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Social determinants of health and obesity: Findings from a national study of US adults

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Abstract

Objective: This study examined the association between social determinants of health (SDOH) burden and overweight/obesity in a nationally representative sample of adults in the United States.

Methods: Data for 161,795 adults aged ≥18 years from the 2013 to 2017 National Health Interview Survey were used. A total of 38 SDOH were aggregated to create a cumulative SDOH score, which was divided into quartiles (Q1-Q4) to denote levels of SDOH burden. Prevalence of overweight and obesity was examined across SDOH quartiles in the total population and by age, sex, and race/ethnicity. Multinomial logistic regression models were used to analyze the association between SDOH quartiles and overweight/obesity, adjusting for relevant covariates.

Results: There was a graded increase in obesity prevalence with increasing SDOH burden. At nearly each quartile, overweight and obesity rates were higher for middle-aged and non-Hispanic Black adults compared with their counterparts; additional differences were observed by sex. In fully adjusted models, SDOH-Q4 was associated with 15%, 50%, and 70% higher relative prevalence of overweight, obesity class 1 and 2, and obesity class 3, respectively, relative to SDOH-Q1.

Conclusions: Cumulative social disadvantage, denoted by higher SDOH burden, was associated with increased odds of obesity, independent of clinical and demographic factors.

INTRODUCTION

The obesity epidemic is a major public health crisis in the United States (1). Despite national calls for measures to curb the spread of the disease, the prevalence of obesity has increased by more than 40% in the past two decades (2). Overweight and obesity are strongly associated with hypertension, hypercholesterolemia, diabetes mellitus, and inflammation, and they are leading modifiable risk factors for cardiovascular disease (CVD) (3,4). Obesity alone puts significant financial strain on the health care system, with more than $300 billion in annual direct and indirect costs (5,6). Furthermore, findings from a meta-analysis of 239 prospective studies suggest a 1.5 to 3 times increased risk of mortality associated with overweight and obesity (7). In this context, novel primary and secondary prevention approaches are imperative for reducing the burden of obesity.

Careful assessment of individuals' social and environmental conditions that predispose them to poor health outcomes, including obesity and more distal cardiovascular (CV) outcomes, is essential for progressing toward evidence-based disease prevention (8). Whereas traditional risk factors for obesity, such as unhealthy diet and physical inactivity, are well established (9,10), the role of social determinants of health (SDOH) is less well understood (7,11). Limited empirical data have suggested correlations between individual SDOH, such as education, income, neighborhood, and food environment, and obesity (12-14). However, the SDOH-obesity link has not been examined from an upstream, cumulative social disadvantage standpoint (15). To the best of our knowledge, no large-scale study to date has examined the association between SDOH and overweight/obesity using a holistic measure of an individual's social burden.

In this study, we sought to apply an exhaustive SDOH framework to achieve the following: 1) create an aggregate measure of SDOH burden; and 2) examine the association between increasing SDOH burden and overweight/obesity. We tested the hypothesis that greater cumulative social disadvantage, as denoted by higher SDOH burden, would be associated with higher likelihood of obesity. Ours is the first population-based study, to our knowledge, to examine the hypothesized association in a nationally representative sample of adults in the United States.

METHODS

Data source

We used data from the 2013 to 2017 National Health Interview Survey (NHIS), a cross-sectional household interview survey conducted annually by the National Center for Health Statistics (NCHS) under the auspices of the Centers for Disease Control and Prevention

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Study Importance

What is already known?

► Existing frameworks of cardiovascular care often ignore the social conditions that impact risk of obesity—a leading public health crisis in the United States.

► Traditional risk factors for obesity are well established; however, there is limited understanding of the role of social determinants of health (SDOH).

► Although limited evidence has suggested correlations between individual SDOH and obesity, such an association has not been examined, to our knowledge, from an upstream, cumulative disadvantage standpoint.

What does this study add?

► We developed a novel tool to quantify cumulative social disadvantage using an aggregate measure of 38 SDOH across six distinct domains.

► There was a graded increase in prevalence of obesity with increasing SDOH burden.

► At nearly each SDOH quartile, overweight and obesity rates were higher for middle-aged and non-Hispanic Black adults compared with their counterparts.

How might these results change the direction of research or the focus of clinical practice?

► Holistic measures of social disadvantage, such as the aggregate SDOH score presented in this study, may help identify individuals with obesity and possibly other risk factors for cardiovascular disease.

► Our results warrant greater attention to SDOH in traditional clinical models of cardiovascular care delivery in the United States and make a strong case for targeting socially vulnerable populations in cardiovascular disease prevention efforts.

(CDC) (16). Years 2013 to 2017 contain the richest data on SDOH available in the database, with a total of 38 SDOH. Given that cumulative SDOH was the primary independent variable in our study, we used data for the period 2013 to 2017 in order to fully capture the richness of available data and maximize the information included in our cumulative SDOH index. The survey collects information on the health of the civilian noninstitutionalized population of the United States. The sample design, a multistage area probability sampling, adjusts for nonresponse and allows for national representativeness.

The survey consists of four core questionnaires: household composition, family core, sample adult core, and sample child core.

The household section collects basic demographic and relationship information about all persons in the household. The family core collects data on basic sociodemographic characteristics, indicators of health status, activity limitations, injuries, insurance coverage, and access to and use of health services (17). From each family, one sample child and one sample adult are randomly selected to gather further information on them. In this study, we used the sample adult file with supplementation of variables from other cores. Because of the deidentified nature of the NHIS, this study was considered exempt from the Institutional Review Board of Houston Methodist Hospital.

Study design

This was a cross-sectional study using pooled 2013 to 2017 NHIS data. We included all adults aged ≥18 years during the study period. We excluded individuals with body mass index (BMI) < 18.5 kg/m^2.

Variables

Overweight and obesity

Overweight was defined as 25 ≤ BMI < 30 and obesity was defined as BMI ≥ 30, according to established cutoffs (18). In order to examine the association of SDOH with different levels of obesity, we further categorized obesity into obesity class 1 and 2 (30 ≤ BMI < 40) and class 3 (BMI ≥ 40).

SDOH

In order to operationalize our SDOH framework, we adapted the model proposed by the Kaiser Family Foundation (19). We grouped individual SDOH into six distinct domains: 1) economic stability; 2) neighborhood, physical environment, and social cohesion; 3) community and social context; 4) food insecurity; 5) education; and 6) health care system. We created a list of 38 SDOH across the six domains, described further in Supporting Information Table S1. Each determinant was assigned a value of "0" if favorable, e.g., insured, or "1" if unfavorable, e.g., uninsured. We summed the values for individual SDOH to create an aggregate SDOH score. Finally, we divided the SDOH score into quartiles, with the lowest quartile (Q1) representing least SDOH burden and the highest quartile (Q4) representing highest SDOH burden.

Covariates

Participant characteristics were described using age, sex, race/ethnicity, geographic region, CV risk factors (CRFs), atherosclerotic CVD (ASCVD), and major medical comorbidities. All covariates were categorical and defined as follows: age (18-39 years, 40-64 years, and ≥65 years); sex (male or female); geographic region (Northeast, Midwest, South, West), and race/ethnicity (non-Hispanic White, non-Hispanic Black, non-Hispanic Asian, and Hispanic). CRF included hypertension (yes/no), diabetes (yes/no), high cholesterol (yes/no), current smoking status (yes/no), and physical activity (sufficient/insufficient, based on participation in ≥150 min/wk of moderate intensity aerobic physical activity, ≥75 min/wk of vigorous intensity aerobic physical activity, or an equivalent combination of moderate/vigorous intensity aerobic physical activity). ASCVD was defined as a binary (yes/no) variable and included myocardial infarction, angina, and stroke. Self-reported medical comorbidities included emphysema, chronic obstructive pulmonary disease, asthma, gastrointestinal ulcer, cancer (any), arthritis, and any liver conditions. Final comorbidity score was defined as presence of 0, 1, or ≥2 comorbidities.

Statistical analysis

We reported general and SDOH-specific characteristics by overweight/obesity status in the study population. χ^2 tests were used to compare differences among the four (normal, overweight, obesity class 1-2, and obesity class 3) BMI groups. We generated weighted proportions to report nationally representative obesity prevalence estimates. Prevalence of overweight and obesity was examined across SDOH quartiles in the total population and stratified by age, sex, and race/ethnicity. We also reported obesity prevalence by SDOH deciles. Multinomial logistic regression models were used to examine the association between SDOH burden and overweight and obesity classes, generating relative prevalence ratios (RPRs) and 95% confidence interval (CI) estimates for overweight and each obesity class (class 1-2; class 3) versus normal weight. Multivariable models were adjusted for age, sex, race/ethnicity, region, and CRFs (diabetes, hypertension, smoking, physical activity, and hypercholesterolemia). In additional analyses reported in the online Supporting Information, we examined the association between SDOH and any obesity (BMI ≥ 30) using binary logistic regression.

Variance estimation for the entire pooled cohort was obtained from the Integrated Public Use Microdata Series (https://nhis.ipums.org/nhis/) (20). For all statistical analyses, $p < 0.05$ was considered statistically significant. All analyses were performed using Stata version 16 (StataCorp LLC) taking into consideration the NHIS survey design.

RESULTS

The final analytic sample comprised 161,795 individuals, representing 237.9 million annualized US adults. Prevalence of overweight, obesity class 1 and 2, and obesity class 3 was approximately 34%, 25%, and 8%, respectively, in the total population. In general, participants with overweight and obesity were more likely to be middle-aged; be male (except obesity class 3, which was more prevalent in female participants); belong to a racial/ethnic minority group; have low income and education; live in the South and Midwest; and experience ASCVD, poor CRF profile, comorbidities, and lack of health insurance, relative to their counterparts (i.e., normal weight). General participant characteristics are presented in Table 1.

TABLE 1 General characteristics of adults by weight categories from the NHIS, 2013 to 2017

	Normal weight (18.5 ≤ BMI < 25)	Overweight (25 ≤ BMI < 30)	Obesity classes 1-2 (30 ≤ BMI < 40)	Obesity class 3 (BMI ≥ 40)	p value
Sample (n)	53,549	54,650	40,231	13,365	
Weighted sample, (weighted %)	79,458,320 (33.4)	80,496,941 (33.8)	58,668,321 (24.7)	19,318,500 (8.1)	
SDOH variables					
Family income, n (weighted %)					<0.001
High	18,199 (42.4)	19,135 (42.3)	12,199 (36.6)	3,067 (30.7)	
Middle income	13,487 (27.5)	14,621 (28.9)	11,269 (30.5)	3,255 (28.5)	
Low income	17,802 (30.1)	17,038 (28.7)	14,251 (32.9)	5,374 (40.8)	
Education, n (weighted %)					<0.001
Some college or higher	34,950 (66.1)	33,223 (62.5)	22,934 (57.8)	7,447 (57.2)	
HS/GED or less than HS	18,413 (33.9)	21,228 (37.5)	17,164 (42.2)	5,774 (42.8)	
Insurance status, n (weighted %)					<0.001
Insured	46,792 (88.5)	47,556 (87.8)	35,216 (88.5)	11,508 (87.0)	
Uninsured	6,121 (11.5)	6,474 (12.2)	4,596 (11.5)	1,688 (13.0)	
Covariates					
Age category, n (weighted %)					<0.001
18-44 years	25,726 (54.0)	20,913 (42.6)	14,923 (41.6)	5,285 (44.2)	
45-64 years	14,827 (27.7)	19,071 (36.4)	15,626 (39.7)	5,284 (39.8)	
65 years and above	12,996 (18.3)	14,666 (21.1)	9,682 (18.7)	2,796 (16.0)	
Sex, n (weighted %)					<0.001
Male	20,710 (41.1)	29,896 (57.9)	18,857 (51.4)	3,842 (31.9)	
Female	32,839 (58.9)	24,754 (42.1)	21,374 (48.6)	9,523 (68.1)	
Race/ethnicity, n (weighted %)					<0.001
Non-Hispanic White	35,909 (67.8)	35,615 (66.0)	25,336 (64.9)	8,386 (65.3)	
Non-Hispanic Black	5,333 (9.7)	6,802 (11.2)	6,682 (15.3)	2,509 (17.8)	
Non-Hispanic Asian	5,020 (9.6)	2,611 (5.2)	861 (2.3)	291 (2.3)	
Hispanic	6,778 (13.0)	9,004 (17.6)	6,654 (17.5)	1,926 (14.5)	
Region, n (weighted %)					<0.001
Northeast	9,174 (18.7)	9,160 (18.0)	6,108 (16.3)	2,180 (17.6)	
Midwest	10,863 (20.9)	11,728 (22.2)	9,375 (24.2)	3,184 (25.0)	
South	18,047 (34.8)	19,373 (36.4)	15,155 (38.5)	5,112 (39.6)	
West	15,465 (25.6)	14,389 (23.3)	9,593 (21.1)	2,889 (17.8)	
Hypertension, n (weighted %)					<0.001
No hypertension	41,771 (81.7)	35,904 (69.3)	21,264 (56.1)	6,819 (55.0)	
Hypertension	11,729 (18.3)	18,691 (30.7)	18,928 (43.9)	6,478 (45.0)	
Diabetes, n (weighted %)					<0.001
No diabetes	50,392 (96.0)	48,488 (91.4)	31,906 (83.8)	10,217 (81.8)	
Diabetes	2,549 (4.0)	5,083 (8.6)	6,980 (16.2)	2,670 (18.2)	
High cholesterol, n (weighted %)				<0.001	
No high cholesterol	42,676 (82.1)	37,761 (70.9)	25,370 (65.1)	8,903 (69.5)	
High cholesterol	10,665 (17.9)	16,686 (29.1)	14,696 (34.9)	4,327 (30.5)	
Smoking, n (weighted %)					<0.001
Nonsmoker	43,889 (83.2)	45,846 (84.7)	33,881 (85.0)	10,890 (84.9)	
Smoker	9,596 (16.8)	8,753 (15.3)	6,307 (15.0)	2,011 (15.1)	
Physical activity, n (weighted %)					<0.001
Sufficient	29,186 (56.5)	27,892 (53.2)	16,911 (44.3)	4,229 (35.1)	

TABLE 1 (Continued)

	Normal weight (18.5 ≤ BMI < 25)	Overweight (25 ≤ BMI < 30)	Obesity classes 1-2 (30 ≤ BMI < 40)	Obesity class 3 (BMI ≥ 40)	p value
Insufficient	23,608 (43.5)	26,050 (46.8)	22,818 (55.7)	8,205 (64.9)	
ASCVD status, n (weighted %)					<0.001
No ASCVD	49,566 (93.9)	49,291 (91.7)	35,501 (89.7)	11,953 (91.0)	
ASCVD	3,983 (6.1)	5,359 (8.3)	4,730 (10.3)	1,412 (9.0)	
Comorbidities, n (weighted %)					<0.001
0	33,151 (65.1)	31,095 (60.2)	19,659 (52.5)	6,307 (50.8)	
1	13,671 (24.2)	15,135 (26.4)	12,367 (29.7)	4,071 (29.5)	
≥2	6,727 (10.7)	8,420 (13.4)	8,205 (17.8)	2,987 (19.7)	

Abbreviations: ASCVD, atherosclerotic cardiovascular disease; HS, high school; GED, general equivalency diploma; NHIS, National Health Interview Survey.

Distribution of individual SDOH by obesity status is presented in Table 2. Participants with obesity had higher burden of unfavorable SDOH across all domains and they were more likely to experience disadvantage for 34 out of 38 SDOH, including higher prevalence of unemployment, low income, low education, psychological distress, food insecurity, difficulty paying medical bills, transportation barriers, and lack of health insurance, compared with participants without obesity. We also reported distribution of aggregate SDOH burden by overweight/obesity status (Supporting Information Figure S1), showing successively greater SDOH burden across increasing BMI categories.

Prevalence of obesity by SDOH quartiles and obesity class in the study population is shown in Figure 1. There was a graded increase in burden of obesity with increasing levels of social disadvantage. The greatest change was observed for obesity class 1 and 2, increasing by eight percentage points (21%-29%), followed by class 3 (3-percentage-point change: 8%-11%) between SDOH-Q1 and SDOH-Q4. Interestingly, prevalence of overweight decreased slightly between SDOH-Q1 (35%) and Q4 (32%). Similar patterns were seen with finer gradations of SDOH, i.e., deciles, which showed nearly a 1.5-fold increase in obesity class 1 and 2 prevalence between the first and tenth deciles (Figure 2).

Overweight/obesity patterns by SDOH quartiles and age, race/ethnicity, and sex are presented in Figure 3A-C, respectively. For each sociodemographic subgroup, prevalence of obesity increased with increasing SDOH burden. As in the overall population, the greatest increase in obesity prevalence, regardless of demographic subgroup, was observed for obesity class 1 and 2, followed by class 3. At each SDOH quartile, obesity rates were higher for middle-aged and non-Hispanic Black adults, relative to their counterparts (Figure 3A); additional differences were observed by sex. Male participants had higher overweight and obesity rates compared with female participants at nearly each SDOH quartile for obesity class 1 and 2, whereas the opposite was observed for obesity class 3, i.e., higher rates at each quartile for female participants (Figure 3C).

Whereas the increase in obesity prevalence with higher SDOH burden was similar for different age groups, the steepest SDOH-obesity gradient was observed in non-Hispanic White adults and in female participants. In contrast to the observed SDOH-obesity relationship, we either found a null or decreasing pattern of overweight with increasing SDOH burden for all sociodemographic subgroups, which merits further examination.

Findings from multinomial regression are shown in Table 3. In fully adjusted models, participants with the highest SDOH burden (SDOH-Q4) had approximately 15% (RPR = 1.16; 95% CI: 1.09-1.22), 50% (RPR = 1.47; 95% CI: 1.38-1.56), and 70% (RPR = 1.70; 95% CI: 1.54-1.87) higher relative prevalence of overweight, obesity class 1 and 2, and obesity class 3, respectively, relative to those with the lowest burden (SDOH-Q1; Table 3). Additional analyses using any obesity (BMI ≥ 30) as the outcome revealed similar results (Supporting Information Table S2). In fully adjusted models, SDOH-Q4 was associated with 40% increased odds of any obesity (odds ratio = 1.40; 95% CI: 1.33-1.47), relative to SDOH-Q1.

DISCUSSION

In this nationally representative study, we found a robust association between SDOH burden and obesity. We demonstrated a graded increase in prevalence of obesity with increasing SDOH quartiles—denoting higher levels of social disadvantage showing approximately a 50% to 70% increase in obesity prevalence between SDOH-Q1 and Q4 overall in the study population. The observed association persisted after adjustment for relevant covariates and it was consistently seen across a variety of sociodemographic strata.

These results highlight the role of SDOH as important and independent determinants of obesity. Our results have important implications from a health-equity standpoint and underline the importance of prioritizing prevention efforts for individuals and communities facing unfavorable social and environmental conditions that predispose society's vulnerable groups to poor health outcomes, including increased risk of obesity and obesity-associated chronic conditions such as CVD. Effective integration of SDOH into existing CVD screening and management approaches may help identify socially vulnerable populations with a high burden of traditional CRFs; such efforts may reduce the overall burden of obesity, improve CV

TABLE 2 General SDOH characteristics among adults by weight categories from the NHIS 2013 to 2017

	Normal weight (18.5 ≤ BMI < 25)	Overweight (25 ≤ BMI < 30)	Obesity classes 1-2 (30 ≤ BMI < 40)	Obesity class 3 (BMI ≥ 40)	p value
Sample (n)	53,549	54,650	40,231	13,365	
Weighted sample (weighted %)	79,458,320 (33.4)	80,496,941 (33.8)	58,668,321 (24.7)	19,318,500 (8.1)	
Economic stability, n (weighted %)					
Never or previously employed	12,064 (23.9)	10,089 (18.6)	9,077 (22.4)	3,942 (29.5)	<0.001
No sick leave	22,834 (46.2)	22,562 (43.0)	16,624 (43.4)	5,530 (45.4)	<0.001
Low family income	17,802 (30.1)	17,038 (28.7)	14,251 (32.9)	5,374 (40.8)	<0.001
Difficulty paying medical bills	7,865 (17.3)	9,356 (19.6)	8,463 (25.1)	2,864 (25.6)	<0.001
Unable to pay medical bills	3,269 (7.8)	3,507 (8.0)	3,877 (12.8)	1,620 (15.9)	<0.001
Worried about money for retirement	21,408 (40.8)	23,948 (45.8)	19,761 (50.7)	6,435 (54.3)	<0.001
Worried about medical costs of illness/accident	20,415 (39.1)	22,386 (42.8)	18,216 (46.7)	5,974 (50.4)	<0.001
Worried about maintaining standard of living	17,939 (34.2)	20,034 (38.3)	16,799 (42.8)	5,621 (47.3)	<0.001
Worried about medical costs of normal health care	13,586 (26.2)	15,286 (29.3)	12,820 (33.1)	4,318 (36.3)	<0.001
Worried about paying monthly bills	13,426 (25.3)	14,809 (27.9)	13,210 (33.0)	4,705 (38.8)	<0.001
Worried about paying rent/mortgage/housing costs	10,724 (20.1)	11,943 (22.6)	10,428 (26.2)	3,628 (30.0)	<0.001
Cost-related medication nonadherence	2,902 (4.9)	3,181 (5.4)	3,709 (8.6)	1,446 (10.3)	<0.001
Foregone/delayed care due to cost	5,812 (9.2)	5,634 (8.9)	5,247 (11.6)	2,186 (14.8)	<0.001
Neighborhood, physical environment, and social cohesion, n (weighted %)					
Renting (vs. owned home)	22,171 (36.0)	20,032 (32.4)	15,610 (34.3)	5,892 (38.5)	<0.001
Disagree: people in neighborhood help each other	8,400 (16.1)	9,014 (16.8)	7,734 (19.6)	2,637 (22.4)	
Disagree: there are people I can count on in neighborhood	8,708 (16.4)	9,048 (17.2)	7,683 (19.7)	2,650 (22.2)	
Disagree: people in neighborhood can be trusted	8,068 (15.1)	8,592 (15.7)	7,467 (18.5)	2,707 (22.6)	<0.001
Disagree: this is a close-knit neighborhood	17,612 (34.2)	18,211 (34.7)	14,622 (37.7)	4,825 (41.4)	
Community and social context, n (weighted %)					
Psychological distress (Kessler K6 Scale)	1,658 (2.9)	1,651 (2.8)	1,799 (4.1)	806 (6.6)	<0.001
Food Insecurity, n (weighted %)					
Could not afford to eat balanced meals	5,081 (8.7)	5,460 (9.0)	5,764 (13.0)	2,476 (16.8)	<0.001
Food did not last before had money to get more	5,719 (9.9)	6,167 (10.3)	6,350 (14.6)	2,675 (18.3)	<0.001
Worried food would run out before got money to buy more	6,751 (11.8)	7,232 (12.3)	7,354 (17.0)	2,987 (20.7)	<0.001
Cut size or skipped meals because not enough money	2,984 (5.1)	3,026 (4.8)	3,303 (7.2)	1,466 (9.6)	<0.001
If above "yes:" did you have ≥3 days of cut size or skipped meals	2,422 (4.1)	2,461 (3.9)	2,741 (6.0)	1,186 (7.6)	<0.001
Eat less than felt should because not enough money	2,742 (4.8)	2,738 (4.4)	3,012 (6.7)	1,323 (8.9)	<0.001
Hungry but did not eat because not enough money	1,699 (2.9)	1,649 (2.6)	1,771 (3.9)	786 (5.2)	<0.001
Lose weight because not enough money for food	1,111 (1.9)	974 (1.5)	1,018 (2.2)	466 (3.0)	<0.001
Not eat for a whole day because not enough money for food	822 (1.3)	755 (1.1)	762 (1.5)	344 (2.3)	<0.001
If above "yes:" did you have ≥3 days in which you did not eat	572 (0.9)	515 (0.7)	538 (1.1)	215 (1.5)	<0.001
Education, n (weighted %)					
≤High school	18,413 (33.9)	21,228 (37.5)	17,164 (42.2)	5,774 (42.8)	<0.001

TABLE 2 (Continued)

	Normal weight (18.5 ≤ BMI < 25)	Overweight (25 ≤ BMI < 30)	Obesity classes 1-2 (30 ≤ BMI < 40)	Obesity class 3 (BMI ≥ 40)	p value
English language proficiency (not well/not at all)	2,527 (5.3)	2,985 (6.3)	1,898 (5.3)	681 (5.5)	<0.001
Did not look up health information on internet in past 12 months	26,550 (47.3)	29,580 (52.1)	21,545 (51.8)	6,391 (49.9)	<0.001
Did not fill a prescription on internet in past 12 months	49,284 (92.3)	50,064 (91.7)	36,345 (90.2)	10,982 (88.9)	<0.001
Did not schedule medical appointment on internet in past 12 months	48,019 (89.2)	49,707 (90.4)	36,600 (90.4)	11,178 (90.3)	<0.001
Did not communicate with health care provider by email in past 12 months	47,596 (88.7)	49,066 (89.4)	36,076 (89.4)	10,993 (89.2)	0.01
Did not use chat groups to learn about health topics in past 12 months	51,214 (96.1)	52,483 (96.6)	38,587 (96.5)	11,747 (96.4)	0.009
Health care system, n (weighted %)					
Uninsured	6,121 (11.5)	6,474 (12.2)	4,596 (11.5)	1,688 (13.0)	<0.001
No usual source of care	8,068 (15.2)	7,489 (14.1)	4,517 (11.7)	1,369 (11.5)	<0.001
Trouble finding a doctor/provider in past 12 mo	1,556 (2.8)	1,517 (2.6)	1,244 (2.9)	468 (4.1)	<0.001
MD's office does not accept you as new patient in past 12 mo	1,373 (2.6)	1,225 (2.2)	1,064 (2.5)	400 (3.0)	<0.001
MD's office does not accept your insurance in past 12 mo	1,764 (3.3)	1,589 (2.9)	1,346 (3.4)	498 (4.0)	<0.001
Delayed medical care: couldn't get through on phone	1,312 (2.3)	1,182 (2.2)	1,105 (2.6)	370 (2.6)	0.01
Delayed medical care: couldn't get appointment soon enough	3,090 (5.6)	2,963 (5.4)	2,717 (6.6)	943 (7.6)	<0.001
Delayed medical care: wait too long at MD's office	2,071 (3.8)	2,078 (3.8)	1,851 (4.5)	655 (5.2)	<0.001
Delayed medical care: not open when you could go	1,368 (2.4)	1,406 (2.6)	1,219 (2.9)	477 (3.8)	<0.001
Delayed medical care: no transportation	1,016 (1.5)	966 (1.4)	1,088 (2.3)	490 (3.0)	<0.001
Somewhat/very dissatisfied (quality) or no health care in past year	8,663 (16.5)	8,658 (16.2)	5,871 (15.0)	1,884 (16.0)	<0.001

Abbreviations: MD, medical doctor; NHIS, National Health Interview Survey; SDOH; social determinants of health.

health outcomes on a population level, and advance the cause of health equity.

Various pathways may explain the link between social disadvantage and obesity. For example, economic instability has been associated with poor access to nutritious food, low healthy food spending, and poor behavioral patterns such as unhealthy dietary habits, which may directly increase the risk of obesity (21-23). Individuals in socioeconomically disadvantaged neighborhoods experience varying levels of food insecurity, owing to multiple barriers such as limited economic resources to buy food, transportation challenges, restricted access to supermarkets/other healthy food options, and increased "exposure" to obesogenic environments such as fast-food outlets (24-26)

Psychological stress associated with lower social class may increase the likelihood of obesity via both behavioral (e.g., increased consumption of energy-dense food) and biological (e.g., raised cortisol increased appetite/fat deposition) mechanisms

(27). Similarly, economically deprived neighborhoods may present limited opportunities for physical activity such as parks/sidewalks, which may be further restricted because of concerns about safety of available physical spaces (e.g., fear of crime) (28-30). These and related structural barriers may increase the risk of having overweight/obesity.

Other unfavorable SDOH such as poor access to care (e.g., lack of health insurance) may restrict access to medical and psychological resources such as primary care and nutrition counseling, which are critical for timely screening for traditional CRFs, including obesity. Whereas limited prior evidence has supported the association between individual SDOH and obesity (12,31), to the best of our knowledge, this is the first national study to assess the SDOH-obesity link using a comprehensive SDOH framework and a unique measure of an individual's cumulative social disadvantage.
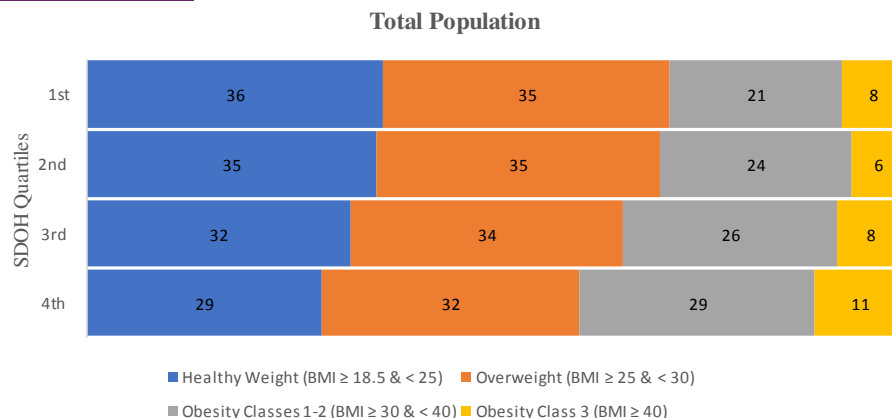
Total Population

FIGURE 1 Obesity prevalence (percentage) by SDOH quartiles and obesity class in the total population, from the NHIS, 2013 to 2017. NHIS, National Health Interview Survey; SDOH, social determinants of health [Color figure can be viewed at wileyonlinelibrary.com]

Prevalence of BMI Categories, by SDOH Deciles
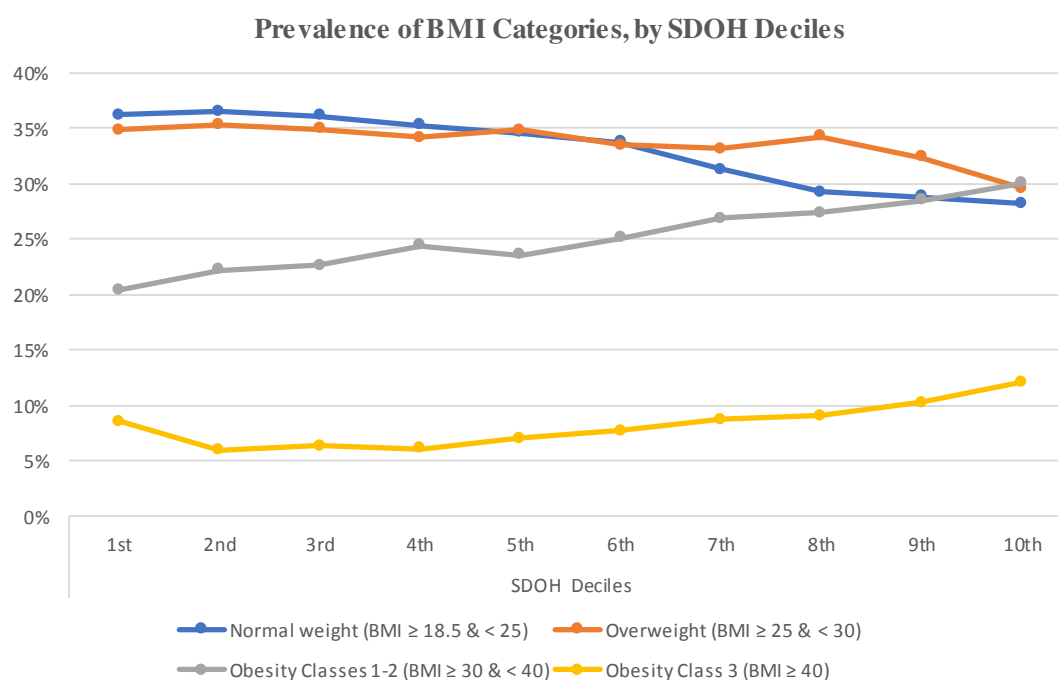
FIGURE 2 Obesity prevalence (percentage) by SDOH deciles and BMI category, from the NHIS, 2013 to 2017. NHIS, National Health Interview Survey; SDOH, social determinants of health [Color figure can be viewed at wileyonlinelibrary.com]

In general, we documented a graded increase in obesity prevalence with increasing SDOH burden in different sociodemographic groups, including age, sex, and race/ethnicity (Figure 3). We found higher rates of all obesity classes in non-Hispanic Black and Hispanic adults at nearly each SDOH quartile compared with non-Hispanic White adults and the lowest rates in the Asian population. Although a higher burden of obesity in non-Hispanic Black and Hispanic populations as well as a lower burden in the Asian population overall has been previously documented (1), this is the first large-scale study, to our knowledge, to report racial/ethnic disparities in obesity across levels of aggregate SDOH burden. Various societal and institutional barriers faced by racial/ethnic minorities, including structural racism and discrimination, may underlie such disparities and explain the observed variation in

quartile-specific obesity rates, beyond SDOH examined herein (32). Future studies should explore the impact of these and related structural barriers to optimum CV health in marginalized populations.

Among females, we reported higher class 3 obesity at higher-quartiles and lower class 1 and 2 obesity overall, compared with male participants. Our finding is consistent with prior reports (33) and it may be explained by possible sex differences in stress coping behaviors such as higher risk of stress-associated energy-dense food consumption in female individuals (34,35). Additional evidence from population-based studies is needed for greater understanding of sex and racial/ethnic disparities in obesity.

In contrast to the reported SDOH-obesity association, we did not find a similar relationship between SDOH and overweight, overall or
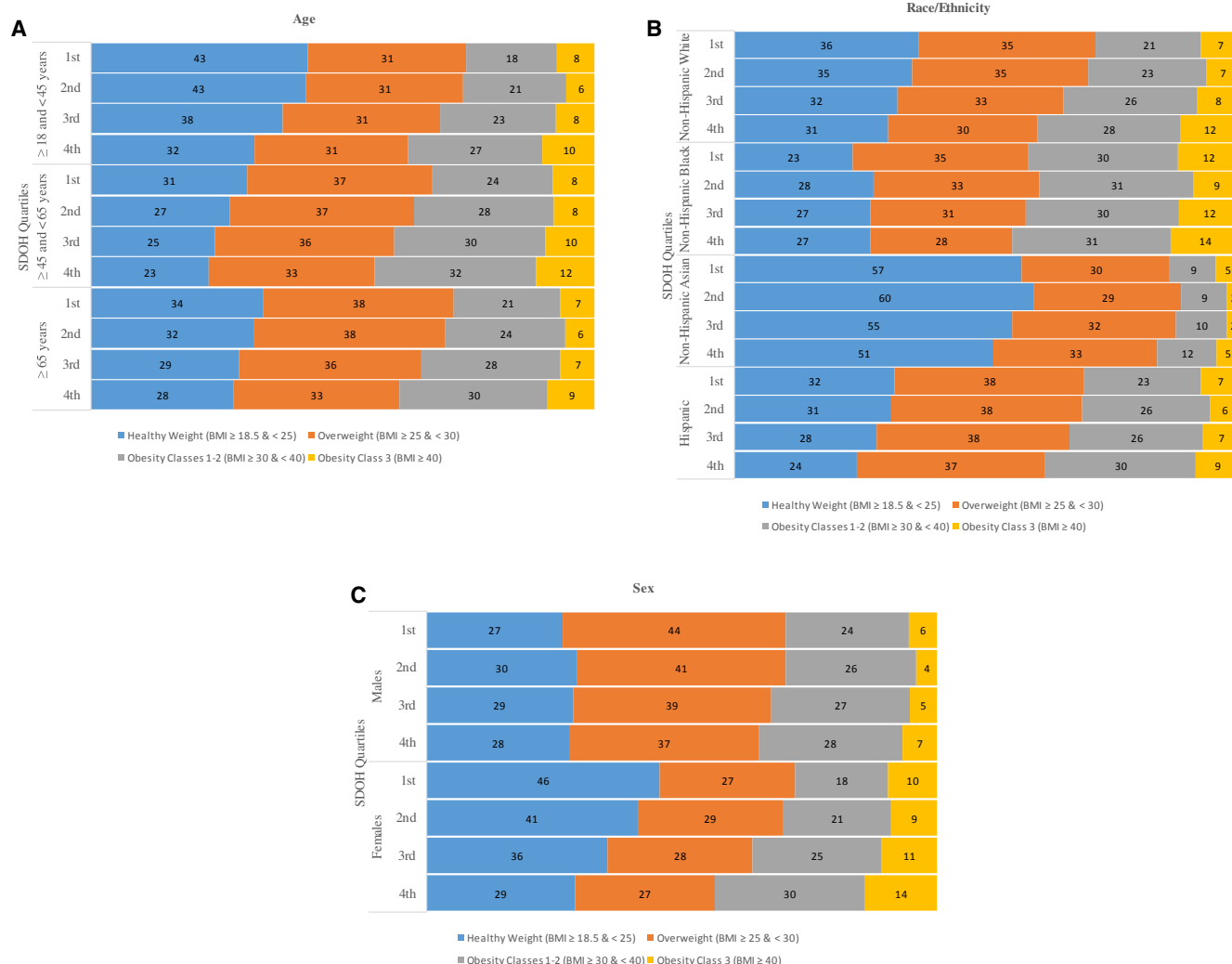
FIGURE 3 Obesity prevalence (percentage) by SDOH quartiles, obesity class, and sociodemographic subgroups. (A) Obesity prevalence by SDOH quartiles, obesity class, and age; (B) obesity prevalence by SDOH quartiles, obesity class, and race/ethnicity; (C) obesity prevalence by SDOH quartiles, obesity class, and sex. SDOH, social determinants of health [Color figure can be viewed at wileyonlinelibrary.com]

for sociodemographic subgroups. It is known that obesity, compared with overweight, is a stronger predictor of distal health outcomes and quality of life (36); therefore, it is possible that the cumulative "negative" effects of SDOH manifest only at higher but not lower BMI levels. While the association between socioeconomic indicators and both overweight and obesity has been well documented (37), this is the first population-based report, to our knowledge, of such differences across BMI categories using an aggregate SDOH score. Further investigation is needed to fully understand the sociodemographic correlates of overweight and obesity on a population level.

Calls for polysocial risk scores for CVD have garnered considerable attention in recent years (37). Palacio et al. recently reported an SDOH score to identify individuals at high risk of CVD (38). The authors examined multiple risk factors such as blood pressure, glycated hemoglobin, and smoking; however, BMI was not examined as an outcome. Furthermore, the reported SDOH score was based only on 12 SDOH. In contrast, we included 38 SDOH from six established domains in our calculation of SDOH score and subsequent quartiles,

which makes this a unique tool for quantifying social disadvantage and studying the link between SDOH and a variety of health outcomes, both CVD and non-CVD.

In this study, we sought to address the knowledge gaps identified previously (33,36,37) and built on recent work in the field (38-40) to provide a novel approach for quantifying cumulative social disadvantage and demonstrating the association between SDOH and obesity. Our methodology may be applied to other CV conditions in diverse populations. We accounted for a variety of demographic and clinical factors in multivariable models and demonstrated that, on an aggregate level, SDOH are independently associated with obesity.

Greater efforts to develop real-world frameworks enabling effective SDOH integration into contemporary CV care models are needed to identify vulnerable individuals at high risk of CV morbidity and mortality and inform CV prevention and management. Future efforts should investigate potential mediators and moderators of the SDOH-obesity relationship and put greater emphasis on improved

TABLE 3 Association between SDOH and overweight and obesity

	Overweight (25 ≤ BMI < 30)* RPR (95% CI)	Obesity classes 1-2 (30 ≤ BMI < 40)* RPR (95% CI)	Obesity class 3 (BMI ≥ 40)* RPR (95% CI)
SDOH quartiles	*Model 1*		
Q1	Reference	Reference	Reference
Q2	1.02 (0.97-1.06)	1.15 (1.09-1.21)	0.87 (0.80-0.94)
Q3	1.08 (1.03-1.13)	1.40 (1.33-1.47)	1.22 (1.13-1.32)
Q4	1.14 (1.09-1.20)	1.74 (1.65-1.83)	1.80 (1.67-1.94)
SDOH quartiles	*Model 2*		
Q1	Reference	Reference	Reference
Q2	1.04 (0.99-1.09)	1.17 (1.10-1.23)	0.88 (0.80-0.95)
Q3	1.13 (1.08-1.19)	1.45 (1.38-1.53)	1.24 (1.15-1.34)
Q4	1.17 (1.11-1.23)	1.72 (1.63-1.82)	1.73 (1.59-1.88)
SDOH quartiles	*Model 3*		
Q1	Reference	Reference	Reference
Q2	1.04 (0.99-1.09)	1.11 (1.05-1.17)	0.99 (0.90-1.08)
Q3	1.13 (1.08-1.19)	1.35 (1.27-1.42)	1.34 (1.22-1.46)
Q4	1.16 (1.09-1.22)	1.47 (1.38-1.56)	1.70 (1.54-1.87)

Note: Model 1 = unadjusted; Model 2 = adjusted for age, sex, race/ethnicity, and geographic region; Model 3 = adjusted for Model 2 + CRF (hypertension, diabetes, lack of physical activity, smoking, and hypercholesterolemia).

Abbreviations: CRF, cardiovascular risk factor; RPR, relative prevalence ratios; SDOH; social determinants of health

*Reference = normal weight (18.5 ≤ BMI < 25)

understanding of structural barriers such as racism and discrimination, factors that create deleterious environmental conditions in the first place. Such actions are imperative to mitigating the observed sociodemographic disparities in obesity burden in the United States.

Our findings should be interpreted in light of a few limitations. First, given the cross-sectional nature of the NHIS, we could not assess causality. Future studies should assess the SDOH-obesity association using longitudinal study designs. Second, our findings are based on self-reported data, which may have resulted in under-/overreporting of SDOH. However, as the principal source of information on the health of the civilian US population, the NHIS is administered by the Centers for Disease Control and Prevention and it undergoes multiple robustness checks to reduce errors/omissions. Future efforts should include building platforms for data cross talk to enable cross-referencing self-reported and medically ascertained data (e.g., clinical conditions). Furthermore, NHIS data have been used extensively to study trends, patterns, and associations of a variety of SDOH across different population subgroups, with good correlation between reported and measured data (41,42). Third, inherent to the NHIS design, our study included only noninstitutionalized US adults; therefore, our findings are not applicable to the institutionalized population. Finally, while binary categorization of individual SDOH is a useful approach for quantifying aggregate SDOH effects, as shown in prior studies (43,44), future studies modeling the cumulative impact of multiple SDOH should consider additional methodological approaches, including machine-learning algorithms, for a better

understanding of the relative and potential nonlinear effects of each determinant.

This study has several strengths, including a large sample size, nationally representative estimates, comprehensive data on SDOH, and a unique methodological approach, which includes development of a novel SDOH score and statistical adjustment for a variety of clinical and demographic factors. This is the first large-scale, population-based study, to our knowledge, to quantify cumulative social disadvantage by operationalizing an exhaustive SDOH framework and creating a unique tool to study the SDOH-obesity association in a national sample of US adults. Other strengths of this work include a variety of sensitivity analyses to check the robustness of our final measure, including age-, sex-, and race-stratified analyses.

CONCLUSION

SDOH are strongly associated with obesity, independent of clinical and demographic factors. Our findings suggest that prevalence of obesity may increase with increasing SDOH burden. Measures of cumulative social disadvantage, such as the aggregate SDOH score presented herein, may help identify individuals with obesity, including those with multiple risk factors for overweight and obesity, and improve existing CVD prevention frameworks. Evidence-based integration of SDOH into contemporary clinical care models is imperative for reducing the burden of obesity and addressing disparities in CVD in the United States.**O**

CONFLICT OF INTEREST

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