ORIGINAL ARTICLE

Cardiometabolic Risks and Severity of Obesity in Children and Young Adults

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ABSTRACT

BACKGROUND

The prevalence of severe obesity among children and young adults has increased over the past decade. Although the prevalence of cardiometabolic risk factors is relatively low among children and young adults who are overweight or obese, those with more severe forms of obesity may be at greater risk.

METHODS

We performed a cross-sectional analysis of data from overweight or obese children and young adults 3 to 19 years of age who were included in the National Health and Nutrition Examination Survey from 1999 through 2012 to assess the prevalence of multiple cardiometabolic risk factors according to the severity of obesity. Weight status was classified on the basis of measured height and weight. We used standard definitions of abnormal values for total cholesterol, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein cholesterol, triglycerides, blood pressure, glycated hemoglobin, and fasting glucose and report the prevalence of abnormal values in children and young adults according to weight status.

RESULTS

Among 8579 children and young adults with a body-mass index at the 85th percentile or higher (according to the Centers for Disease Control and Prevention growth charts), 46.9% were overweight, 36.4% had class I obesity, 11.9% had class II obesity, and 4.8% had class III obesity. Mean values for some, but not all, cardiometabolic variables were higher with greater severity of obesity in both male and female participants, and the values were higher in male participants than in female participants; for HDL cholesterol, the mean values were lower with greater severity of obesity. Multivariable models that controlled for age, race or ethnic group, and sex showed that the greater the severity of obesity, the higher the risks of a low HDL cholesterol level, high systolic and diastolic blood pressures, and high triglyceride and glycated hemoglobin levels.

CONCLUSIONS

Severe obesity in children and young adults was associated with an increased prevalence of cardiometabolic risk factors, particularly among boys and young men.

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The prevalence of severe obesity among children and young adults has increased in recent years[1] and has led to a heightened awareness and concern about the cardiovascular and metabolic health of persons in this age group. In 1999–2004, almost 4% of children and young adults in the United States 2 to 19 years of age were classified as having severe obesity,[2] and as recently as 2011–2012, the prevalence of severe obesity increased to approximately 6% in this age group[1]; however, the prevalence of cardiometabolic risk factors accompanying severe obesity in these children and young adults is unclear.

Cardiometabolic risk factors are more prevalent among overweight or obese children and young adults than among those of healthy weight.[3] However, the use of only a single category for obesity does not take into account the varying severity of obesity. The American Heart Association identified several relatively small studies that showed that more severe forms of obesity were associated with a greater immediate risk of complications related to weight, including abnormal lipid and blood glucose levels and increased blood-pressure levels[4]; however, various definitions of severe obesity were used in these studies. Clearer guidelines now exist to define severe obesity as 120% of the 95th percentile for body-mass index (BMI, the weight in kilograms divided by the square of the height in meters) and to define markedly severe obesity as 140% of the 95th percentile.[1,4] As children approach adulthood, these high percentile curves approximate a BMI of at least 35 for severe obesity (class II obesity) and a BMI of at least 40 for markedly severe obesity (class III obesity).[1] To improve the understanding of the distribution of cardiometabolic risk factors, we examined the prevalence of multiple cardiometabolic risk factors according to the severity of obesity using nationally representative data.

Methods

Data Source and Study Design

We obtained data from the National Health and Nutrition Examination Survey (NHANES, 1999–2012). The NHANES includes a stratified, multistage probability sample of the civilian, noninstitutionalized U.S. population. The data obtained included responses to an in-home interview on a variety of demographic variables and health topics, findings from a physical examination performed at a mobile examination center that included measured height and weight, and laboratory measurements.[5] The National Center for Health Statistics (NCHS) designed the NHANES and collected the data after obtaining written informed consent from the participants or their parents or guardians and assent from minors; most components of the NHANES, including those used in the current study, are publicly available. The first author designed and performed the analyses, with no input from the NCHS, and assumes responsibility for the analyses. The institutional review board at the University of North Carolina at Chapel Hill, in accordance with the Code of Federal Regulations, deemed this study to be exempt from further review and from the requirement to obtain written informed consent because it used only deidentified secondary data.

Study Sample

Our study sample included NHANES participants who were 3 to 19 years of age at the time of examination. We excluded 513 children and young adults with missing BMI values. Given our focus on obesity, we excluded 807 participants who were underweight and 15,469 participants who had a healthy weight (i.e., all participants who were below the 85th percentile for age-specific and sex-specific BMI, as defined below). Thus, the final sample comprised 8579 children and young adults. Because certain NHANES measures have a more targeted sampling frame (e.g., limited to specific ages), specific reported measures had different sample sizes (Table 1).[5]

Weight Status

We classified weight status using height and weight measurements obtained at the time of the physical examination component of the NHANES to calculate BMI and to determine the BMI percentile, which we derived from the Centers for Disease Control and Prevention (CDC) growth charts using the SAS code that was developed for this purpose.[6] In 2011–2012, the NHANES reported age in years for children and young adults 2 to 19 years of age, rather than age in months as in previous releases; age in months was reported only for children from birth to 2 years of age. To estimate the preva-

lence of obesity consistently across our study period, we used the midpoints of the whole-year ages of the children in all calculations (e.g., an 11-year-old child was considered to be 11.5 years of age). This method of calculation yielded prevalence rates that were similar to calculations based on age in months, with differences of 0.1 to 0.2 percentage points,[1] and was used for all 2-year cycles of the NHANES to ensure consistency in the determinations of weight status.

The weight categories according to age-specific and sex-specific BMI percentiles that we used in the current study were as follows: overweight (≥85th to <95th percentile), class I obesity (≥95th percentile to <120% of the 95th percentile), class II obesity (≥120% to <140% of the 95th percentile, or BMI ≥35, whichever was lower), and class III obesity (≥140% of the 95th percentile, or BMI ≥40, whichever was lower). The definitions of healthy weight, overweight, and obesity were based on the recommendations of the CDC,[7] and the definition of class II obesity was based on the recommendation of the American Heart Association.[4] We used the range of 120% to less than 140% of the 95th percentile to define class II obesity instead of the 99th percentile or higher because the former definition has been shown to have more stability in estimation procedures.[8] We used 140% of the 95th percentile to define class III obesity because it approximated a BMI of 40 in late adolescence, the same age at which 120% of the 95th percentile approximated a BMI of 35.[1] Among adults, persons with these ranges of BMI are considered to be at a higher risk for earlier death.[9] The BMI percentiles in our study were not derived from the study sample we evaluated but were defined by the CDC growth charts that used a historical sample; this allowed for a consistent categorization of weight status throughout the entire study sample.

CARDIOMETABOLIC RISK FACTORS

Because we evaluated children and young adults, we examined variables that are associated with known cardiometabolic risk rather than hard end points of cardiovascular events. Total cholesterol and high-density lipoprotein (HDL) cholesterol levels were measured in the full study sample in the targeted age ranges, whereas measurements of low-density lipoprotein (LDL) cholesterol and triglyceride levels were limited to a subgroup of participants who underwent an examination in the morning as part of the NHANES study procedures. Fasting times varied among participants in whom fasting laboratory studies were performed. We used standard cutoff values for levels of total cholesterol (≥200 mg per deciliter [>5.18 mmol per liter]), HDL cholesterol (<35 mg per deciliter [<0.9 mmol per liter]), LDL cholesterol (≥130 mg per deciliter [≥3.4 mmol per liter]), and triglycerides (≥150 mg per deciliter [>1.7 mmol per liter]) to define abnormal values; when the recommendations for cutoff values were inconsistent, we chose the more conservative definition.[10-12]

Blood pressure was recorded as the mean value of up to three measurements or as a single measurement (86% of the children and young adults had three measurements, 8% had two, and 6% had one). For children younger than 18 years of age, we used standardized blood pressure tables in which abnormal values were determined according to age, sex, and height; abnormal values were defined as any value that was in at least the 95th percentile in those tables.[13] For young adults 18 and 19 years of age, we used cutoffs of 140 mm Hg for systolic blood pressure and 90 mm Hg for diastolic blood pressure.[14]

Glycated hemoglobin levels were measured in all participants 12 years of age or older as part of the standard NHANES laboratory measure-

Table 1. Definitions of Abnormal Values for Risk-Factor Variables.*

Variable	Age Range	No. of Participants Evaluated	Definition of Abnormal Value
	yr		
Total cholesterol	3–19	6876	≥200 mg/dl
HDL cholesterol	3–19	6873	<35 mg/dl
Systolic BP	8–19	6412	≥95th percentile
Diastolic BP	8–19	6412	≥95th percentile
LDL cholesterol	3–19	2464	≥130 mg/dl
Triglycerides	3–19	2537	≥150 mg/dl
Glycated hemoglobin	12–19	4237	>5.7%
Glucose	12–19	1991	≥100 mg/dl

* A total of 8579 children and young adults 3 to 19 years of age were evaluated. To convert the values for cholesterol to millimoles per liter, multiply by 0.0259. To convert the values for triglycerides to millimoles per liter, multiply by 0.0113. To convert the values for glucose to millimoles per liter, multiply by 0.0555. BP denotes blood pressure, HDL high-density lipoprotein, and LDL low-density lipoprotein.

ments; a value greater than 5.7% was defined as abnormal. Fasting glucose was measured in the subgroup of NHANES participants who attended the morning session; a value of 100 mg per deciliter or higher (≥5.6 mmol per liter) was defined as abnormal. The definitions of abnormal values for glycated hemoglobin and fasting glucose were based on recommendations by the American Diabetes Association for identifying persons at high risk for diabetes.[15]

Detailed information about the collection and measurement procedures of the NHANES can be found in the NHANES Laboratory Procedures Manual.[16] The specific measures obtained and the age group for which they were obtained varied by NHANES cycle. The sampling frame for each laboratory measure is detailed in the NHANES content brochure.[5] The ages for the sampling frame, the total sample size, and the definitions used for abnormal values are shown in Table 1. We did not limit lipid values to those measured when the participants were fasting because previous research has shown that the differences in values according to fasting status are minimal.[17]

STATISTICAL ANALYSIS

The primary results of the bivariate analysis are presented as mean values for cardiometabolic variables and for prevalence of cardiometabolic risk factors, according to weight status. All differences were examined with the use of adjusted Wald tests. We report only the results of joint Wald tests of differences across all four weight categories and include 95% confidence intervals to allow for further interpretation of the differences between specific groups (e.g., class II obesity as compared with class III obesity). We report mean values for all children and young adults, as well as for male and female participants separately. Because the quantification of risk is critical to policy development, we report the results of a further examination of the prevalence of cardiometabolic risk factors by weight category according to subgroups defined by age, sex, and race or ethnic group. Age, sex, and race or ethnic group categories were specified before analysis, and we report all cardiometabolic risk factors for each. We provide sample sizes throughout our results for reference, but all reported mean values, percentages, prevalence values, and results of statistical tests are weighted to represent the U.S. population.

Multivariable analyses were performed with the use of generalized linear models with a logarithmic link. Exponentiation of the coefficients was used to report risk ratios for the effect of obesity severity on cardiometabolic risks. All analyses were adjusted for the strata, primary sampling units, and probability weights used in the complex survey design of the NHANES[18,19] and were performed with the use of the survey estimation routines in Stata software, version 13.1 (StataCorp). We pooled all years and adjusted the probability weight accordingly, as directed by the NCHS.[19] Because our primary interest was the relationship between severe obesity and cardiometabolic risks and because the prevalence of obesity changed minimally during the time frame of our study,[1] we did not perform any time-trend analysis in this study. P values of less than 0.05 were considered to indicate statistical significance, although the differences between the groups are better represented by the confidence intervals, and we believe that the focus should be on the clinical importance of the estimates rather than on statistical significance. Finally, missing data were due primarily to the design of the NHANES, and therefore no additional imputation of data was performed.

RESULTS

Among the 8579 children and young adults with a BMI at the 85th percentile or higher, 46.9% were overweight, 36.4% had class I obesity, 11.9% had class II obesity, and 4.8% had class III obesity (Table 2). Table S1 in the Supplementary Appendix (available with the full text of this article at NEJM.org) shows the mean values for each cardiometabolic variable in all participants and separately in male and female participants. With few exceptions, in both male and female participants, the mean values for the cardiometabolic variables were higher with greater severity of obesity; for HDL cholesterol, the mean values were lower with greater severity of obesity.

Table 3 and Figure 1 show the prevalence of abnormal values for each cardiometabolic variable. As was the case with mean values for cardiometabolic variables, the prevalence of abnormal values was higher with greater severity of obesity. Table 3 also shows the statistical significance of differences across all weight categories, although the multivariable analyses described

below better represent the differences between individual categories. We report our findings for all age groups; however, the sample sizes for children 3 to 5 years of age were very small, and the associated point estimates for those participants must be interpreted with caution. Among participants 12 to 19 years of age, the prevalence of all risk factors, with the exception of LDL cholesterol, increased by weight category, and most risk factors increased by weight category among children 6 to 11 years of age. Prevalence according to sex and race or ethnic group are shown in Tables S2 and S3 in the Supplementary Appendix, respectively.

Table 4 shows the results from multivariable general linear models (see Table S4 in the Supplementary Appendix for data on all variables). In models that controlled for age, race or ethnic group, and sex, the risks of low HDL cholesterol level, high systolic blood pressure, high diastolic blood pressure, high triglyceride level, and high glycated hemoglobin level were greater among children and young adults with class III obesity than among those with class I obesity. There were few significant differences in these variables according to weight category among female participants, but all the differences remained significant among male participants. As expected, overweight children and young adults had a lower risk of most risk factors than did those with class I obesity.

Table 2. Demographic Variables and Sample Size Weighted for Survey Design.*

Variable	No. of Participants	Weighted %
Age		
3–5 yr	1098	13.3
6–11 yr	2857	36.8
12–19 yr	4629	50.0
Race or ethnic group†		
White	1991	53.7
Black	2579	16.5
Hispanic	3581	24.0
Other	433	5.7
Sex		
Male	4331	52.0
Female	4253	48.0
Weight category‡		
Overweight	3833	46.9
Class I obesity	3093	36.4
Class II obesity	1141	11.9
Class III obesity	512	4.8

* Data are shown for children and young adults with an age-specific and sex-specific body-mass index at the 85th percentile or higher, according to the Centers for Disease Control and Prevention growth charts. Values may not add to 100% because of rounding.
† Race or ethnic group was self-reported.
‡ Weight categories were defined as follows: overweight (≥85th to <95th percentile), class I obesity (≥95th percentile to <120% of the 95th percentile), class II obesity (≥120% to <140% of the 95th percentile), and class III obesity (≥140% of the 95th percentile).

DISCUSSION

Severe obesity in children and young adults is associated with a high prevalence of abnormal levels of cardiometabolic variables. A high prevalence of abnormal values for certain variables among children and young adults with class II or class III obesity may provide important information beyond that identified with the use of standard obesity classifications, especially for boys and young men. The greater prevalence among participants 12 to 19 years of age is consistent with a previous report of the overall U.S. population of children and adolescents.[20]

Determination of the severity of obesity can help identify children and young adults who are at the greatest risk for the negative health effects associated with obesity. Current guidelines for screening do not differentiate among levels of obesity.[7,21] Although the prevalence of abnormal values does not increase with obesity severity in the case of all risk-factor variables, our findings of greater risks of abnormal HDL cholesterol level, systolic blood pressure, and glucose metabolism support the stratification of risk on the basis of the American Heart Association recommendations for classification of a higher level of obesity at 120% of the 95th percentile.[4] Our findings of the additional risk of abnormal triglyceride and glycated hemoglobin levels provide initial support for further risk stratification according to 140% of the 95th percentile.

The differences between male and female participants in our study are notable; severe obesity is associated with a higher prevalence of abnormal systolic blood pressure, triglyceride level, and glycated hemoglobin level among male participants than among female participants. It is possible that cardiometabolic risk factors develop earlier in boys than in girls. Alternatively,

Table 3. Prevalence of Abnormal Values for Risk-Factor Variables by Age and Weight Category.*

Risk-Factor Variable and Weight Category	All Ages			Ages 3–5 Yr†			Ages 6–11 Yr‡			Ages 12–19 Yr		
	Participants	Prevalence	P Value	Participants	Prevalence	P Value	Participants	Prevalence	P Value	Participants	Prevalence	P Value
	no.	*% (95% CI)*		*no.*	*% (95% CI)*		*no.*	*% (95% CI)*		*no.*	*% (95% CI)*	
Total cholesterol	6875		<0.001	295		<0.003	2359		0.004	4221		0.008
Overweight	3056	10.02 (8.36 to 11.67)		143	6.70 (2.27 to 11.13)		1032	9.12 (6.73 to 11.51)		1881	10.87 (8.62 to 13.12)	
Class I obesity	2452	14.27 (12.46 to 16.07)		119	6.27 (1.04 to 11.50)		899	15.40 (12.35 to 18.45)		1434	14.14 (11.39 to 16.90)	
Class II obesity	956	16.19 (12.35 to 20.03)		26	0		321	15.66 (9.84 to 21.47)		609	17.41 (12.77 to 22.06)	
Class III obesity	411	18.59 (12.86 to 24.32)		7	7.57 (–8.45 to 23.60)		107	16.98 (7.38 to 26.59)		297	19.40 (12.40 to 26.41)	
HDL cholesterol	6872		<0.001	293		0.68	2359		<0.001	4220		<0.001
Overweight	3054	6.13 (4.93 to 7.33)		142	6.85 (0.75 to 12.95)		1032	3.61 (2.01 to 5.21)		1880	7.76 (5.98 to 9.54)	
Class I obesity	2451	11.40 (9.84 to 12.97)		118	10.14 (1.91 to 18.36)		899	8.81 (6.35 to 11.27)		1434	13.38 (10.92 to 15.84)	
Class II obesity	956	18.18 (14.35 to 22.00)		26	9.90 (–3.88 to 23.68)		321	16.36 (9.46 to 23.26)		609	19.75 (15.10 to 24.40)	
Class III obesity	411	19.53 (13.94 to 25.12)		7	25.67 (–12.14 to 63.48)		107	7.92 (3.01 to 12.84)		297	23.03 (15.66 to 30.40)	
LDL cholesterol	2362		0.11	130		0.02	423		0.03	1809		0.38
Overweight	1096	8.16 (5.84 to 10.47)		66	11.26 (2.53 to 19.99)		208	5.99 (2.09 to 9.89)		822	8.56 (6.08 to 11.03)	
Class I obesity	806	12.08 (8.91 to 15.25)		47	2.24 (–0.95 to 5.43)		144	19.08 (9.98 to 28.19)		615	11.01 (7.34 to 14.68)	
Class II obesity	305	11.63 (6.90 to 16.36)		13	0		51	5.32 (0.42 to 10.23)		241	13.57 (7.84 to 19.30)	
Class III obesity	155	10.46 (4.61 to 16.30)		4	0		20	8.96 (–3.69 to 21.62)		131	10.84 (4.63 to 17.05)	
Triglycerides	2379		<0.001	130		0.44	425		0.43	1824		0.002
Overweight	1102	12.16 (9.26 to 15.07)		66	7.95 (–0.17 to 16.07)		209	13.19 (7.15 to 19.24)		827	12.21 (9.00 to 15.41)	
Class I obesity	812	20.35 (16.48 to 24.22)		47	10.77 (–3.40 to 24.93)		144	19.68 (10.95 to 28.41)		621	21.23 (16.42 to 26.04)	
Class II obesity	307	18.81 (12.76 to 24.86)		13	23.18 (–3.84 to 50.19)		52	12.73 (5.46 to 19.99)		242	19.85 (12.16 to 27.54)	
Class III obesity	158	28.82 (18.22 to 39.42)		4	42.72 (–13.90 to 99.33)		20	23.99 (2.95 to 45.03)		134	28.95 (17.05 to 40.86)	

Systolic BP	6412		<0.001			1951		<0.001	4461		0.03
Overweight	2825	3.22 (2.27 to 4.18)		—	—	845	3.15 (1.59 to 4.71)		1980	3.26 (2.15 to 4.37)	
Class I obesity	2246	5.02 (3.87 to 6.17)		—	—	731	5.62 (3.26 to 7.98)		1515	4.70 (3.17 to 6.22)	
Class II obesity	929	8.52 (5.76 to 11.27)		—	—	277	10.15 (5.08 to 15.23)		652	7.69 (4.46 to 10.91)	
Class III obesity	412	11.10 (6.10 to 16.09)		—	—	98	22.48 (11.04 to 33.92)		314	7.63 (3.08 to 12.18)	
Diastolic BP	6412		0.004			1951		0.08	4461		0.03
Overweight	2825	0.45 (0.16 to 0.73)		—	—	845	0.67 (0.00 to 1.33)		1980	0.33 (0.09 to 0.57)	
Class I obesity	2246	1.20 (0.47 to 1.94)		—	—	731	1.33 (–0.07 to 2.74)		1515	1.13 (0.30 to 1.97)	
Class II obesity	929	0.60 (–0.16 to 1.37)		—	—	277	1.09 (–1.06 to 3.25)		652	0.35 (–0.04 to 0.75)	
Class III obesity	412	4.66 (1.92 to 7.39)		—	—	98	7.38 (0.37 to 14.40)		314	3.83 (0.89 to 6.77)	
Glycated hemoglobin	4237		<0.001						4237		<0.001
Overweight	1883	1.87 (1.22 to 2.52)		—	—	—	—		1883	1.87 (1.22 to 2.52)	
Class I obesity	1437	3.40 (2.26 to 4.53)		—	—	—	—		1437	3.40 (2.26 to 4.53)	
Class II obesity	615	6.38 (4.02 to 8.73)		—	—	—	—		615	6.38 (4.02 to 8.73)	
Class III obesity	302	13.19 (8.07 to 18.30)		—	—	—	—		302	13.19 (8.07 to 18.30)	
Glucose	1838		0.003						1838		0.003
Overweight	833	15.56 (11.62 to 19.49)		—	—	—	—		833	15.56 (11.62 to 19.49)	
Class I obesity	626	19.42 (14.32 to 24.52)		—	—	—	—		626	19.42 (14.32 to 24.52)	
Class II obesity	243	31.77 (23.90 to 39.65)		—	—	—	—		243	31.77 (23.90 to 39.65)	
Class III obesity	136	24.27 (14.54 to 34.00)		—	—	—	—		136	24.27 (14.54 to 34.00)	

* Sample sizes are provided for reference; all estimates are weighted for survey design. P values are from adjusted Wald tests of differences across all weight categories. BP denotes blood pressure.
† For participants 3 to 5 years of age, variables were not measured for systolic BP, diastolic BP, glycated hemoglobin, and glucose.
‡ For participants 6 to 11 years of age, data were not reported for glycated hemoglobin and glucose.

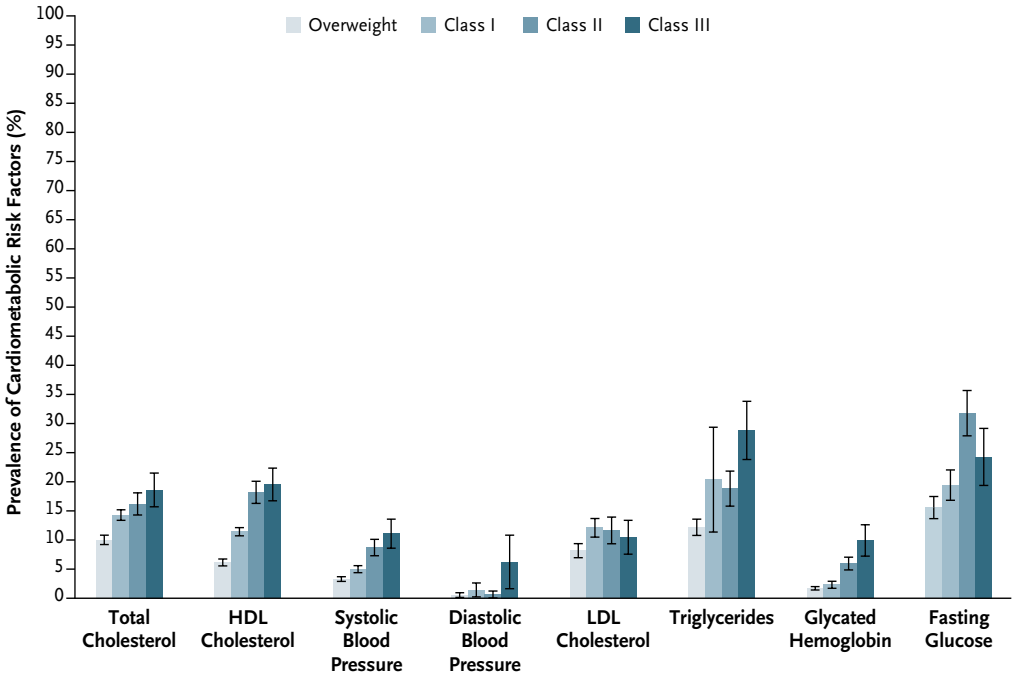

Figure 1. Prevalence of Cardiometabolic Risk Factors by Weight Status.

The study sample comprised 8579 children and young adults 3 to 19 years of age in the National Health and Nutrition Examination Survey from 1999 through 2012. Weight categories were defined as follows: overweight (≥85th to <95th percentile for age-specific and sex-specific BMI, according to the Centers for Disease Control and Prevention growth charts), class I obesity (≥95th to <120% of the 95th percentile), class II obesity (≥120% to <140% of the 95th percentile), and class III obesity (≥140% of the 95th percentile). HDL denotes high-density lipoprotein, and LDL low-density lipoprotein.

use of the same definitions of obesity for girls and boys may not determine equivalent risk. Our findings differ from those in other reports that used only standard definitions and showed minimal differences between boys and girls.[22-24]

Obesity during childhood increases the risk of long-term obesity,[25,26] as well as the risks of substantial complications and death in adulthood.[27,28] Severe obesity during adolescence is associated with significantly higher risks of complications.[29] Although prevention remains the primary goal in the management of obesity, focus has shifted to also identifying and treating complications associated with obesity.[21] Classifying obesity into three categories provides a more fine-tuned approach to identifying patients with the greatest risk of potential complications and death.[28,29] The treatment of childhood obesity is both recommended and effective[30]; however, intensive therapies, such as medically supervised meal replacement, pharmacologic treatment, and bariatric surgery, confer certain risks and are often costly. In addition, resources are too limited to appropriately service every child with obesity because most treatment clinics and programs are concentrated within tertiary-care pediatric hospitals.[31] The confluence of risks and limited resources leaves many children with severe obesity and established cardiometabolic risk factors without effective options. The application of a more complex classification of obesity, if it identifies those at highest risk, may permit targeted interventions that could decrease morbidity and mortality and may also be cost-effective.

An accurate classification of children with marked obesity may improve the care of this patient population. The cost of treating complications related to obesity in adults has been estimated to be as high as $147 billion[32] and will probably continue to rise.[33] Children with obesity have higher outpatient health care expenditures than those with normal weight, with the

Table 4. Risk Ratios for Cardiovascular Risk Factors by Sex and Weight Category.*

Risk-Factor Variable and Weight Category	All Participants		Female Participants		Male Participants	
	Risk Ratio (95% CI)	P Value	Risk Ratio (95% CI)	P Value	Risk Ratio (95% CI)	P Value
Total cholesterol						
Overweight	0.70 (0.58–0.85)	<0.001	0.79 (0.58–1.07)	0.12	0.63 (0.49–0.82)	<0.001
Class I obesity	Reference		Reference		Reference	
Class II obesity	1.12 (0.88–1.45)	0.34	1.17 (0.78–1.77)	0.45	1.09 (0.78–1.54)	0.60
Class III obesity	1.29 (0.92–1.80)	0.14	1.08 (0.56–2.00)	0.80	1.41 (0.93–2.15)	0.10
HDL cholesterol						
Overweight	0.55 (0.44–0.69)	<0.001	0.46 (0.33–0.65)	<0.001	0.60 (0.43–0.85)	0.004
Class I obesity	Reference		Reference		Reference	
Class II obesity	1.65 (1.31–2.01)	<0.001	1.06 (0.70–1.60)	0.78	2.00 (1.45–2.74)	<0.001
Class III obesity	1.89 (1.35–2.66)	<0.001	1.19 (0.66–2.12)	0.56	2.36 (1.55–3.58)	<0.001
LDL cholesterol						
Overweight	0.67 (0.48–0.93)	0.02	0.66 (0.41–1.06)	0.08	0.69 (0.42–1.12)	0.13
Class I obesity	Reference		Reference		Reference	
Class II obesity	0.92 (0.57–1.48)	0.19	1.04 (0.51–2.18)	0.90	0.80 (0.42–1.52)	0.50
Class III obesity	0.79 (0.44–1.43)	0.59	0.85 (0.38–1.89)	0.68	0.75 (0.32–1.78)	0.51
Triglycerides						
Overweight	0.62 (0.46–0.82)	<0.001	0.80 (0.52–1.24)	0.32	0.52 (0.34–0.79)	0.003
Class I obesity	Reference		Reference		Reference	
Class II obesity	0.99 (0.68–1.45)	0.97	0.82 (0.44–1.50)	0.52	1.09 (0.70–1.70)	0.71
Class III obesity	1.63 91.08–2.47)	0.02	1.66 (0.73–3.79)	0.23	1.62 (1.00–2.63)	0.05
Systolic BP						
Overweight	0.65 (0.45–0.94)	0.02	0.98 (0.57–1.67)	0.94	0.47 (0.28–0.79)	0.005
Class I obesity	Reference		Reference		Reference	
Class II obesity	1.67 (1.10–2.53)	0.02	1.93 (0.96–3.88)	0.06	1.55 (0.93–2.56)	0.09
Class III obesity	2.24 (1.42–3.54)	<0.001	1.67 (0.86–3.26)	0.13	2.45 (1.44–4.16)	<0.001
Diastolic BP						
Overweight	0.37 (0.15–0.92)	0.03	0.19 (0.06–0.57)	0.003	0.73 (0.21–2.58)	0.63
Class I obesity	Reference		Reference		Reference	
Class II obesity	0.53 (0.13–2.19)	0.38	0.13 (0.03–0.63)	0.01	1.24 (0.22–6.91)	0.80
Class III obesity	4.57 (1.88–11.06)	<0.001	3.00 (0.63–14.20)	0.17	7.56 (2.48–23.09)	<0.001
Glycated hemoglobin						
Overweight	0.54 (0.34–0.85)	0.008	0.59 (0.31–1.12)	0.10	0.45 (0.25–0.83)	0.01
Class I obesity	Reference		Reference		Reference	
Class II obesity	1.58 (0.96–2.57)	0.07	1.19 (0.57–2.51)	0.64	2.00 (1.08–3.70)	0.03
Class III obesity	2.59 (1.55–4.34)	<0.001	1.82 (0.93–3.58)	0.08	3.53 (1.67–7.49)	<0.001
Glucose						
Overweight	0.84 (0.60–1.17)	0.30	0.70 (0.39–1.24)	0.22	0.90 (0.63–1.30)	0.58
Class I obesity	Reference		Reference		Reference	
Class II obesity	1.67 (1.26–2.22)	<0.001	1.41 (0.77–2.59)	0.26	1.77 (1.28–2.45)	<0.001
Class III obesity	1.24 (0.78–1.96)	0.09	1.19 (0.55–2.60)	0.66	1.21 (0.71–2.09)	0.48

* Generalized linear models that controlled for age, race or ethnic group, and sex were used for these analyses. Class I obesity is the referent group. Total cholesterol was measured in 6875 participants (3424 females and 3451 males), HDL cholesterol in 6872 participants (3422 females and 3450 males), LDL cholesterol in 2362 participants (1188 females and 1174 males), triglycerides in 2379 participants (1195 females and 1184 males), systolic BP in 6412 participants (3233 females and 3179 males), diastolic BP in 6412 participants (3233 females and 3179 males), glycated hemoglobin in 4237 participants (2132 females and 2105 males), and glucose in 1838 participants (923 females and 915 males).

increased costs believed to stem from the evaluation and treatment of coexisting conditions[34]; an improved estimation of risk that is based on obesity severity could lower the costs of evaluation without resulting in missed diagnoses of coexisting conditions. Children with severe obesity already have increased cardiometabolic risk, which may predict the early onset of serious diseases such as hypertension and diabetes.

As older adolescents transition to young adulthood, the recognition that teens with obesity have increased cardiometabolic risk will be important. Current treatment approaches are not as effective at higher levels of obesity than they are at lower levels of obesity.[35-37] The findings in our study, when considered in the context of the negative effect that these risk factors have on subsequent quality of life,[38] imply a need for the early identification of abnormal weight gain, primary and secondary prevention of obesity, and systemwide policy changes in the evaluation and management of obesity in health care.[39]

We examined a range of cardiometabolic risk-factor variables in a large and nationally representative population; however, our study has certain methodologic limitations. First, because this is a cross-sectional study, we could not show causality between obesity and risk factors. Second, although we used standard definitions of abnormal values for risk-factor variables, the cross-sectional design did not allow us to examine the effects of these abnormal values on future morbidity or mortality. Finally, the sample size was small in certain subgroups, particularly in the subgroup of young children, which resulted in wide confidence intervals and point estimates that should be interpreted with caution.

In conclusion, severe obesity in children and young adults is associated with a high prevalence of abnormal levels of cardiometabolic risk-factor variables. The prevalence of these abnormal values among children and young adults appears to be dependent on both age and severity of obesity. The inclusion of class II obesity in the standard obesity classification may assist in the identification of children who could be at the greatest risk for abnormal levels of HDL cholesterol, systolic blood pressure, and glucose, and the inclusion of class III obesity in the standard obesity classification may assist in the identification of those at the greatest risk for abnormal levels of triglycerides, diastolic blood pressure, and glycated hemoglobin.

Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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