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Stability of relative weight category and cardiometabolic risk factors among moderately and severely obese middle school youth

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Abstract

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.

Design and 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.

Keywords

obesity; severe obesity; glucose; insulin; blood pressure lipids

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Conflicts of Interest Statement

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 by no longer exist. Currently, Dr. Foster is a full-time employee of Weight Watchers International. Ms. El ghormli reports grants from NIDDK.

Introduction

Severe obesity in the U.S. 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 9 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 3-year period in a multi-ethnic sample of US middle school children who were participants in HEALTHY, a multi-site, cluster randomized, school-based study designed to evaluate a comprehensive intervention to mitigate risk for type 2 diabetes.[12] We found 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 and Procedures

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 7 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 uU/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 cut-offs for pre-hypertension (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 5 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 due to 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 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 5 BMI shift categories were examined further only if an overall association was found. All analyses were considered exploratory but due to the number of tests performed, we considered p-values <. 001 to be statistically significant. Statistical analyses were performed using SAS 9.2 statistical software (SAS Institute Inc, 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 ± 3.5 vs. 30.8 ± 1.8, respectively, p<.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 ±1.4 vs. 26.9 ± 1.6; p < .0001).

Among youth who remained severely obese from 6th to 8th grades (n=338), average BMI increased from 33.9 (± 3.5) in 6th grade to 37.2 (± 4.3) in the 8th grade (p <.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 <.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 <.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 ≥ 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 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 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 categorical 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 due to 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 ≥ 30 uU/ml in 8th grade ($p<.001$). 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 ($p<.001$). Finally, 33.4% of persistently severely obese youth compared with 20.7% of persistently moderately obese youth had triglycerides ≥ 130 mg/dl ($p<.001$). 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 U.S. 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 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).

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HEALTHY intervention materials are available for download at http://www.healthystudy.org/.

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What is already known about this subject

- Changes in relative weight category are common among middle school youth and are associated with corresponding changes in cardometabolic risk factors.
- Cross-sectional clinical data indicate that severe pediatric obesity is associated with a poorer cardiometabolic risk profile relative to moderate obesity, but longitudinal data from community samples are lacking.

What this study adds

- Severe pediatric obesity in a school-based community sample is more stable than moderate obesity over the middle school years.
- The current findings document that the cardiometabolic risk associated with enduring severe obesity during middle-school is striking.
- Given evidence that severe obesity is difficult to treat, particularly in older children, efforts to identify and treat severe obesity in younger children are indicated.

Table 1

Mean (SD) or % for Student Characteristics by Moderately and Severely Obese Weight Categories at Baseline (6th Grade)

		Moderately Obese 100–119% of 95th percentile (N=845)	Severely Obese ≥ 120% of 95th percentile (N=460)	P-value*
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)	<.0001
	Percentile (%)	97.1 (1.0)	99.1 (0.3)	<.0001
	Z-score	1.9 (0.2)	2.4 (0.2)	<.0001
Waist Circumference	**cm**	88.1 (6.6)	103.0 (9.2)	<.0001
	≥ 90th Percentile	76.2%	99.3%	<.0001
SBP	**mmHg**	110.2 (9.7)	112.0 (11.1)	0.0018
DBP	**mmHg**	66.0 (7.8)	70.4 (8.6)	<.0001
Blood Pressure	**≥ 90th or 120/80**	23.8%	37.4%	<.0001
Glucose	**mg/dl**	94.6 (6.5)	94.2 (6.7)	0.3075
	≥ 100	20.4%	19.8%	0.7791
Insulin	**μU/ml*****	17.9 (10.8)	28.7 (19.9)	<.0001
	≥ 30	10.4%	35.7%	<.0001
Total Cholesterol	**mg/dl**	160.5 (29.9)	161.2 (28.3)	0.6190

		Moderately Obese 100–119% of 95th percentile (N=845)	Severely Obese ≥ 120% of 95th percentile (N=460)	P-value*
	≥ 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)	<.0001
	≤ 40	27.2%	38.9%	<.0001
Triglycerides	**mg/dl****	108.8 (59.3)	125.9 (70.9)	<.0001
	≥ 130	26.6%	34.3%	0.0037

* P-values are from generalized linear mixed models comparing the 2 baseline weight categories and including a random effect to account for the original school intervention cluster. Due to the number of comparisons, p<.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.

*** Testing was performed on the log transform to normalize the distribution.

Table 2

Changes in BMI Percentile Categories (frequency and percent) in Moderately and Severely Obese Youth from 6th to 8th Grade

	8th grade									
	Healthy Weight (< 85th %ile)		Overweight (85–94th %ile)		Moderately Obese (100–119% of 95th %ile)		Severely Obese (≥ 120% of 95th %ile)		Overall 6th	
6th grade	N	ROW %	N	ROW %	N	ROW %	N	ROW %	N	COL %
Moderately Obese (100–119% of 95th %ile)	49	5.8%	268	31.7%	440	52.1%	88	10.4%	845	64.8%
Severely Obese (≥ 120% of 95th %ile)	1	0.2%	20	4.3%	101	22.0%	338	73.5%	460	35.2%
Overall 8th	50	3.8%	288	22.1%	541	41.5%	426	32.6%	1305	100.0%

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Table 3

Mean (SD) for 6th Grade, 8th Grade, and Change (Δ) in Cardiometabolic Outcomes by Shift in Relative Weight Category

Cardiometabolic Outcome	Severely Obese to Healthy or Overweight or Moderately Obese (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 comparisons*
Glucose (mg/dl)						
6th	94.5 (6.1)	94.7 (6.1)	94.9 (6.7)	94.2 (6.9)	93.1 (7.1)	*<.0001* *1 vs. 4* *2 vs. 3, 4, and 5* *3 vs. 4*
8th	94.1 (8.6)	93.6 (7.2)	95.4 (7.8)	96.5 (8.9)	95.6 (8.8)	
Δ	*−0.3 (8.8)*	*−1.1 (7.0)*	*+0.5 (7.0)*	*+2.4 (7.9)*	*+2.5 (7.4)*	
Insulin (μU/ml)						
6th	23.0 (12.4)	17.1 (10.1)	18.4 (11.3)	30.7 (21.6)	18.7 (10.7)	*<.0001* *1 vs. 4 and 5* *2 vs. 3, 4, and 5* *3 vs. 4 and 5*
8th	22.0 (12.2)	14.1 (7.9)	23.1 (13.4)	38.6 (27.5)	33.5 (18.4)	
Δ	*−1.1 (14.0)*	*−2.5 (10.5)*	*+4.7 (13.4)*	*+7.9 (29.2)*	*+14.8 (17.4)*	
SBP (mmHg)						
6th	112.7 (10.2)	110.9 (9.3)	109.9 (9.6)	111.8 (11.4)	109.2 (11.4)	*0.0022*
8th	116.2 (10.7)	113.3 (10.2)	115.4 (10.8)	114.2 (11.7)	112.8 (11.6)	
Δ	*+3.5 (12.0)*	*+2.4 (9.7)*	*+5.5 (11.2)*	*+2.4 (12.5)*	*+3.6 (11.6)*	
DBP (mmHg)						
6th	69.4 (8.0)	66.3 (7.7)	65.8 (7.8)	70.8 (8.8)	66.1 (8.2)	*<.0001* *2 vs. 3, 4, and 5*
8th	66.9 (7.8)	64.4 (7.6)	67.3 (8.0)	70.3 (8.4)	68.8 (7.8)	
Δ	*−2.4 (10.1)*	*−1.9 (7.7)*	*+1.4 (9.0)*	*−0.5 (10.2)*	*+2.7 (9.8)*	
Cholesterol (mg/dl)						
6th	160.0 (27.2)	157.8 (28.6)	162.3 (30.8)	161.7 (28.7)	160.8 (29.5)	*<.0001* *1 vs. 5* *2 vs. 3, 4, and 5* *3 vs. 5*
8th	145.8 (26.9)	141.4 (24.6)	152.7 (28.2)	154.7 (29.2)	160.0 (27.6)	
Δ	*−14.2 (21.8)*	*−16.4 (22.0)*	*−9.6 (23.0)*	*−6.9 (21.6)*	*−0.8 (22.3)*	
LDL (mg/dl)						
6th	91.5 (22.2)	89.6 (23.5)	93.0 (25.9)	92.8 (24.0)	92.8 (24.7)	*<.0001* *1 vs. 3, 4, and 5* *2 vs. 3, 4, and 5*

Cardiometabolic Outcome	Severely Obese to Healthy or Overweight or Moderately Obese (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 comparisons*
8th	79.3 (20.5)	76.1 (20.6)	86.6 (24.4)	90.0 (24.3)	93.2 (22.2)	*3 vs. 5*
Δ	*−12.1 (17.4)*	*−13.5 (17.4)*	*−6.4 (18.6)*	*−2.8 (17.3)*	*+0.4 (18.6)*	
HDL (mg/dl)						
6th	45.5 (10.6)	47.2 (9.3)	47.0 (9.9)	43.2 (8.6)	47.3 (11.6)	*<.0001*
8th	48.0 (12.4)	50.8 (10.5)	46.1 (10.6)	41.3 (8.6)	45.1 (9.8)	*1 vs. 3, 4, and 5* *2 vs. 3, 4, and 5*
Δ	*+2.4 (8.8)*	*+3.6 (8.2)*	*−0.9 (8.0)*	*−1.9 (7.6)*	*−2.2 (7.6)*	*3 vs. 4*
Triglycerides (mg/dl)						
6th	116.1 (57.3)	105.6 (58.9)	112.2 (61.0)	129.4 (75.0)	103.3 (50.6)	*<.0001*
8th	95.6 (98.7)	72.8 (34.3)	100.0 (52.7)	117.4 (63.6)	110.0 (57.8)	*1 vs. 4 and 5* *2 vs. 3, 4, and 5*
Δ	*−20.5 (84.2)*	*−32.9 (49.8)*	*−12.2 (57.5)*	*−12.0 (58.3)*	*+6.7 (42.6)*	

*P-values are from generalized linear mixed models testing for differences ($8^{th} - 6^{th}$ change) across the 5 columns labeled [1] to [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<.001 was considered significant.

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Table 4

Percent for 6th Grade, 8th Grade, and Change (Δ) with Cardiometabolic Risk (based on clinical cut-offs) by Stable Relative Weight Categories

Cardiometabolic Risk	Stayed Moderately Obese (N=440)	Stayed Severely Obese (N=338)	P-value*
Glucose ≥ 100 mg/dl			
6th	23.2%	20.1%	
8th	28.4%	34.3%	
Δ	*+5.2%*	*+14.2%*	*0.0015*
Insulin ≥ 30 μU/ml			
6th	10.9%	40.8%	
8th	20.0%	57.7%	
Δ	*+9.1%*	*+16.9%*	*<.0001*
BP ≥ 90th %ile or 120/80 mmHg			
6th	22.7%	38.2%	
8th	38.0%	39.1%	
Δ	*+15.3%*	*+0.9%*	*0.9950*
Cholesterol ≥ 200 mg/dl			
6th	12.0%	9.5%	
8th	5.2%	7.1%	
Δ	*−6.8%*	*−2.4%*	*0.1232*
LDL ≥ 130 mg/dl			
6th	8.4%	7.4%	
8th	3.9%	5.9%	
Δ	*−4.5%*	*−1.5%*	*0.1471*
HDL ≤ 40 mg/dl			
6th	28.2%	39.1%	
8th	30.0%	47.6%	
Δ	*+1.8%*	*+8.5%*	*<.0001*
Triglycerides ≥ 130 mg/dl			
6th	28.9%	35.5%	
8th	20.7%	33.4%	
Δ	*−8.2%*	*−2.1%*	*0.0001*

*P-values are from generalized linear mixed models testing for change from 6th to 8th between those in the cohort who stayed in the moderately obese and in the severely obese categories. Models were adjusted for the baseline value of the cardiometabolic outcome and change in height (cm). Due to the number of comparisons, p<.001 was considered significant.