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Cardiometabolic Risk Factors among Severely Obese Children and Adolescents in the United States, 1999–2012

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Abstract

Background: Severely obese children and adolescents are at high risk of suffering obesity-related comorbidities. This article is to examine the dose-response relationship between weight status and cardiometabolic risk factors among US adolescents.

Methods: Youths aged 6–19 years participating in the National Health and Nutrition Examination Surveys (NHANES) 1999–2012 were included ($N = 20{,}905$). Severe obesity was defined as BMI ≥120% of 95th percentile of gender-specific BMI-for-age or BMI ≥35 kg/m^2. Obesity-related cardiometabolic risk factors included blood pressure (BP), high-density lipoprotein cholesterol (HDL), low-density lipoprotein cholesterol (LDL), total cholesterol (TC), triglycerides, and fasting glucose (FG). Weighted multiple logistic regression was used to assess whether severe obesity significantly changed the odds of having cardiometabolic risk factors.

Results: The prevalence of high BP, high TC, low HDL, high triglycerides, high LDL, and high FG among severely obese adolescents was 9.9%, 16.5%, 40.0%, 30.0%, 13.0%, and 26.8%, respectively. Severely obese adolescents had at least twice the odds compared to normal weight adolescents of presenting high BP (OR = 5.3, 95% CI: 3.8–7.3); high TC (OR = 2.3, 95% CI: 1.8–3.0); low HDL (OR = 7.3, 95% CI: 6.1–8.8); high triglycerides (OR = 4.5, 95% CI: 3.4–5.9); high LDL (OR = 2.3, 95% CI: 1.5–3.5); and high FG (OR = 2.7, 95% CI: 1.8–4.0). Significant differences were also found between severely obese status and moderately obese status in the odds of having high BP (OR = 1.8, 95% CI: 1.7–2.2) and low HDL (OR = 1.9, 95% CI: 1.6–2.3).

Conclusion: Adolescents classified as severe status exhibit higher odds of having cardiometabolic risk factors compared to those with normal weight and moderately obese weight status.

Introduction

Common medical comorbidities of childhood obesity include prediabetes and type II diabetes, hypertension, hypercholesterolemia, hyperlipidemia, cardiovascular disease, sleep apnea, asthma, nonalcoholic fatty liver disease, orthopedic disease, reproductive abnormalities, and certain cancers.[1] In addition, obese children are at higher risk of psychosocial comorbidities, including isolation, stigmatization, negative stereotyping, discrimination, teasing, and bullying.[2,3] Children with extremely high body mass index (BMI) are classified as severely obese, which is defined as a BMI ≥120% of 95th percentile of BMI-for-age or above 35 kg/m^2.[4–6] Several studies have reported an elevated risk among severely obese youth compared with less obese or nonobese youth for a number of obesity-related comorbidities, particularly cardiometabolic risk factors, mainly including high blood pressure (BP), high fasting glucose (FG), high total cholesterol (TC), low high density lipoprotein (HDL) cholesterol, high low density lipoprotein (LDL) cholesterol, and high triglycerides.[6–8] With increasing severity and magnitude of obesity, the probability of developing multiple comorbidities rises concomitantly, resulting in complicated and worsening of health consequences.[7] Among all those comorbidities, metabolic and cardiovascular diseases, as well as the persistence of obesity into adulthood, are the most commonly seen in clinical practice.[9]

The rates of cardiovascular and metabolic comorbidities among obese children have been well documented; however, the literature focusing on severe obesity is limited, particularly with regard to population representation. The objectives of this study are to examine the dose-response relationship between weight status and cardiometabolic risk factors and to evaluate the excessive cardiometabolic risk resulting from severely obese status relative to normal/

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overweight/moderately obese children and adolescents (ages 8–19 years) in the United States using the National Health and Nutrition Examination Survey (NHANES) data from 1999 to 2012.

Methods

Data and Study Population

NHANES is a surveillance program evaluating the health and nutritional status of adults and children in the United States.[10] The sample of NHANES was selected by a complex multistage probability sampling design, representing the noninstitutionalized US population for all ages. NHANES was initiated in the early 1960s and has been conducted as a series of periodic surveys, including NHANES I (1971–1975), NHANES II (1976–1980), and NHANES III (1988–1994). Since 1999, in order to accommodate emerging health needs and issues, NHANES has been administered as a continuous survey, with data collection periods occurring every two years. In each two-year survey period about 5000 participants from 15 counties across the United States were interviewed regarding their demographic, socioeconomic, dietary, and health-related information, followed by a physical examination and laboratory tests. Details of the NHANES data collection method and process can be found elsewhere.[10]

In this study, seven periods of NHANES surveys were included in the analyses (NHANES 1999–2000, 2001–2002, 2003–2004, 2005–2006, 2007–2008, 2009–2010, and 2011–2012). Demographic information on participants (age, gender, race/ethnicity, etc.) was extracted from the interview data. The height and weight information for calculating BMIs was extracted from the physical examination data, and the information on cardiovascular risk factors was extracted from the laboratory data.[10] Participants with missing BMI and cardiometabolic risk factors were excluded from analyses. Given different sample sizes across survey periods, the final total participants included in the analyses varied by each outcome variable: BP (n = 17,510); FG (n = 4615); TC (n = 18,151); HDL (n = 18,150); LDL (n = 4550); and triglycerides (n = 4563).

Measurements

Severe obesity and other BMI categories. A BMI ≥120% of 95th percentile of gender-specific BMI-for-age or a BMI ≥35 kg/m^2—whichever was lower based on age and gender—was classified as severe obesity status; and adolescents with BMI ≥95th percentile but <120% of 95th percentile were considered to have moderately obese status.[4–6] Other BMI categories in the analysis included overweight status (85th percentile ≤ BMI-for-age <95th percentile); normal weight (5th percentile ≤ BMI-for-age <85th percentile); and underweight (BMI-for-age <5th percentile).[11] Given the small proportion of participants in the underweight category, children who were underweight were collapsed into the normal weight status category.

Cardiovascular/metabolic risk factors. In 2011, an expert panel organized by the National Heart, Lung, and Blood Institute (NHLBI) developed guidelines addressing cardiovascular health and risk prevention in children and adolescents. The goals of these recommendations were to assist all primary pediatric care providers in both diagnosis and treatment of cardiovascular diseases and the identification and management of specific cardiovascular risk factors from infancy into young adult life.[12] The criteria for deciding whether a child was at high risk of one of the six cardiovascular factors in this study were based on the guidelines recommended by NHLBI (Table 1),[12] including high BP (systolic BP or diastolic BP ≥95th percentile sex/age/height specific); high FG (≥100 mg/dl); high TC (≥200 mg/dl); low HDL cholesterol (<40 mg/dl); high LDL cholesterol (≥130 mg/dl); and high triglycerides (≥130 mg/dl).

Age. The age ranges of the included sample were based on the target age range of measurements defined in NHANES data, and varied by risk factors (Table 1).

Race/ethnicity. All races/ethnicities reported were classified into four categories: non-Hispanic white; non-Hispanic Black; Hispanic; and other,[13] representing smaller minor groups including American Indian, Alaska Native, Native Hawaiian, Guamanian, Samoan, Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese, other Asian, and other race.

Social economic status. Poverty-income ratio (PIR) was used as the indicator of children's family social economic status. PIR was computed as monthly family income divided

Table 1. Criteria for Assessing High Risks of Cardiovascular Risk Factors in Children and Adolescents and the Target Age Range in NHANES Survey

Cardiovascular risk ractors	High risk	Age range in NHANES
BP	SBP or DBP ≥95th percentile sex/age/height specific	8–19 years
FG[a]	≥100 mg/dl	12–19 years; fasting sample
TC	≥200 mg/dl	3–19 years (6–19 years since NHANES 2005–2006)
HDL cholesterol	<40 mg/dl	3–19 years (6–19 years since NHANES 2005–2006)
LDL cholesterol	≥130 mg/dl	12–19 years; fasting sample
Triglycerides	≥130 mg/dl	12–19 years; fasting sample

[a]Fasting is defined as no caloric intake for at least eight hours.

BP, blood pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure; FG, fasting glucose; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TC, total cholesterol.

by the poverty threshold, which was adjusted to family size and inflated annually. A PIR below 1 indicated that the family was below the federal poverty level, and higher PIR values indicated higher socioeconomic status.[14]

Statistical Analyses

Descriptive statistics were calculated for the overall sample and by gender. The prevalence of each cardiometabolic risk factor from 1999–2012 was estimated. Univariate analyses were performed to check whether the weight status and other related covariates were significantly associated with each cardiometabolic risk factor. Weighted logistic regression models were estimated to assess whether the severely obese status significantly changed the odds of developing cardiometabolic risk factors after controlling for age, gender, race/ethnicity, PIR, and survey periods. ORs were estimated to measure the association between severely obese status and each outcome; and their associated 95% CI were reported. All analyses took into account the complex design and sampling weights of NHANES survey data. A type I error level of 0.05 was used. The data were analyzed by statistical software SAS (SAS version 9.3; SAS Institute Inc., Cary, NC).

Results

The descriptive statistics and the mean values of cardiometabolic risk factors for all children and adolescents aged 6–19 years from NHANES 1999–2000 to NHANES 2011–2012 ($N = 20,905$) are presented in Table 2. Overall, 50.6% of the sample was male, and 59.0% was non-Hispanic white. Non-Hispanic Black, Hispanic, and other racial/ethnic groups accounted for 14.7%, 19.2%, and 7.1% of the sample, respectively. Tables 3 and 4 show the prevalence of cardiometabolic risk factors, ORs, and 95% CIs.

High Blood Pressure

The overall prevalence of high BP, after adjusting for age, gender, race/ethnicity, PIR, and survey periods, was 3.1%. Children and adolescents in the severely obese weight status category had the highest prevalence of high

Table 2. Characteristics of U.S. Children and Adolescents (6–19 Years) from 1999–2012 ($N = 20,905$)[a]

	Total			Boys			Girls		
Characteristics	***N***	**Mean**	**SD**	***N***	**Mean**	**SD**	***N***	**Mean**	**SD**
Age (year)[b]									
6–11	7987	8.4	0.02	4000	8.4	0.0	3987	8.5	0.0
12–19	12,918	15.5	0.04	6586	15.5	0.0	6332	15.5	0.1
Race/ethnicity (%)[b]									
Non-Hispanic white	5626	59.0	1.5	2870	59.5	1.6	2756	58.4	1.4
Non-Hispanic Black	6214	14.7	0.9	3159	14.5	0.9	3055	15.0	0.9
Hispanic	7743	19.2	1.2	3901	19.0	1.2	3842	19.3	1.2
Other	1322	7.2	0.5	656	7.0	0.6	666	7.2	0.5
PIR[b]	19,295	0.8	0.0	9755	0.8	0.0	9540	0.8	0.0
BMI[b]	20,905	21.4	0.1	10,586	21.3	0.1	10,319	21.5	0.1
SBP (mm Hg)[c]	17,510	107.1	0.2	8857	109.0	0.2	8653	105.1	0.2
DBP (mm Hg)[c]	17,363	59.2	0.3	8764	58.5	0.3	8599	59.9	0.3
FG (mg/dl)[d]	5239	93.7	0.5	2722	95.6	0.4	2517	91.8	0.9
TC (mg/dl)[b]	18,151	162.0	0.4	9246	160.1	0.5	8905	164.0	0.5
HDL cholesterol(mg/dl)[b]	18,150	51.9	0.2	9244	50.9	0.2	8906	53.0	0.2
LDL cholesterol (mg/dl)[d]	6755	91.5	0.5	3491	90.6	0.7	3264	92.5	0.6
Triglycerides (mg/dl)[d]	6776	88.0	1.1	3503	88.8	1.5	3273	87.2	1.4

[a]Sample size is unweighted. The results are weighted.

[b]Sample age range: 6–19.

[c]Sample age range: 8–19.

[d]Sample age range: 12–19.

BP, blood pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure; FG, fasting glucose; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TC, total cholesterol.

Table 3. Prevalence and Unadjusted Odds Ratios of Cardiometabolic Risk Factors among U.S. Children and Adolescents (12–19 Years) from 1999–2012

%, Unadjusted OR (95%CI)	High BP (SBP or DBP ≥95th percentile, *n* = 17,510)		High TC (≥200 mg/dl, *n* = 18,151)		Low HDL (<40mg/dl, *n* = 18,150)		High triglycerides (≥130 mg/dl, *n* = 4563)		High LDL (≥130 mg/dl, *n* = 4550)		High FG (≥100 mg/dl, *n* = 4615)	
	%	OR (95% CI)	%	OR (95% CI)	%	OR (95% CI)	%	OR (95% CI)	%	OR (95% CI)	%	OR (95% CI)
Overall weight status	3.11	–	9.38	–	14.35	–	13.67	–	7.45	–	13.64	–
Normal (ref)	2.06	1.00	7.62	1.00	8.86	1.00	9.71	1.00	6.08	1.00	11.93	1.00
Overweight	3.09	1.52 (1.04, 2.23)	10.02	1.35 (1.13, 1.61)	18.23	2.21 (1.90, 2.56)	16.36	1.89 (1.37, 2.41)	8.66	1.47 (1.07, 2.02)	14.66	1.27 (0.90, 1.78)
Moderately obese	5.16	2.59 (1.95, 3.44)	14.47	2.01 (1.69, 2.40)	25.78	3.38 (2.88, 3.97)	25.25	3.14 (2.48, 3.99)	11.15	1.94 (1.31, 2.88)	16.94	1.51 (0.98, 2.31)
Severely obese	9.85	5.21 (3.85, 7.04)	16.53	2.36 (1.87, 2.99)	39.97	6.48 (5.46, 7.68)	29.77	3.94 (2.99, 5.20)	12.96	2.30 (1.55, 3.41)	26.80	2.70 (1.87, 3.92)
Gender												
Boys	3.15	1.03 (0.75, 1.41)	8.67	0.84 (0.72, 0.99)	17.01	1.47 (1.32, 1.64)	14.89	1.24 (0.99, 1.56)	7.02	0.88 (0.68, 1.14)	18.95	2.50 (2.06, 3.04)
Girls (ref)	3.08	1.00	10.15	1.00	11.51	1.00	12.37	1.00	7.90	1.00	8.55	1.00
Age (yr)												
8–11 (ref)	3.10	1.00	9.39	1.00	11.24	1.00	–	–	–	–	–	–
12–19	3.12	1.01 (0.77, 1.32)	9.38	1.02 (0.88, 1.18)	16.34	1.54 (1.36, 1.75)	13.67	–	7.45	–	13.86	–
Race/ethnicity												
Non-Hispanic white (ref)	2.81	1.00	9.46	1.00	15.44	1.00	15.18	1.00	7.61	1.00	13.30	1.00
Non-Hispanic Black	4.00	1.44 (1.10, 1.90)	10.52	1.10 (0.95, 1.28)	8.33	0.50 (0.42, 0.58)	5.92	0.35 (0.27, 0.45)	8.79	1.17 (0.90, 1.52)	9.68	0.70 (0.50, 0.97)
Hispanic	3.05	1.09 (0.80, 1.48)	8.14	0.84 (0.72, 0.98)	16.16	1.04 (0.92, 1.17)	16.32	1.09 (0.88, 1.35)	5.48	0.70 (0.52, 0.96)	19.29	1.56 (1.15, 2.12)
Other	4.04	1.45 (0.93, 2.29)	9.84	1.02 (0.77, 1.34)	12.66	0.79 (0.61, 1.02)	10.24	0.64 (0.41, 1.00)	8.31	1.10 (0.62, 1.95)	13.92	1.05 (0.68, 1.64)
PIR												
High income (PIR >1) (ref)	2.88	1.00	9.20	1.00	14.00	1.00	13.59	1.00	7.36	1.00	13.35	1.00
Low income (PIR ≤1)	3.37	1.18 (0.92, 1.51)	9.78	1.05 (0.89, 1.24)	15.74	1.13 (0.98, 1.30)	13.98	1.03 (0.84, 1.27)	7.79	1.06 (0.80, 1.42)	15.53	1.19 (0.90, 1.58)

[a]Sample sizes are unweighted; results are weighted estimates.

[b]HDL and TC data for age 3–5 group were not collected after 2003–2004 period, so that the data for ages 3–5 were not included in the analyses.

BP, blood pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure; FG, fasting glucose; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TC, total cholesterol; OR, odds ratio; CI, confidence interval; ref, reference group.

Table 4. Adjusted Odds Ratios of Cardiometabolic Risk Factors and Weight Status among U.S. Children and Adolescents (8–19 Years) from 1999–2012[a–d]

Adjusted OR (95% CI)*	High BP (SBP or DBP ≥95th percentile, *n* = 17,510)	High TC (≥200 mg/dl, *n* = 18,151)	Low HDL (<40 mg/dl, *n* = 18,150)	High triglycerides (≥130 mg/dl, *n* = 4563)	High LDL (≥130 mg/dl, *n* = 4550)	High FG (≥100 mg/dl, *n* = 4615)
Overweight vs. normal	**1.70 (1.14, 2.55)**	**1.28 (1.06, 1.55)**	**2.30 (1.98, 2.68)**	**1.95 (1.45, 2.62)**	1.39 (0.99, 1.95)	1.19 (0.83, 1.71)
Moderately obese vs. normal	**2.92 (2.06, 4.12)**	**2.09 (1.75, 2.50)**	**3.56 (3.03, 4.17)**	**3.46 (2.67, 4.48)**	**2.00 (1.33, 3.04)**	1.49 (0.93, 2.37)
Severely obese vs. normal	**5.27 (3.78, 7.33)**	**2.31 (1.81, 2.96)**	**7.30 (6.06, 8.81)**	**4.45 (3.36, 5.90)**	**2.26 (1.48, 3.47)**	**2.68 (1.81, 3.99)**
Severely obese vs. overweight	**3.10 (2.08, 4.61)**	**1.81 (1.35, 2.42)**	**2.95 (2.44, 3.56)**	**2.28 (1.57, 3.32)**	1.63 (0.97, 2.74)	**2.12 (1.37, 3.27)**
Severely obese vs. moderately obese	**1.81 (1.24, 2.63)**	1.11 (0.86, 1.43)	**1.91 (1.55, 2.34)**	1.29 (0.90, 1.84)	1.13 (0.65, 1.97)	1.65 (1.00, 2.71)

[a]The model was adjusted for age, gender, race/ethnicity, PIR, survey periods, and the complex design.

[b]Sample sizes are unweighted; results are weighted estimates.

[c]HDL and TC data for age 3–5 group were not collected after the 2003–2004 period, so that the data for ages 3–5 were not included in the analyses.

[d]Boldface: $p < 0.05$.

BP, blood pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure; FG, fasting glucose; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TC, total cholesterol; OR, odds ratio; CI confidence interval.

BP (9.9%), and their adjusted odds of having high BP was 5.3 (95% CI: 3.8–7.3) compared with those in the normal weight status category. Children and adolescents in the moderately obese weight status category had adjusted odds of high BP of 2.9 (95% CI: 2.1–4.1), and the overweight weight status category had adjusted odds of 1.7 (95% CI: 1.1–2.6) of high BP. Children and adolescents in the severely obese weight status category had adjusted odds of 3.1 (95% CI: 2.1–4.6) and 1.8 (95% CI: 1.2–2.6) of having high BP compared with overweight and moderately obese categories, respectively. The prevalence of high BP among non-Hispanic Black children and adolescents was 4%, and the unadjusted odds for non-Hispanic Black children and adolescents of having high BP in comparison to the non-Hispanic white group was 1.4 (95% CI: 1.1–1.9).

High Total Cholesterol

The overall prevalence of high TC was 9.4%. Nearly 16.5% of severely obese children and adolescents were considered at a high TC level, whereas only 7.6% of normal weight youth had high TC. The univariate analyses suggested that there was no significant difference in the prevalence of high TC between adolescents aged 12–19 years and younger children aged 6–11 years. Approximately 8% of Hispanic adolescents (8.1%, $p < 0.001$) showed high TC, whereas the prevalence was 9.5% among non-Hispanic white and 10.5% among non-Hispanic Black. Severely obese children and adolescents had 2.3 times higher odds (95% CI: 1.8–3.0) of having high TC compared with those of normal weight status, adjusting for age, gender, race/ethnicity, PIR, and survey periods. Similar but slightly attenuated associations could be observed in other less-obese categories (moderately obese: AOR = 2.1, 95% CI = 1.8–2.5; overweight: AOR = 1.3, 95% CI = 1.1–1.6). Compared with the overweight category, the severely obese category was 1.8 times (95% CI: 1.4–2.4) more likely to have TC above 200 mg/dl; however, no significant difference in the odds of having high TC was found between severe obesity and moderate obesity.

High Low-Density Lipoprotein Cholesterol

Nearly 7.5% of the fasting participants were classified as having high LDL. The prevalence ranged from 6.1% in the normal weight category to approximately 13.0% among the severely obese category. Compared with those in the normal weight category, both the severely obese category (AOR = 2.3, 95% CI: 1.6–3.4) and the moderately obese category (AOR = 1.9, 95% CI = 1.3–2.9) showed higher odds of having high LDL; however, these two categories did not differ in increasing the odds of having high LDL. No significant difference in the odds of having high LDL was found across race/ethnicities and genders.

Low High-Density Lipoprotein Cholesterol

Results on low HDL cholesterol (<40mg/dl) showed that 14.4% of the participants were at a low HDL level. Noticeably, the prevalence among severely obese children was approximately 4.5–fold of the prevalence in the normal weight group (severely obese 40.0% versus moderately obese 25.8% versus overweight 18.2% versus normal weight 8.9%; $p < 0.001$). Adjusting for age, gender, race/ethnicity, PIR, and survey periods, the odds of having low HDL among those in the severely obese category was 7.3 times higher (95% CI: 6.1–8.8) comparing with those in normal weight category, and the higher odds persisted even compared with the moderately obese (AOR = 2.0, 95% CI: 1.6–2.3) and overweight categories (AOR = 3.0, 95% CI: 2.4–3.6). The prevalence of having low HDL among boys was more than 5% higher than that among girls (17.0% versus 11.5%, $p < 0.001$), and older youths aged 12–19 years were more vulnerable to low HDL than the 6–11 years group (unadjusted OR = 1.54, 95% CI: 1.36–1.75). Non-Hispanic Black children and adolescents were less likely to have low HDL compared with the non-Hispanic white group (unadjusted OR = 0.5, 95% CI: 0.4–0.6).

High Triglycerides

Approximately 13.7% of the fasting participants were considered to have high triglyceride levels ($n = 4563$). The prevalence significantly differed by weight status (severely obese 29.8% versus moderately obese 25.5% versus overweight 16.4% versus normal 9.7%; $p < 0.001$). After adjusting for age, gender, race/ethnicity, PIR, and survey periods, severely obese children and adolescents had 4.5 times (95% CI: 3.4–5.9) and 2.3 times (95% CI: 1.6–3.3) higher odds of having high triglyceride comparing with the normal weight and overweight categories, respectively, but no difference in comparison to the moderately obese category. Non-Hispanic Black children and adolescents had lower odds of having high triglyceride (unadjusted OR = 0.4, 95% CI: 0.3–0.5) compared with the non-Hispanic white group.

High Fasting Glucose

The prevalence of high FG was 13.6%, and the severely obese category had more than twofold of the prevalence compared with the normal weight category (severely obese 26.8% versus moderately obese 16.9% versus overweight 14.7% versus normal weight 11.9%; $p < 0.001$). The univariate analyses suggested that boys had higher odds of high FG than girls (unadjusted OR = 2.5, 95% CI: 2.1–3.0). Surprisingly, comparing with non-Hispanic white adolescents (13.3%), high FG was less prevalent in the non-Hispanic Black group (9.7%, $p < 0.05$), whereas the Hispanic group showed the highest prevalence (19.3%, $p < 0.05$). After adjusting for age, gender, race/ethnicity, PIR, and survey periods, severely obese adolescents were 2.7 times (95% CI: 2.8–4.0) more likely to have high FG compared with those with normal weight; however, no significant higher odds of having FG were found in the moderately obese and overweight categories. The severely obese category had 2.1 (95% CI: 1.4–3.3) times higher odds of presenting high FG than the overweight status.

Discussion

With increasing severity and magnitude of obesity among children and adolescents, the probability of developing multiple comorbidities rises concomitantly, resulting in complicated and worsening health consequences.[7] Our results suggested that children and adolescents classified as severely obese had higher odds of having each of the six cardiometabolic risk factors (ORs ranged from 1.6 to 7.3) than children and adolescents classified as normal weight. Compared with those with moderately obese weight status, severely obese youth showed at least twofold higher odds for three of the six risk factors analyzed in this study. Similarly, the HEALTHY study,[8] including 6358 middle school students (mean age 11.8 ± 0.6), found that severely obese children (≥99th of BMI percentile) versus moderately obese children (95th–99th of BMI percentile), overweight children (85th–95th of BMI percentile), and normal weight children (5th–85th of BMI percentile) were more likely to have a family history of diabetes (28.5% versus 21.3% versus16.5% versus 12.4%); elevated insulin level (40% versus 13.4% versus 3% versus 0.8%); waist circumference (99.5% versus 84.5% versus 18.7% versus 0.24%); high BP (31.6% versus 21.3% versus 9.8% versus 8.9%); and low HDL (16.4% versus 8.8% versus 4.3% versus 1.1%). Calcaterra et al.[17] examined the prevalence of cardiometabolic risk factors (high triglyceride, low HDL, high TC, high BP, and impaired glucose tolerance) among 191 obese (≥97% of BMI percentile) and 76 nonobese children and adolescents. They found that about 31% of severely obese children had at least three cardiometabolic risk factors, whereas prevalence was only 12% among moderately obese children.

Our results also revealed that boys were more likely to have low HDL and high FG but less likely to have high TC than girls. Non-Hispanic Black adolescents tended to have higher odds of presenting high BP but lower odds of low HDL, high triglycerides, and high FG, compared with non-Hispanic whites. The Hispanic group had the highest odds of high FG and the lowest odds of high TC and high LDL. Age difference was also observed in certain risk factors. For example, the older age group (12–19 years) was more likely to present low HDL. No significant difference was found by poverty levels in any of the risk factors, suggesting a biologic mechanism between obesity and cardiometabolic risk factors. We identified two studies[18,19] using NHANES data to explore the association between cardiometabolic risk factors and obesity among children and adolescents. Neither of them differentiated the magnitude of cardiometabolic risks by levels of obesity.

Our study enriched previous findings and confirmed the excessive odds of cardiometabolic risk factors attributed to severe obesity. This finding indicated that health strategies and policies for prevention and treatment are needed, specifically targeting overweight, obese, and severely obese adolescents, to avoid future severe medical comorbidities. Moreover, the economic burden of obesity and chronic diseases,[20] especially cardiometabolic diseases, could be alleviated by initiating early interventions such as lifestyle modifications at either the family or school level (i.e., physical activity or diet management) or surgical methods (i.e., bariatric surgery) during childhood and adolescence rather than during adulthood.

One major limitation of this study is the inconsistency of the laboratory measuring methods through all NHANES survey periods. To eliminate the laboratory method effects, all lipid results have been standardized according to the CDC-NHLBI Lipid Standardization Program.[21] In addition, minorities surprisingly had lower odds of having certain risks factors compared to non-Hispanic white children and adolescents. The non-Hispanic Black group was found having lower odds of high FG, low HDL, and high triglycerides; and the Hispanic group was less likely to have high TC. Some studies reported similar findings regarding racial/ethnic differences and suggested the non-Hispanic Black group was less susceptible to some of the risk factors.[15] However, most research was based on the NHANES data. More evidences of such racial/ethnic differences derived from other national or large-scale studies are needed in the future to confirm the lower susceptibility to certain cardiovascular risk factors among minority youths.

Conclusions

Overall, our findings, based on the nationally representative NHANES data, demonstrated that a substantial proportion of US children and adolescents were suffering from obesity-related cardiometabolic risks in the past two decades. The odds of having cardiometabolic risk factors differed by weight status and were significantly associated with obesity. Severely obese children and adolescents were more susceptible to cardiometabolic risks than those of moderately obese status. Therefore, interventions should be continued to prevent elevation and aggravation of cardiovascular risks and to control the prevalence of obesity. Primary care services should be strengthened by closely following and tracking severely obese children and adolescents' physical indicators and providing more individualized treatment plans, to optimize the quality of health service and maximize treatment efficacy. Future research is needed to investigate the racial/ethnic difference in terms of certain cardiometabolic risk factors from both epidemiological and biological perspectives. Longitudinal studies are needed to examine the trend of cardiometabolic risk factors over time and potential modifiable correlates other than obesity.

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Author Disclosure Statement

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