that controlled for relevant covariables were used to examine the relation between baseline demographic and cardiometabolic risk factors and BMI status, as well as changes in relative weight category and risk factors during middle school.

Results: Severe obesity was more likely to endure over the course of middle school than was moderate obesity, and was associated with significantly higher levels of cardiometabolic risk.

Conclusions: Research with a specific focus on understanding, preventing, and treating severe obesity in children is warranted.

Obesity (2014) 22, 1118-1125. doi:10.1002/oby.20688

Introduction

Severe obesity in the US has increased more rapidly than obesity in general (1), and in contrast with evidence that increases in the prevalence of obesity overall have slowed (2), rates of severe obesity have continued to escalate. Indeed, a recent forecast projected a 130% increase in severe obesity among adults over the next two decades, with substantial impact on associated morbidity and health care costs (3). Severe obesity in childhood also has increased (4), and is strongly associated with medical and psychosocial consequences and persistence of obesity into adulthood (5).

Because of the heightened interest in the more extreme values of BMI, investigators have examined the use of the 2000 Centers for Disease Control and Prevention (CDC) growth charts (6), which include nine smoothed percentiles between the 3rd and 97th percentile for age and gender to estimate severe pediatric obesity, defined as the 99th percentile of BMI for age and gender (7). Extrapolation of values from the CDC parameters for the 97th percentile did not provide a good fit to the 99th percentile values. Consequently, Flegal and colleagues (8) have recommended using 120% of the smoothed 95th percentile of BMI as an approximation of severe obesity in order to assess and follow extremely heavy children. Cross-sectional studies using the new threshold to describe severe pediatric obesity have reported prevalence rates ranging from 6.4% (9) in youth aged 2-19 years to 9.1% (10) in middle school children. Further, cross-sectional data have documented that severely obese youth have a worse cardiometabolic risk profile when compared with moderately obese youth (11), but we are not aware of longitudinal investigations.

We recently examined shifts in relative weight category over a three-year period in a multi-ethnic sample of US middle school children who were participants in HEALTHY, a multisite, cluster randomized, school-based study designed to evaluate a comprehensive intervention to mitigate risk for type 2 diabetes (12). We found

1 Department of Psychiatry, University of Pittsburgh School of Medicine, Pennsylvania, USA
2 Center for Obesity Research and Education, Temple University, Pennsylvania, USA
3 Biostatistics Center, George Washington University, Rockville, Maryland, USA

Correspondence: Laure El ghormli (elghorml@bsc.gwu.edu)

Funding agencies: This work was completed with funding from NIDDK/NIH grant numbers U01-DK61230, U01-DK61249, U01-DK61231, and U01-DK61223, with additional support from the American Diabetes Association.

Disclosure: Dr. Marcus reports grants from NIDDK, during the conduct of the study; personal fees from Scientific Advisory Board for United Health Group, outside the submitted work. Dr. Foster reports grants from NIH/NIDDK, during the conduct of the study; personal fees from Con Agra Foods, Tate and Lyle, and United Health Group for Service on Scientific Advisory. These relationships were present during the study but no longer exist. Currently, Dr. Foster is a full-time employee of Weight Watchers International. Ms. El ghormli reports grants from NIDDK.

Received: 28 August 2013; Accepted: 17 December 2013; Published online 23 December 2013. doi:10.1002/oby.20688
that shifts in weight category were common in middle school children, and associated with clinically meaningful changes in cardiometabolic risk factors. In this manuscript, we extended the analysis to evaluate the stability of severe obesity defined as ≥120% of the 95th percentile of BMI. Thus, we examined shifts in severe obesity in the HEALTHY cohort over a three-year period relative to shifts in moderate obesity (100-119% of the 95th percentile of BMI), and the relationship between the severity of obesity and changes in cardiometabolic risk factors.

Methods
Study design
Details of the HEALTHY protocol (13) and outcomes (14) have been reported. Briefly, 42 US middle schools with at least 50% of students eligible for free or reduced-price lunch or belonging to a minority group were recruited by seven participating centers. The study was approved by the site Institutional Review Boards, and parent consent and child assent were obtained. Schools were randomized within each center to intervention or control conditions. Intervention schools were provided 2.5 years of a comprehensive program, which included changes to the school food environment (15) and physical education classes (16), and classroom-based education (17) that incorporated behavior change activities. Activities were complemented by communication and social marketing strategies (18). Participation of control schools was limited to recruitment and data collection.

Data collection
Methods for data collection were described previously (13). Students participated in standardized assessments at baseline (start of 6th grade) and end of study (end of 8th grade). Blood was drawn from fasted students to measure glucose, insulin, and lipids. Assays were conducted by the Northwest Lipid Metabolism and Diabetes Research Laboratories, University of Washington, Seattle. Height and weight were measured by trained, certified study staff using the Prospective Enterprises PE-AIM-101 stadiometer and the SECA Corporation Alpha 882 electronic scale. A Gulick tape was used to measure waist circumference just above the iliac crest. Blood pressure was recorded three times using an automated blood pressure monitor (Omron HEM-907 or HEM-907XL, Vernon Hills, IL) and the mean of the second and third recordings was used for analysis.

Elevated levels of each of the cardiometabolic risk factors were defined by thresholds recommended in the literature. Elevated fasting glucose was defined by a level ≥ 100 mg/dL, as recommended by the American Diabetes Association (19), and elevated insulin was defined by a level ≥ 30 μU/ml as used previously in the HEALTHY study (20). Blood pressure (BP) percentiles were determined using the National Heart, Lung, and Blood Institute guidelines and adjusted for age, sex, and height percentile (21), with elevated risk classified as systolic (SBP) or diastolic (DBP) blood pressure ≥ 90th percentile or a blood pressure ≥ 120/80 mmHg. This threshold incorporates cutoffs for prehypertension (BP > 90th percentile but < 95th percentile) and hypertension (BP > 95th percentile) recommended by the Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents. The Integrated Guidelines (22) also were used to define high risk lipid levels: total cholesterol ≥ 200 mg/dL, low-density lipoprotein (LDL) ≥ 130 mg/dL, triglycerides ≥ 130 mg/dL, and low high-density lipoprotein (HDL) ≤ 40 mg/dL].

Pubertal status was self-reported using the Pubertal Development Scale (23) and converted to the pubertal stage groups outlined by Tanner (24). The scale was administered to males and females separately by trained study staff in a private area, with oral instructions provided from a written script.

Ethnicity and race were self-reported by students. Because participants frequently misunderstood the distinction between ethnicity and race, the information from the separate items was combined: anyone checking “Hispanic or Latino” ethnicity was classified as Hispanic; non-Hispanics choosing only “Black or African American” race were classified as Black; non-Hispanics choosing only “White” race were White; all other responses were combined into “Other.” A parent or guardian reported the highest level of household education.

BMI percentile for age and sex was calculated using the 2000 growth charts of the Centers for Disease Control (CDC) reference charts (6) and BMI percentile categories were created (25). Specifically, students with a BMI ≥ 5th and < 85th percentile were classified as healthy weight and those with a BMI ≥ 85th but < 95th percentile were classified as overweight. Children with a BMI ≥ 95th were classified as obese, but were further classified as moderately obese (100-119% of the 95th percentile) or severely obese (≥ 120% of the 95th percentile) (8). Relative weight shifts from 6th to 8th grade were assigned to five categories (small numbers were combined to ensure adequate sample size per category for analysis): (1) severely obese to healthy (n = 1), overweight (n = 20), or moderately obese (n = 101); (2) moderately obese to healthy (n = 49) or overweight (n = 268); (3) stayed moderately obese (n = 440); (4) stayed severely obese (n = 338); and (5) moderately obese to severely obese (n = 88).

Student sample
All 6th grade students were invited to participate in a health screening at the start of 6th grade in fall 2006, and 57.6% of students agreed. A total of 6358 students provided complete and valid data. Of these, 4603 (72.4%) were reassessed at the end of 8th grade in spring 2009 and valid outcome measurements were obtained; these students constituted the HEALTHY cohort. Student attrition was identical (27.6%) in the intervention and control schools.

For the purposes of this manuscript we used the subsample of 1393 students with BMI ≥ 95th percentile in 6th grade. Of these, 88 (6.3%) were omitted from analyses as a result of missing data for cardiometabolic factors in 6th or 8th grade, resulting in a sample of 1305 students available for analysis. There were no significant baseline differences between students who were included and excluded because of the missing data.

Statistical methods
Characteristics of the sample were summarized using means and standard deviations, or percents. Generalized linear mixed models (GLMM) that included a random effect for school to adjust for clustering of children within schools were used to examine relationships between demographic characteristics, cardiometabolic risk factors, and BMI percentile categories.
Similar GLMM were used to analyze associations between cardiometabolic outcomes (continuous measures) and elevated risk (categorical cut-offs) across shifts in BMI categories from 6th to 8th grade. The following covariates were individually investigated as both contributory (i.e., significant as a main effect) and interactive (i.e., significant interaction between the factor and the BMI shift categorical variable): school intervention status, baseline age, sex, race/ethnicity, highest level of household education, 6th and 8th grade pubertal stage, and change in height from 6th to 8th grade. Longitudinal associations were unaffected by adjusting the models for covariates, except for change in height from 6th to 8th grade ($P = 0.0001$), and none of the interactions were significant. Therefore, change in height was included as a covariate in longitudinal models in addition to baseline values of the cardiometabolic parameters. Pairwise comparisons among the five BMI shift categories were examined further only if an overall association was found. All analyses were considered exploratory but because of the number of tests performed, we considered $P$-values $< 0.001$ to be statistically significant. Statistical analyses were performed using SAS 9.2 statistical software (SAS Institute, Cary, NC).

**Results**

The 1305 students included in the current sample were equally distributed across intervention (49.9%) and control (50.1%) schools. Table 1 compares the 845 individuals (64.8%) who were moderately obese at the beginning of 6th grade with the 460 (35.2%) that were severely obese. Age, sex, race/ethnicity, highest level of household education, youth pubertal status, and treatment group assignment were not associated with more severe obesity in the sample. As expected, measures of adiposity were significantly different. The severely obese students already exhibited significant levels of cardiometabolic risk when compared to those who were moderately obese, with higher DBP, insulin, and triglycerides, lower HDL, and higher proportions with elevated risk levels for blood pressure, insulin, and HDL.

Shifts in weight categories from 6th to 8th grade are presented in Table 2. Of the 460 severely obese children in 6th grade, 73.5% ($n = 338$) remained severely obese by the end of 8th grade, whereas 22.0% ($n = 101$) became moderately obese and 4.3% ($n = 20$) became overweight. Only one severely obese child in 6th grade had a healthy weight by the end of 8th grade. We compared severely obese youth who had improvements in relative weight category with those who stayed severely obese during the period of observation. No baseline characteristics were associated with improvements in relative weight category other than baseline indices of adiposity (BMI, BMI z-score, waist circumference): youth who stayed extremely obese over time were significantly heavier at baseline than those who improved relative weight category (BMI $33.9 \pm 3.5$ vs. $30.8 \pm 1.8$, respectively, $P < 0.0001$).

Of the 845 moderately obese children in 6th grade, 52.1% ($n = 440$) remained moderately obese, 31.7% ($n = 268$) moved to the overweight category, and 5.8% ($n = 49$) moved to the healthy weight category by the end of 8th grade. Youth who were moderately obese in the 6th grade and became severely obese at the end of the 8th grade (10.4%; $n = 88$) had significantly higher baseline BMI than youth who did not progress to severe obesity ($28.1 \pm 1.4$ vs. $26.9 \pm 1.6$; $P < 0.0001$).

Among youth who remained severely obese from 6th to 8th grades ($n = 338$), average BMI increased from $33.9 \pm 3.5$ in 6th grade to $37.2 \pm 4.3$ in the 8th grade ($P < 0.0001$). The increase in average BMI among youth with stable severe obesity was significantly greater than the increase observed in those who remained moderately obese ($P < 0.0001$).

Table 3 presents longitudinal data for risk factors across the five categories of shift in relative weight. Changes in glucose, insulin, DBP, total cholesterol, LDL, HDL, and triglycerides differed across the BMI shift categories (all $P < 0.0001$). In particular, children who improved relative weight category by the end of 8th grade demonstrated larger decreases in glucose, insulin, LDL, triglycerides, and larger increases in HDL compared with those who stayed in the same weight category (columns 1 vs. 4 and 2 vs. 3). Conversely, children who increased weight category demonstrated greater increases in glucose, insulin, total cholesterol, and LDL compared to those who stayed in the same category (columns 3 vs. 5). Of particular relevance, children who stayed severely obese over time had greater increases in mean glucose and insulin and decreases in HDL compared with those who stayed moderately obese (columns 3 vs. 4).

As documented in Table 1, severely obese youth were characterized by higher levels of cardiometabolic risk than moderately obese youth at the 6th grade baseline. Table 4 focuses on the changes in cardiometabolic risk factors observed in the subgroups that remained moderately obese or severely obese over the course of middle school. The percent of youth at risk in both the moderately and severely obese groups increased from 6th to 8th grades for glucose, insulin, and HDL, but rates were significantly higher for severely obese youth. By the end of 8th grade the moderately and severely obese youth did not differ in rates of at risk blood pressure levels. Levels for cholesterol, LDL, and triglycerides decreased in both moderately and severely obese youth by 8th grade, but rates of elevated triglycerides were significantly higher in severely obese youth.

**Discussion**

This manuscript documents that severe pediatric obesity characterized as $\geq 120\%$ of the 95th percentile of BMI for age and gender is more stable than moderate obesity during the middle school years. Further, although the cardiometabolic risk associated with pediatric obesity, in general, is well documented, the present findings show that health risks associated with enduring severe obesity are particularly striking.

We reported previously that there was a notable amount of shifting across relative weight categories during the middle school years among participants in the HEALTHY study, which was independent of school intervention status (i.e., whether youth attended intervention or control schools) (12). More than one-third of obese 6th graders shifted to a lower weight category by the end of 8th grade, with associated favorable changes in cardiometabolic risk factors. Conversely, upward shifts in BMI and stable obesity were associated with unfavorable changes in risk (12). In the current analysis, we utilized the current recommended threshold for following children with more severe obesity to evaluate shifts in severe obesity relative to moderate obesity during middle school.

The present findings, which also are independent of the HEALTHY study school intervention status, indicate that severe obesity is less
mutable than moderate obesity. Of youth who were severely obese in 6th grade, 73.5% remained so, whereas moderate obesity persisted in 52.1% of youth. Among moderately obese 6th grade youth, 37.5% improved in relative weight category and were in the overweight or healthy weight range at the end of 8th grade. In contrast, despite the fact that more than one quarter of severely obese youth showed a decrease in relative weight category during the middle school years, 95.5% remained moderately or severely obese at the end of 8th grade. Further, 10.4% of youth progressed from moderate obesity to severe obesity over the period of study so that the overall proportion of severely obese children (among those who were obese at the start of middle school) was relatively stable and represented

| TABLE 1 Mean (SD) or % for student characteristics by moderately and severely obese weight categories at baseline (6th grade) |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
|                          | Moderately Obese | Severely Obese                                    |
|                          | 100-119% of 95th percentile (N = 845) | ≥120% of 95th percentile (N = 460) |
| Age years                | 11.2 (0.6)       | 11.3 (0.5)                                       | 0.0789 |
| Sex Male                 | 52.7%            | 54.6%                                           | 0.5399 |
| Female                  | 47.3%            | 45.4%                                           |
| Race/Ethnicity Hispanic | 60.0%            | 58.9%                                           | 0.9407 |
| NH Black                | 17.6%            | 17.8%                                           |
| NH White                | 15.0%            | 15.4%                                           |
| Other                   | 7.3%             | 7.8%                                            |
| Head of Household Education< High School | 26.5% | 31.5%                                           | 0.1125 |
| High School Grad        | 28.3%            | 23.3%                                           |
| Some College            | 26.7%            | 27.6%                                           |
| ≥ College Degree        | 16.8%            | 14.8%                                           |
| Pubertal Development Stage 1 | 9.9% | 8.9%                                           | 0.2901 |
| Stage 2                 | 25.3%            | 23.3%                                           |
| Stage 3                 | 38.7%            | 38.3%                                           |
| Stage 4                 | 20.7%            | 21.1%                                           |
| Stage 5                 | 3.0%             | 3.7%                                            |
| HEALTHY Study Intervention Group Control School | 50.6% | 49.1%                                           | 0.9941 |
| Intervention School     | 49.4%            | 50.9%                                           |
| BMI kg/m²                | 26.7 (1.6)       | 33.1 (3.5)                                      | <0.0001 |
| Percentile (%)          | 97.1 (1.0)       | 99.1 (0.3)                                      | <0.0001 |
| Z-score                 | 1.9 (0.2)        | 2.4 (0.2)                                       | <0.0001 |
| Waist Circumference Cm   | 88.1 (6.6)       | 103.0 (9.2)                                     | <0.0001 |
| ≥ 90th Percentile       | 76.2%            | 99.3%                                           | <0.0001 |
| SBP mmHg                | 110.2 (9.7)      | 112.0 (11.1)                                    | 0.0018 |
| DBP mmHg                | 66.0 (7.8)       | 70.4 (8.6)                                      | <0.0001 |
| Blood Pressure ≥ 90th or 120/80 | 23.8% | 37.4%                                           | <0.0001 |
| Glucose mg/dl           | 94.6 (6.5)       | 94.2 (6.7)                                      | 0.3075 |
| ≥ 100                   | 20.4%            | 19.8%                                           | 0.7791 |
| Insulin μU/mlf           | 17.9 (10.8)      | 28.7 (19.9)                                     | <0.0001 |
| ≥ 30                    | 10.4%            | 35.7%                                           | <0.0001 |
| Total Cholesterol mg/dl | 160.5 (29.9)     | 161.2 (28.3)                                    | 0.6190 |
| ≥ 200                   | 9.5%             | 8.5%                                            | 0.5535 |
| LDL mg/dl               | 91.7 (24.9)      | 92.5 (23.5)                                     | 0.5745 |
| ≥ 130                   | 6.6%             | 6.3%                                            | 0.8243 |
| HDL mg/dl               | 47.1 (9.9)       | 43.8 (9.3)                                      | <0.0001 |
| ≤ 40                    | 27.2%            | 38.9%                                           | <0.0001 |
| Triglycerides mg/dl     | 108.8 (59.3)     | 125.9 (70.9)                                    | <0.0001 |
| ≥ 130                   | 26.6%            | 34.3%                                           | 0.0037 |

P-values are from generalized linear mixed models comparing the two baseline weight categories and including a random effect to account for the original school intervention cluster. As a result of the number of comparisons, P < 0.001 was considered significant.

²% of the sample had missing data for highest education level of head of household and 3% had missing data for pubertal development stage.

³Testing was performed on the log transform to normalize the distribution.
more than a third of the obese group. Finally, there were no significant predictors of the persistence of moderate or severe obesity or the progression of moderate obesity to severe obesity except higher baseline BMI within 6th grade weight categories, which would be expected given the use of categorial thresholds.

Data from the present study replicate our previous finding that shifts in relative weight category during middle school are associated with significant changes in cardiometabolic risk factors (12), but extend previous work by focusing on the risks associated with severe obesity relative to moderate obesity over time. There is evidence that remaining obese during the period from childhood to adolescence is associated with significant cardiometabolic risk (26), as well as cross-sectional evidence that severely obese youth have significantly worse cardiometabolic risk profiles than moderately obese youth (11), with higher blood pressure and rates of insulin resistance and metabolic syndrome.

In the current longitudinal study, we confirmed that staying severely obese over the middle school years was associated with a poorer risk factor profile than staying moderately obese. Youth that remained severely obese in comparison to those who remained moderately obese had significantly larger increases in glucose and insulin and decreases in HDL over time. In contrast to the previous cross-sectional investigation that compared more moderate and severely obese youth (11), we did not observe differences between more and less severely obese youth in blood pressure; the discrepant findings may be because of the fact that the youth in the earlier study were aged 6-16 years in contrast to the narrower range in the current study, or to differences in study design.

Even more striking, our findings documented that enduring severe obesity was associated with higher rates of elevated cardiometabolic risk defined by guidance-based thresholds. For example, 20.0% of youth with stable moderate obesity compared with 57.7% of those with stable severe obesity had insulin levels $\geq 30$ $\mu$U/ml in 8th grade ($P < 0.001$). With regard to HDL, 47.6% of youth who stayed severely obese had HDL levels $< 40$ mg/dl in comparison with 30.0% of youth with enduring moderate obesity ($P < 0.001$). Finally, 33.4% of persistently severely obese youth compared with 20.7% of persistently moderately obese youth had triglycerides $\geq 130$ mg/dl ($P < 0.001$). Although differences between severely and moderately obese youth in rates of elevated blood pressure were not observed, more than one third of moderately and severely obese youth in the current study had blood pressure readings consistent with prehypertension or hypertension in the 8th grade. Given that increases in average BMI of severely obese children were significantly larger than those observed in moderately obese children during middle school, there is concern that the health burdens associated with severe obesity relative to moderate obesity may become even more marked over time.

The strengths of the study include the diverse sample from across the US and the standardized assessment and analysis protocols. Nevertheless, there are several limitations. Study participants all were participating in a study designed to mitigate risk for type 2 diabetes, and schools were included based on adequate minority status and low socioeconomic status representation; thus participants may not be representative of all US school children. Data regarding pubertal status were self-reported. Further, although examination of moderately and severely obese categories provides useful information about the utility of monitoring children based on relative weight classifications, future studies and analyses utilizing continuous measures will provide a more refined examination of weight change and stability in growing children. Finally, available data indicate that patterns of comorbidity associated with changes in relative weight vary by sex and race/ethnicity (12). The relation between changes in relative weight and cardiometabolic risk did not differ as a function of sex or race/ethnicity in the present study, but additional longitudinal investigations are needed to resolve whether shifts in relative weight have different effects on risk among sub-groups of US youth and whether other psychosocial or behavioral factors affect the observed relations.

In summary, this study adds to the literature about severe obesity in youth by documenting that onset of severe obesity by the 6th grade is considerably more likely to endure than is moderate obesity and that the elevated cardiometabolic risk of severe obesity relative to
| Cardiometabolic Outcome | Severe Obese to Healthy or Overweight (N=122) [1] | Moderately Obese to Healthy or Overweight (N=317) [2] | Stayed Moderately Obese (N=440) [3] | Stayed Severely Obese (N=338) [4] | Moderately Obese to Severely Obese (N=88) [5] | Overall P-value for 8th - 6th Δ and significant pairwise comparisonsa |
|------------------------|--------------------------------------------------|--------------------------------------------------|---------------------------------|---------------------------------|---------------------------------|--------------------------------------------------|
| Glucose (mg/dl)        | 6th: 94.5 (6.1)                                  | 8th: 94.1 (8.6)                                  | 6th: 94.9 (6.7)                 | 8th: 94.2 (6.9)                 | 6th: 93.1 (7.1)                 | <.0001 1 vs. 4                                    |
|                        | Δ: -0.3 (8.8)                                    | Δ: -1.1 (7.0)                                    | Δ: +0.5 (7.0)                   | Δ: +2.4 (7.9)                   | Δ: +2.5 (7.4)                   |                                                  |
| Insulin (µU/ml)        | 6th: 23.0 (12.4)                                 | 8th: 22.0 (12.2)                                 | 6th: 18.4 (11.3)                | 8th: 30.7 (21.6)                | 6th: 18.7 (10.7)                | <.0001 1 vs. 4, 2 vs. 3, 4, and 5                 |
|                        | Δ: -1.1 (14.0)                                   | Δ: -2.5 (10.9)                                   | Δ: +4.7 (13.4)                  | Δ: +7.9 (29.2)                  | Δ: +14.8 (17.4)                 |                                                  |
| SBP (mmHg)             | 6th: 112.7 (10.2)                                | 8th: 116.2 (10.7)                                | 6th: 109.9 (9.6)                | 8th: 114.2 (11.7)               | 6th: 110.9 (9.3)                | 0.0022 2 vs. 3, 4, and 5                         |
|                        | Δ: +3.5 (12.0)                                   | Δ: +2.4 (9.7)                                    | Δ: +5.5 (11.2)                  | Δ: +2.4 (12.5)                  | Δ: +3.6 (11.8)                  |                                                  |
| DBP (mmHg)             | 6th: 69.4 (8.0)                                  | 8th: 66.9 (7.8)                                  | 6th: 65.8 (7.8)                 | 8th: 70.3 (8.4)                 | 6th: 66.1 (8.2)                 | <.0001 2 vs. 3, 4, and 5                         |
|                        | Δ: -2.4 (10.1)                                   | Δ: -1.9 (7.7)                                    | Δ: +1.4 (9.0)                   | Δ: -0.5 (10.2)                  | Δ: +2.7 (9.8)                   |                                                  |
| Cholesterol (mg/dl)    | 6th: 160.0 (27.2)                                | 8th: 145.8 (26.9)                                | 6th: 157.8 (28.6)               | 8th: 152.7 (28.2)               | 6th: 161.7 (28.7)               | <.0001 1 vs. 5                                   |
|                        | Δ: -14.2 (21.8)                                  | Δ: -16.4 (22.0)                                  | Δ: -9.6 (23.0)                  | Δ: -6.9 (21.6)                  | Δ: -0.8 (22.3)                  |                                                  |
| LDL (mg/dl)            | 6th: 91.5 (22.2)                                 | 8th: 79.3 (20.5)                                 | 6th: 89.6 (23.5)                | 8th: 86.6 (24.4)                | 6th: 93.0 (25.9)                | <.0001 1 vs. 3, 4, and 5                         |
|                        | Δ: -12.1 (17.4)                                  | Δ: -13.5 (17.4)                                  | Δ: -6.4 (18.6)                  | Δ: -2.8 (17.3)                  | Δ: +0.4 (18.6)                  |                                                  |
| HDL (mg/dl)            | 6th: 45.5 (10.6)                                 | 8th: 48.0 (12.4)                                 | 6th: 47.2 (9.3)                 | 8th: 46.1 (10.6)                | 6th: 47.0 (9.9)                 | <.0001 1 vs. 3, 4, and 5                         |
|                        | Δ: +2.4 (8.8)                                    | Δ: +3.6 (8.2)                                    | Δ: -0.9 (8.0)                   | Δ: -1.9 (7.6)                   | Δ: +2.2 (7.6)                   |                                                  |
| Triglycerides (mg/dl)  | 6th: 116.1 (57.3)                                | 8th: 95.6 (98.7)                                 | 6th: 105.6 (58.9)               | 8th: 100.0 (62.7)               | 6th: 112.2 (61.0)               | <.0001 1 vs. 4 and 5                             |
|                        | Δ: -20.5 (84.2)                                  | Δ: -32.9 (49.8)                                  | Δ: -12.2 (57.5)                 | Δ: -12.0 (58.3)                 | Δ: +6.7 (42.6)                  |                                                  |

aP-values are from generalized linear mixed models testing for differences (8th-6th change) across the five columns labeled 1-5. All models are adjusted for the baseline value of the cardiometabolic outcome and change in height (cm) and include a random effect to account for the school intervention cluster. If the overall p-value was significant, pairwise comparisons were performed and significant comparisons across the 5 columns are listed. Due to the number of comparisons, P < 0.001 was considered significant.
moderate obesity also persists. These results are consistent with observations that severe pediatric obesity is likely to have ominous consequences for the health of these youngsters as they age. Given converging evidence, which documents that available interventions are less effective for older and more obese children (27,28), there is a compelling need for additional research focusing on severe obesity. Although surveillance of obesity in young children currently is recommended, monitoring strategies may need to include a specific emphasis on severely obese children. Moreover, investigations that focus on the development and evaluation of multifaceted interventions targeting the child, family, school, and community, and alternative strategies including specific dietary interventions (e.g., use of prepared meals) and the use of medications are indicated. Finally, in light of the morbidity associated with severe pediatric obesity, effective treatment is likely to require the elaboration of chronic care models that include developmentally appropriate strategies delivered over childhood (e.g., school-based intervention options) and adolescence (e.g. focus on peer group, use of electronic and social media).

**Acknowledgments**

We wish to thank the administration, faculty, staff, students, and their families at the middle schools and school districts that participated in the HEALTHY study. The following individuals and institutions constitute the HEALTHY Study Group (* indicates principal investigator or director): Study Chair Childrens Hospital Los Angeles: F.R. Kaufman Field Centers Baylor College of Medicine: T. Baranowski*, L. Adams, J. Baranowski, A. Canada, K.T. Carter, K.W. Cullen, M.H. Dobbins, R. Jago, A. Oceguera, A.X. Rodriguez, C. Speich, L.T. Tatum, D. Thompson, M.A. White, C.G. Williams Oregon Health & Science University: L. Goldberg*, D. Cusimano, L. DeBar, D. Elliot, D. Elliot, H.M. Grund, S. McCormick, E. Moe, J.B. Roullet, D. Studler Temple University: G. Foster* (Steering Committee Chair), J. Brown, B. Creighton, M. Faith, E.G. Ford, H. Glick, S. Kumanyika, J. Nachmani, L. Rosen, S. Sherman, S. Solomon, A. Virus, S. Volpe, S. Willi University of California at Irvine: D. Cooper*, S. Bassin, S. Bruecker, D. Ford, P. Galassetti, S. Greenfield, J. Hartstein, M. Krause,
HEALTHY intervention materials are available for download at http://www.healthystudy.org/.

© 2013 The Obesity Society

References

1. Sturm R. Increases in morbid obesity in the USA: 2000-2005. Public Health 2007; 121:492-496.
2. Flegal KM, Carroll MD, Kit BK, Ogden CL. Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999-2010. JAMA 2012; 307:491-497.
3. Finkelstein EA, Khavjou OA, Thompson H, et al. Obesity and severe obesity forecasts through 2030. Am J Prev Med 2012;42:563-570.
4. Skelton JA, Cook SR, Aninger P, Klein JD, Barlow SE. Prevalence and trends of severe obesity among US children and adolescents. Acad Pediatr 2009;9:322-329.
5. Freedman DS, Khan LK, Serdula MK, Ogden CL, Dietz WH. Racial and ethnic differences in secular trends for childhood BMI, weight, and height. Obesity (Silver Spring) 2006;14:301-308.
6. Centers for Disease Control National Center for Health Statistics. CDC Growth Charts for the United States, 2000.
7. Freedman DS, Mei Z, Srinivasan SR, Berenson GS, Dietz WH. Cardiovascular risk factors and excess adiposity among overweight children and adolescents: the Bogalusa Heart Study. J Pediatr 2007;150:12-17 e2.
8. Flegal KM, Wei R, Ogden CL, Freedman DS, Johnson CL, Curtin LR. Characterizing extreme values of body mass index for age by using the 2000 Centers for Disease Control and Prevention growth charts. Am J Clin Nutr 2009;90:1314-1320.
9. Koebnick C, Smith N, Coleman KJ, et al. Prevalence of extreme obesity in a multiethnic cohort of children and adolescents. J Pediatr 2010;157:26-31 e2.
10. Robbins JM, Malyia G, Polansky M, Schwarz DF. Prevalence, disparities, and trends in obesity and severe obesity among students in the Philadelphia, Pennsylvania, school district, 2006-2010. Prev Chronic Dis 2012;9:E145.
11. Rank M, Siegrist M, Wilks DC, et al. The cardio-metabolic risk of moderate and severe obesity in children and adolescents. J Pediatr 2013; 163:137-142.
12. Marcus MD, Foster GD, El Ghorni L, et al. Shifts in BMI category and associated cardiometabolic risk: Prospective results from HEALTHY study. Pediatrics 2012; 129:e983-e991.
13. Hirst K, Baranowski T, DeBar L, et al. HEALTHY study rationale, design and methods: Moderating risk of type 2 diabetes in multi-ethnic middle school students. Int J Obes (Lond) 2009;33(Suppl 4):S4-S20.
14. Foster GD, Linder B, Baranowski T, et al. A school-based intervention for diabetes risk reduction. N Engl J Med 2010;363:443-453.
15. Gillis B, Moley C, Stadler DD, et al. Rationale, design and methods of the HEALTHY study nutrition intervention component. Int J Obes (Lond) 2009; 33(Suppl 4):S29-S36.
16. McMurray RG, Bassin S, Jago R, et al. Rationale, design and methods of the HEALTHY study physical education intervention component. Int J Obes (Lond) 2009;33(Suppl 4):S37-S43.
17. Venditti EM, Elliot DL, Faith MS, et al. Rationale, design and methods of the HEALTHY study behavior intervention component. Int J Obes (Lond) 2009; 33(Suppl 4):S44-S51.
18. DeBar LL, Schneider M, Ford EG, et al. Social marketing-based communications to integrate and support the HEALTHY study intervention. Int J Obes (Lond) 2009; 33(Suppl 4):S52-S59.
19. Report of the expert committee on the diagnosis and classification of diabetes mellitus. Diabetes Care 2003;26(Suppl 1):S5-S20.
20. Marcus MD, Baranowski T, DeBar LL, et al. Severe obesity and selected risk factors in a sixth grade multiracial cohort: the HEALTHY study. J Adolesc Health 2010;47:604-607.
21. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. Pediatrics 2004;114(2 Suppl 4th Report):555-576.
22. Expert panel on integrated guidelines for cardiovascular health and risk reduction in children and adolescents: Summary report. Pediatrics 2011;128(Suppl 5):S213-S266.
23. Robertson EB, Skinner ML, Love MM, et al. The pubertal development scale: A rural and suburban comparison. J Early Adolesc 1992;12:174-186.
24. Carskadon MA, Acebo C. A self-administered rating scale for pubertal development. J Adolesc Health 1993;14:190-195.
25. Barlow SE. Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight and obesity: Summary report. Pediatrics 2007;120(Suppl 4):S164-S192.
26. Lawlor DA, Benfield L, Logue J, et al. Association between general and central adiposity in childhood, and change in these, with cardiovascular risk factors in adolescence: Prospective cohort study. BMJ 2010;341:c6224.
27. Kelly AS. The harsh reality of severe obesity. J Pediatr 2013;163:6-8.
28. Danielsson P, Kowalski J, Ekblom O, Marcus C. Response of severely obese children and adolescents to behavioral treatment. Arch Pediatr Adolesc Med 2012; 166:1103-1108.