Neighborhood Deprivation, Obesity, and Diabetes in Residents of the US Gulf Coast

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Socioeconomic status has been associated with cardiovascular disease risk factors. However, few studies have examined this relationship among populations in the US Gulf Coast region. We assessed neighborhood deprivation in relation to obesity and diabetes in 9,626 residents participating in the Gulf Long-Term Follow-Up Study (2011–present) who completed a home visit (2011–2013) with height, weight, waist, and hip measurements. Obesity was categorized as body mass index of at least 30, and diabetes was defined by doctor's diagnosis or prescription medication. Participant home addresses were linked to an established Area Deprivation Index and categorized into 4 levels (1 = least deprived). In adjusted, modified Poisson regression models, participants with greatest deprivation were more likely to have obesity compared with those with least deprivation (adjusted prevalence ratio (aPR) = 1.21, 95% confidence interval (CI): 1.08, 1.35), central obesity (aPR = 1.11, 95% CI: 1.04, 1.19), and diabetes (aPR = 1.49, 95% CI: 1.03, 2.14). Repeated analyses among a subgroup of participants (n = 3,016) whose hemoglobin A1C values were measured 3 years later indicated the association with diabetes (defined as diagnosis, medications, or hemoglobin A1C $\geq$ 6.5) was similar (aPR = 1.46, 95% CI: 1.14, 1.86). Results suggest neighborhood deprivation is associated with obesity and diabetes in a US region with high baseline prevalence.

diabetes; HbA1c; neighborhood deprivation; obesity; socioeconomic status

Abbreviations: aPR, adjusted prevalence ratio; ADI, Area Deprivation Index; BMI, body mass index; CI, confidence interval; CVD, cardiovascular disease; HbA1C, hemoglobin A1C; OR, odds ratio.

Obesity and diabetes are major risk factors for cardiovascular disease (CVD), which is the leading cause of death worldwide (1). According to the World Health Organization, obesity rates have nearly tripled worldwide since 1975 (2), with prevalence in certain US states approaching 40% (3). The worldwide rate of diabetes has similarly nearly doubled in the past 3 decades (4), and the US Centers for Disease Control and Prevention estimates that almost one-third of Americans have elevated blood glucose levels (5), a defining characteristic of diabetes.

Both obesity and diabetes are influenced by environmental factors, including socioeconomic status (6). Mechanisms explaining the link between socioeconomic status and CVD risk factors are complex and include stress-related pathways (7) and unhealthy behaviors (8). Low neighborhood socioeconomic status, or neighborhood deprivation, is characterized by small-area high poverty rates and low levels of education (9). Residents of deprived neighborhoods have decreased access to grocery stores and supermarkets (10) and limited recreational infrastructure such as parks and sidewalks (11). Physical neighborhood traits may adversely affect individual-level cardiovascular health directly by increasing intake of unhealthy foods (12) and limiting physical activity (13, 14). Deprived neighborhoods also have increased rates of violence and crime (15), which may lead to chronic stress. Stress results in overactivation of compensatory hormonal, immune, and autonomic nervous systems, which chronically may decrease the capacity of these systems in responding to further nutritional and physical imbalances (16) that contribute to cardiovascular risk.

Neighborhood socioeconomic status has been reported to be independently associated with increased risk for obesity (17) and diabetes (18). Small-area-level deprivation is associated with self-reported obesity and diabetes (19–24), as well as objectively body mass index (BMI) and fasting glucose (25–27). In previous studies in US populations, researchers found potential variations of these associations by race (27) and age (28). However, this association has been examined in only a few studies in regions with preexisting high prevalence of obesity and diabetes. Living in a neighborhood with high prevalence of overweight is itself associated with increased odds of becoming overweight (29), potentially because being overweight is more socially acceptable in those neighborhoods (19). Populations living in the US Gulf Coast states have some of the highest rates of CVD risk factors in the country (3, 5); thus, our objective for this study was to assess the relationship between neighborhood deprivation and the CVD risk factors of obesity and diabetes in a vulnerable region.

METHODS

Study design and population

Participants in the Gulf Long-Term Follow-Up Study are a prospective cohort of adults who trained for and/or participated in oil spill response and clean-up after the 2010 *Deepwater Horizon* disaster (30, 31). At enrollment (March 2011–March 2013), 32,608 participants completed a structured telephone interview about their demographics, lifestyle, and health, including previous physician diagnoses of chronic diseases. A total of 11,193 English- and Spanish-speaking participants living in the Gulf Coast states of Texas, Louisiana, Mississippi, Alabama, and Florida completed a home visit between May 2011 and May 2013, which included an additional interview on health and lifestyle factors, anthropometric measurements, and biological sample collection. Approximately 3 years later (August 2014–June 2016), we followed up 3,401 of those participants who lived within 60 miles of Mobile, Alabama, or New Orleans, Louisiana, with a clinic examination, which included additional anthropometric and clinical measurements as well as point-of-care measurement of hemoglobin A1C (HbA1C). We conducted primary complete case analyses to assess cross-sectional relationships among 9,626 home-visit participants. We repeated analyses to assess prospective associations in the subsample of participants who completed the clinical examination ($n = 3{,}016$) for whom we had measured HbA1C.

Analytic sample

Of the 11,193 participants who completed home visits, we were unable to geocode addresses for 426 participants. Another 989 participants were missing at least 1 covariate, and 202 participants were missing at least 1 outcome, yielding a final primary analytic sample of 9,626 participants.

Of the 3,401 participants who completed clinic examinations, we were unable to geocode addresses for 96 participants. Another 279 participants were missing at least 1 covariate response, and 10 participants were missing at least 1 outcome, yielding a final secondary analytic sample of 3,016.

Ethical approval

This research was approved by the Institutional Review Board of the National Institute of Environmental Health Sciences. Written informed consent was obtained from all participants completing the home visit and clinic examination.

Obesity

To calculate obesity, height and weight were measured in triplicate. Average values for each were calculated, and BMI was derived as weight (kg) divided by the square of the height measurement (m^2). BMI was classified into 3 categories per the World Health Organization (2): BMI less than 25 (underweight or normal), BMI at least 25 and less than 30 (overweight), and BMI at least 30 (obese). We collapsed underweight and normal categories because of the small percentage of participants in our sample who were underweight (2%) and considered this the reference group. Both home visit and clinic-examination participants additionally had waist and hip measurements (in centimeters, measured in triplicate) to assess central obesity. Women were classified as having central obesity if they had a waist-to-hip ratio greater than 0.85, and men were classified as having central obesity if they had a waist-to-hip ratio greater than 0.90, according to guidelines from the World Health Organization (32).

Diabetes

For home-visit participants, we classified diabetes using interview data collected at enrollment about whether participants had a diagnosis of diabetes from a doctor, as well as information on current medication use obtained from prescriptions shown directly to home-visit agents. Diabetes was defined as an affirmative response to the interview item or use of any diabetes medication.

For the smaller sample of clinic-examination participants, we classified diabetes using clinical measurement values of HbA1C, obtained from point-of-care fingerstick measurements with a Siemens DCA Vantage machine (Malvern, PA), to classify participants as having diabetes. Participants also reported, during a structured interview at the clinic examination, current diabetes medication use as well as previous diagnoses of diabetes. As our reference group, we used participants with an HbA1C value of less than 5.7 who did not have previous reported diagnoses or medications for diabetes. Among clinical examination participants, the primary definition of diabetes was positive response for any of the following: doctor's diagnosis of diabetes, currently taking diabetes medication, or having an HbA1C of at least 6.5 (33). Among clinical examination participants, we also analyzed those who were diabetic or prediabetic by expanding the diabetes definition to include participants with an HbA1C value of at least 5.7 and less than 6.5. We also conducted a sensitivity analysis to evaluate diabetes prevalence in the clinic-examination sample, using the home-visit definition of diabetes.

Neighborhood deprivation

The 2013 Area Deprivation Index (ADI), published by Kind et al. (34) at the University of Wisconsin School of Medicine and Public Health, is a measure of deprivation at the census block–group level that assesses neighborhood socioeconomic conditions and allows for comparisons across census-block groups (https://www.neighborhoodatlas.medicine.wisc.edu/). The ADI incorporates 17 census tract–level socioeconomic variables from the Census Bureau's American Community Survey (2009–2013), including education, family income, poverty level, occupation, unemployment rate, rate of home ownership, and access to telephones and vehicles. The ADI represents national percentiles, with higher levels corresponding to increased deprivation (1 = lowest deprivation, 100 = highest deprivation). The index, which is publicly available online (34), is associated with chronic disease management (35) and hospital readmission (36) outcomes.

For the larger home-visit sample, we categorized ADI into 4 levels on the basis of the US distribution (level 1: 1st–24th percentiles; level 2: 25th–49th percentiles; level 3: 50th–74th percentiles; level 4: 75th–100th percentiles). For the smaller clinic-examination sample, ADI was also categorized into these levels, but we collapsed the bottom 2 levels to have an adequately sized reference group (level 1/2: 1st–49th percentiles; level 3: 50th–74th percentiles; level 4: 75th–100th percentiles). We considered the lowest level (levels 1/2) as the reference group representing the least amount of neighborhood deprivation.

Statistical analysis

To assess the association between neighborhood deprivation and the mentioned CVD risk factors, we calculated prevalence ratios and 95% confidence intervals using adjusted, modified Poisson regression models, as described by Spiegelman et al (37).

Potential confounders for adjusted models were selected using directed acyclic graphs (Web Figure 1) (available at https://academic.oup.com/aje) (38). We considered the following individual-level variables, obtained at enrollment, as potential confounders: age (years), sex (male, female), race (White, Black, other), ethnicity (Hispanic, non-Hispanic), smoking status (heavy current smoker, light current smoker, former smoker, never smoker), alcohol use (current drinker, former drinker, never drinker), educational attainment (less than high school or equivalent, high school diploma/General Educational Development test, some college or 2-year degree, and $\geq$ 4-year college graduate), annual household income (< US \$20,000, \$20,000–\$49,999, $\geq$ \$50,000), and employment status (working now, looking for work/unemployed, other). We adjusted for participant age at the time of the encounter. With each sample, we considered age a continuous covariate to minimize residual confounding. For sensitivity analyses, we assessed the relationship between age as a continuous versus categorical variable (20–29 years, 30–39 years, and so forth) and our various outcomes in both analytic samples via unadjusted logistic regressions. We also conducted sensitivity analyses between neighborhood deprivation and obesity and diabetes adjusting only for age, as well as an analysis including maximum total hydrocarbon exposure as estimated from a job-exposure matrix (39) as a proxy for oil exposure.

Also, in analyses exploring effect measure modification, we looked at the ADI, using both national and sample-specific quartiles, when the national cutpoints led to sample sizes in the reference category that were very small. We stratified by race (White, Black) using both categorizations. We assessed associations with incident obesity, central obesity, and diabetes in the clinic-examination sample, classifying as positive those participants in whom these cardiovascular risk factors developed in the time between the home visit and the clinic examination and excluding participants with these outcomes at baseline. We also used multiple imputation with both samples as a sensitivity analysis. SAS, version 9.4 (SAS Institute, Inc., Cary, North Carolina) was used to conduct all statistical analyses.

RESULTS

The overall prevalence of obesity and diabetes in our population was 42% and 10%, respectively. Selected population characteristics are shown by ADI levels for the primary analytic sample (Table 1) and the clinic-examination sample (Table 2). In the home-visit sample ($n = 9,626$), participants living in the most, compared with least, deprived neighborhoods (i.e., level 4 vs. level 1) were younger on average (42 vs. 47 years); less likely to be White (35% vs. 86%); more likely to be a current smoker, whether heavy or light (39% vs. 19%); less likely to be currently drinking (68% vs. 85%); less likely to have at least a college degree (7% vs. 47%); and less likely to have been employed at study enrollment (47% vs. 72%). The home-visit and clinic-examination samples differed by sample size and by age but were otherwise sociodemographically similar (Web Table 1). Trends were similar in the clinic-examination cohort.

In the home-visit sample, compared with those living in the least-deprived neighborhoods (level 1), neighborhood deprivation was associated with overweight and obesity, defined by measured BMI, for level 2 (adjusted prevalence ratio (aPR), 1.10, 95% confidence interval (CI): 1.03, 1.17), level 3 (aPR, 1.12, 95% CI: 1.06, 1.20), and level 4 (aPR, 1.10, 95% CI: 1.03, 1.17) compared with participants who were of normal weight or underweight (Table 3). Neighborhood deprivation was also associated with obesity alone for level 2 (aPR, 1.18, 95% CI: 1.06, 1.32), level 3 (aPR, 1.24, 95% CI: 1.11, 1.38), and level 4 (aPR, 1.21, 95% CI: 1.08, 1.35) compared with the normal/underweight group (Table 3). Neighborhood deprivation was associated with central obesity, measured by waist-to-hip ratio, for level 2 (aPR, 1.07, 95% CI: 1.01, 1.14), level 3 (aPR, 1.10, 95% CI: 1.03, 1.17), and level 4 (aPR, 1.11, 95% CI: 1.04, 1.19). In

Table 1. Characteristics of Home-Visit Study Sample (n = 9,626), the Gulf Long-Term Follow-up Study, 2011–2013

Characteristic	Level (Percentiles)							
	1 (1st–24th)		2 (25th–49th)		3 (50th–74th)		4 (75th–100th)	
	No.	%	No.	%	No.	%	No.	%
Age at home visit, years[a]	47 (14)		46 (13)		44 (13)		42 (12)	
Total no. of participants	439	5	2,177	23	3,390	35	3,620	38
Sex								
Male	350	80	1,677	77	2,653	78	2,822	78
Female	89	20	500	23	737	22	798	22
Race								
White	378	86	1,608	74	2,061	61	1,249	35
Black	28	6	344	16	932	27	2,033	56
Other	33	8	225	10	397	12	338	9
Ethnicity								
Hispanic	26	6	113	5	220	6	218	6
Non-Hispanic	413	94	2,064	95	3,170	94	3,402	94
Smoking status								
Heavy current smoker	29	7	249	11	512	15	422	12
Light current smoker	52	12	461	21	806	24	986	27
Former smoker	133	30	525	24	710	21	655	18
Never smoker	225	51	942	43	1,362	40	1,557	43
Drinking status								
Current drinker	373	85	1,681	77	2,367	70	2,457	68
Former drinker	56	13	387	18	768	23	847	23
Never drinker	10	2	109	5	255	8	316	9
Education								
Less than high school/equivalent	24	5	269	12	754	22	943	26
High school diploma/GED	72	16	621	29	1,209	36	1,368	38
Some college/2-year degree	137	31	752	35	979	29	1,054	29
≥4-year college graduate	206	47	535	25	448	13	255	7
Employment								
Working now	317	72	1,340	62	1,843	54	1,705	47
Looking for work/unemployed	53	12	417	19	887	26	1,257	35
Other	69	16	420	19	660	19	658	18
Household income, USD								
<20,000	57	13	564	26	1,328	39	1,874	52
20,000–49,000	112	26	777	36	1,131	33	1,185	33
≥50,000	270	62	836	38	931	27	561	16
Weight categories[b]								
Normal	126	29	521	24	798	24	931	26
Overweight	157	36	792	36	1,151	34	1,093	30
Obese	156	36	864	40	1,441	43	1,596	44

Table continues

Table 1. Continued

Characteristic	Level (Percentiles)							
	1 (1st–24th)		2 (25th–49th)		3 (50th–74th)		4 (75th–100th)	
	No.	%	No.	%	No.	%	No.	%
Waist-to-hip ratio[c]								
Normal	134	31	581	27	886	26	1,059	29
Centrally obese	305	69	1,596	73	2,504	74	2,561	71
Diabetes								
No	414	93	1,980	91	3,035	90	3,281	91
Yes (diagnosed or taking medications)	30	7	197	9	355	10	339	9

Abbreviations: BMI, body mass index; GED, General Education Development test.
[a] Values are expressed as mean (standard deviation).
[b] BMI calculated as weight (kg)/height (m)^2 and categorized as follows: normal, <25.0; overweight, 25.0–29.9; obese, ≥30.0.
[c] Categories: normal, ratio ≤0.85 for women, ≤0.90 for men; centrally obese, ratio >0.85 for women, >0.90 for men.

this sample, neighborhood deprivation was associated with diabetes for level 2 (aPR, 1.37, 95% CI 0.95, 1.96), level 3 (aPR, 1.57, 95% CI: 1.10, 2.24), and level 4 (aPR, 1.49, 95% CI: 1.03, 2.14).

Among clinic-examination participants, neighborhood deprivation was not associated with obesity measured according to BMI or central obesity (Table 4). However, deprivation levels 3 and 4 were associated with diabetes, compared with the referent (levels 1 and 2 combined); the level 3 aPR was 1.48 (95% CI: 1.17, 1.87) and the level 4 aPR was 1.46 (95% CI: 1.14, 1.86). Associations between deprivation and prediabetes/diabetes were less pronounced (level 3 aPR, 1.20, 95% CI: 1.05, 1.37; level 4 aPR, 1.17, 95% CI: 1.02, 1.34). We found similar associations using the home-visit classification of diabetes in this sample (Web Table 2).

Neighborhood deprivation recategorized into quartiles on the basis of our sample distribution, rather than on the entire United States, was associated only with the clinic-examination definition of diabetes (Web Tables 3 and 4). Race was a significant modifier in the relationship between neighborhood deprivation and overweight and obesity, with stronger associations seen in Black participants compared with White participants (Web Table 5)—a pattern also seen with race-stratified results using the distributional categorization of neighborhood deprivation (Web Table 6). Results from analyses including multiple imputation for missing covariates were similar to results from complete case analyses (Web Tables 7 and 8). Results from models that were adjusted only for age, as well as those adjusted for maximum total hydrocarbon exposure during the spill cleanup, were also similar to those estimated with the fully adjusted model (Web Tables 9 and 10). Results for associations of neighborhood deprivation and incident obesity and diabetes at the clinic examination were similar to results for disease prevalence (Web Table 11).

DISCUSSION

Among adults living in the US Gulf states, we found a positive association between neighborhood deprivation at the census block–group level and doctor's diagnosis of diabetes. We confirmed this association within a smaller sample of participants for whom we had measured blood levels of HbA1C. These associations were robust after adjustments for individual-level socioeconomic and other potential confounders. We also identified associations between neighborhood deprivation and obesity, as well as neighborhood deprivation and central obesity measured as waist-to-hip ratio, in the home-visit but not in the smaller clinic-examination sample. In stratified analyses, we observed differences in associations for overweight and obesity by race.

We observed associations with obesity and central obesity only in our primary analytic sample. We used the home-visit sample as our primary analytic sample because it was larger, which gave us more power to detect differences. We were only able to assess associations in the clinic-examination sample prospectively, because the published neighborhood deprivation index that we used was based on American Community Survey data collected around the time of the home visit. We also collapsed the lowest 2 levels (ADI percentiles 1–49) in the clinic-examination sample to form our reference group, whereas in our home-visit sample, our referent remained the lowest level (ADI percentiles 1–24).

The magnitude and direction of associations between neighborhood deprivation and obesity that we observed in our primary analytic sample are similar to those found in previous studies. Small area measures of deprivation are linked to obese populations from Germany (odds ratio (OR) = 1.14, 95% CI: 1.02, 1.26) (20) and Sweden (OR = 1.26; $P < 0.01$) (40). Our results are also concordant with the overall results among US adults aged 45 years or older reported by Keita et al. (27). Keita et al., however, observed stronger

Table 2. Characteristics of Clinic-Examination Study Sample (n = 3,016), the Gulf Long-Term Follow-up Study, 2014–2016

Characteristic	Level (Percentiles)					
	1/2 (1st–49th)		3 (50th–74th)		4 (75th–100th)	
	No.	%	No.	%	No.	%
Age at clinic examination, years[a]	52 (13)		49 (13)		46 (12)	
No. of patients	811	27	1,034	34	1,171	39
Sex						
Male	636	78	801	77	863	74
Female	175	22	233	23	308	26
Race						
White	602	74	631	61	326	28
Black	133	16	302	29	761	65
Other	76	9	101	10	84	7
Ethnicity						
Hispanic	19	2	24	2	28	2
Non-Hispanic	792	98	1,010	98	1,143	98
Smoking status						
Heavy current smoker	71	9	141	14	115	10
Light current smoker	137	17	229	22	291	25
Former smoker	233	29	226	22	234	20
Never smoker	370	46	438	42	531	45
Drinking status						
Current drinker	620	76	726	70	802	68
Former drinker	144	18	243	24	265	23
Never drinker	47	6	65	6	104	9
Education						
High school equivalent	99	12	236	23	294	25
High school diploma/GED	229	28	366	35	455	39
Some college/2-year degree	253	31	292	28	357	30
≥4-year college graduate	230	28	140	14	65	6
Employment						
Working now	495	61	551	53	537	46
Looking for work/unemployed	145	18	259	25	418	36
Other	171	21	224	22	216	18
Household income, USD						
<20,000	180	22	381	37	624	53
20,000–49,000	289	36	335	32	380	32
≥50,000	342	42	318	31	167	14
Weight categories[b]						
Normal	151	19	210	21	267	24
Overweight	249	32	281	29	289	26
Obese	379	49	489	50	568	51
Waist-to-hip ratio[c]						
Normal	186	23	237	23	333	28
Centrally obese	625	77	797	77	838	72

Table continues

Table 2. Continued

Characteristic	Level (Percentiles)					
	1/2 (1st–49th)		3 (50th–74th)		4 (75th–100th)	
	No.	%	No.	%	No.	%
Diabetes status						
Normal (HbA1C <5.7%)	579	71	677	65	714	61
Prediabetic only (HbA1C ≥5.7% but <6.5%)	140	17	195	19	276	24
Diabetic (diagnosed, taking medications, or HbA1C ≥6.5%)	92	11	162	16	181	15

Abbreviations: BMI, body mass index; GED, General Education Development test; HbA1C, hemoglobin A1C.
[a] Values are expressed as mean (standard deviation).
[b] BMI was calculated as weight (kg)/height (m)^2 and categorized as follows: normal, <25.0; overweight, 25.0–29.9; obese, ≥30.0.
[c] Categories: normal, ratio ≤0.85 for women, ≤0.90 for men; centrally obese, ratio >0.85 for women, >0.90 for men.

associations among White participants (OR = 1.69, 95% CI: 1.36, 1.84) compared with Black participants (OR = 1.27, 95% CI: 1.02, 1.58), whereas we observed the opposite.

Our findings with central obesity in the home-visit sample are in accordance with those of prior studies. Keita et al. (27) found an association between neighborhood deprivation and greater waist circumference among White participants (OR = 1.58, 95% CI: 1.36, 1.84). Chen and Tunstall-Pedoe (41) also reported this association (OR for men = 1.46, 95% CI: 1.17, 1.82; OR = 1.81 for women, 95% CI: 1.47, 2.23) in a Scottish population. Our associations are smaller than reported in these previous studies; this may be because the prevalence of central obesity in our sample was greater than 70%, as compared with 37%–56% by waist circumference in the study by Keita et al. (27), 16%–31% by waist circumference in the study by Chen and Tunstall-Pedoe (41), and a Centers for Disease Control and Prevention–estimated 59% in the United States overall (42). It is possible that neighborhood factors may have less of an impact on central obesity above a certain prevalence level. In addition, although we found a significant linear trend for central obesity in our results, our effect sizes remained small and the practical public health significance of this finding is unclear.

Table 3. Associations of Neighborhood Deprivation with Obesity and Diabetes at the Home Visit (*n* = 9,626), the Gulf Long-Term Follow-Up Study, 2011–2013[a]

Body Mass Index Status	Level (Percentiles)							
	1 (1st–24th; *n* = 439)		2 (25th–49th; *n* = 2,177)		3 (50th–74th; *n* = 3,390)		4 (75th–100th; *n* = 3,620)	
	aPR	95% CI	aPR	95% CI	aPR	95% CI	aPR	95% CI
Overweight/obese vs. normal	1.00	Referent	1.10	1.03, 1.17	1.12	1.06, 1.20	1.10	1.03, 1.17
Obese vs. normal	1.00	Referent	1.18	1.06, 1.32	1.24	1.11, 1.38	1.21	1.08, 1.35
Central obesity								
Waist-to-hip ratio of >0.85 for women, >0.90 for men vs. normal	1.00	Referent	1.07	1.01, 1.14	1.10	1.03, 1.17	1.11	1.04, 1.19
Self-reported diabetes diagnosis								
Yes vs. no	1.00	Referent	1.37	0.95, 1.96	1.57	1.10, 1.24	1.49	1.03, 2.14

Abbreviations: aPR, adjusted prevalence ratio; CI, confidence interval.
[a] Model was adjusted for age at home visit, sex, race, ethnicity, smoking status, drinking, education, income, and employment.

Table 4. Associations of Neighborhood Deprivation with Obesity and Diabetes at the Clinic Examination (*n* = 3,016), the Gulf Long-Term Follow-Up Study, 2014–2016[a]

Body Mass Index Status	Level (Percentiles)					
	1/2 (1st–49th; *n* = 811)		3 (50th–74th; *n* = 1,034)		4 (75th–100th; *n* = 1,171)	
	aPR	95% CI	aPR	95% CI	aPR	95% CI
Overweight/obese vs. normal	1.00	Referent	1.00	0.96, 1.05	0.98	0.93, 1.03
Obese vs. normal	1.00	Referent	1.02	0.95, 1.09	0.99	0.92, 1.06
Central obesity						
Waist-to-hip ratio of >0.85 for women, >0.90 for men vs. normal	1.00	Referent	1.03	0.98, 1.08	1.01	0.95, 1.06
Diabetes						
Prediabetes/diabetes vs. normal	1.00	Referent	1.20	1.05, 1.37	1.17	1.02, 1.34
Diabetes vs. normal	1.00	Referent	1.48	1.17, 1.87	1.46	1.14, 1.86

Abbreviations: aPR, adjusted prevalence ratio; CI, confidence interval.

[a] Models were adjusted for age at clinic examination, sex, race, ethnicity, smoking status, drinking, education, income, and employment.

Our findings with diabetes are also consistent with those reported in previous studies in which researchers used survey data from Germany (for women only, OR = 1.28, 95% CI: 1.05, 1.55) (21) and Sweden (OR = 1.66, 95% CI: 1.22, 1.34) (22), hospital records of diagnoses from the United Kingdom (for women aged 60–79 years, OR = 1.32, 95% CI: 1.13, 1.53) (26), and from measured diabetes by fasting glucose values taken from venous samples (≥100 mg/dL for prediabetes and diabetes) in Australia (OR = 1.53, 95% CI: 1.07, 2.18) (25) and in the United States (for Black participants, OR = 1.41, 95% CI: 1.10, 1.79; for White participants, OR = 1.58, 95% CI: 1.32, 1.89) (27).

Overall, our study findings suggest that neighborhood deprivation contributes to these cardiovascular risk factors, including in areas where the prevalence of these risk factors is already high. Primary hypothesized mechanisms explaining this link are the lack of healthy foods, proliferation of unhealthy food options (12), and the lack of recreational infrastructure such as parks and sidewalks (11), which promote more unhealthy behaviors. Chronic levels of stress contributing to neurohormonal dysregulation and reduced compensatory capacity may also play a role (16).

Strengths of our study include the use of a publicly available ADI, which measures neighborhood deprivation at the census block–group level. Use of ADI enables characterization of deprivation at the smallest geographic level in the United States and allows for comparability across studies that vary greatly in the literature. We had a large sample size with detailed information on sociodemographic, lifestyle, and health factors, allowing for control of potential confounding. We also used objective measures of obesity and confirmed diabetes at a clinic examination, including HbA1C values. Objective measures allowed us to identify undiagnosed participants as well as participants in elevated but nondiagnostic states, such as being overweight and having prediabetes.

Limitations of our study include the cross-sectional design, which limits causal inferences. It is possible that reverse causation may have played a role in our study such that participants who were chronically ill clustered in deprived neighborhoods either because of lack of resources (e.g., job loss related to income) or to live closer to health care facilities. However, the latter is unlikely because our cohort reported low medical care access (30). In this study, we used the 2013 version of the ADI, which was constructed from 2009 to 2013 American Community Survey data from the Census Bureau. Because we were interested in assessing the impacts of neighborhood deprivation primarily cross-sectionally, we linked ADI at the census block–group level to participants by using home addresses provided at the time of home visit. Because clinic examinations were conducted 3 years afterward, on average, results from the clinic examinations are not directly comparable to those from the home visit. We also adjusted for smoking, alcohol consumption, and employment status, among other covariates in our models; however, these and other covariates may be mediators rather than confounders. We conducted another sensitivity analysis with the home-visit primary analytic sample, adjusting only for age (Web Table 9), and the results were similar to those from the fully adjusted model (Table 3). We also cannot account for variability in deprivation within census-block groups. However, deprivation at the block-group level is already more precise than in prior studies in which deprivation was characterized at the municipality level (20), and we account for the individual-level factors of education and income. As was done in many previous studies, we used self-reported doctor's diagnosis of diabetes in our larger home-visit sample, although we were able to incorporate HbA1C values via point-of-care measurements in a smaller clinic-examination sample. In addition, although not a diagnostic standard, point-of-care measurements have strong correlations of up to 97% with laboratory-derived HbA1C values (43).

Our assessment of deprivation at the block-group level and objective health measures contribute to the growing body of evidence suggesting that neighborhood deprivation is independently associated with cardiovascular risk factors, including in areas with high baseline prevalence of poor health indicators. In future studies, researchers should incorporate location-specific methodologies including qualitative approaches to better contextualize the mechanisms of neighborhood impacts on CVD risk and should consider using a publicly available index of neighborhood deprivation to allow for comparability across studies.

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