Associations between neighborhood socioeconomic deprivation and severity of depression: Data from the National Health and Nutrition Examination Survey, 2011–2014

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ABSTRACT

Neighborhood socioeconomic disadvantage may contribute to depression. This study examined associations between neighborhood socioeconomic disadvantage, measured as deprivation, and depression severity within a broadly representative sample of the U.S. adult population. The sample (n = 6308 U.S. adults) was from the 2011–2014 National Health and Nutrition Examination Survey. Neighborhood deprivation was calculated using the 2010 U.S. Census and shown in tertile form. Depression severity was calculated from responses to the Patient Health Questionnaire-9 (PHQ-9) as a continuous depression severity score and binary Clinically Relevant Depression (CRD). Multilevel modeling estimated the relationship between deprivation and depression (reference = low deprivation). Models were additionally stratified by gender and race/ethnicity. U.S. adults living in high deprivation neighborhoods were more likely to have a higher PHQ-9 score (p < 0.0001). In unadjusted models, living in high deprivation neighborhoods associated with higher PHQ-9 ($\beta = 0.89$, SE = 0.15, p < 0.0001) and higher odds of CRD (OR = 1.35, 95% CI = 1.20–1.51). Living in medium deprivation neighborhoods associated with higher PHQ-9 ($\beta = 0.49$, SE = 0.16, p = 0.0019). Associations between deprivation and depression severity lost significance after adjusting for individual-level SES. The results suggest that, for U.S. adults, the relationship between neighborhood-level disadvantage and depression may be attenuated by individual-level SES.

1. Introduction

Depressive disorders, including major depressive disorder (MDD) and chronic, low-grade depressive moods, are complex and wide-spread disabilities affecting at least one in twelve U.S. adults (Association, 2013; Brody, Pratt, & Hughes, 2018). Depressive disorders and their symptoms pose significant difficulties to affected individuals. Of those experiencing depressive symptoms, 80% report difficulty with work, home, or social activities (Brody et al., 2018). The occurrence of

depressive symptoms or disorders also associates with worse physical, social, and role functioning (Brody et al., 2018; Wells et al., 1989). Depression is the second-leading cause of years lived with disability worldwide (Egede, Bishu, Walker, & Dismuke, 2016). In the U.S., depression is associated with higher or equal levels of disability compared to chronic diseases such as cancer, diabetes, and cardiovascular disease and acts as a consistent predictor of poor chronic disease outcomes (Kessler, 2012). As a result, depressive disorders and their symptoms pose significant health consequences in the U.S.

The social determinants of depression are complex and multifaceted, including individual-level socio-demographic characteristics (e.g., socioeconomic status (SES), health conditions and behaviors) and neighborhood-level factors (e.g., socioeconomic composition, geographic location, physical and social environment) (Silva, Loureiro, & Cardoso, 2016). In particular, socioeconomic inequalities are thought to relate to depression, with lower SES individuals having higher odds of depression and higher odds of persistent depression (Lorant et al., 2003; Muntaner, Eaton, Diala, Kessler, & Sorlie, 1998; Murphy et al., 1991).

Living in a socioeconomically disadvantaged neighborhood may also be a significant precursor to depression (Jesulola, Micalos, & Baguley, 2018; Nabeshima & Kim, 2013). One study of 1010 U.S. adults with diabetes found that living in neighborhoods with more poverty was associated with higher depression scores after adjusting for individual-level covariates including poverty and education (Gary-Webb et al., 2011). A longitudinal study of 820 New York City residents with no MDD history found greater incidence and odds of depression in low compared to high SES neighborhoods after adjusting for individual-level covariates including SES (Galea et al., 2007). A study among low-income families in the Denver, Colorado metropolitan area found that neighborhood socioeconomic disadvantage and poverty-related stress positively associated with depressive symptoms after adjustment for individual-level covariates including individual and family poverty (Santiago, Wadsworth, & Stump, 2011). A longitudinal mediation study of Illinois adults found that neighborhood disadvantage associated directly with depression after adjusting for individual-level covariates including income and education (J. Kim, 2010). A longitudinal study of New York City seniors indicated that positive neighborhood socioeconomic influences protected against worsening depressive symptoms over time after adjusting for individual-level covariates including household income (Beard et al., 2009). Another study of urban senior adults in Chicago found that seniors with higher neighborhood income rank had fewer depressive symptoms (Kelley-Moore, Cagney, Skarupski, Everson-Rose, & de Leon, 2016).

Review of existing literature has shown that some studies have indicated the expected directionality (i.e., greater neighborhood socioeconomic disadvantage associating with greater depression), while others have reported mixed and null findings (Blair, Ross, Gariepy, & Schmitz, 2014; Julien, Richard, Gauvin, & Kestens, 2012; D. Kim, 2008; Mair, Roux, & Galea, 2008; Richardson, Westley, Gariepy, Austin, & Nandi, 2015). A 2015 review found that half of studies on neighborhood socioeconomic disadvantage and depression found significant associations between greater disadvantage and odds of depression, with longitudinal studies with less than 5 years of follow-up indicating a significant association between neighborhood socioeconomic disadvantage and depression among studies (Richardson et al., 2015). It has been posited that mixed results may be due to methodological challenges, including differences in how neighborhood disadvantage is defined, and contextual factors, including specific demographic groups and geographic areas. In the 2015 review, all studies used a different measure of neighborhood socioeconomic disadvantage, and the authors stated that they could not assess type of neighborhood disadvantage as a source of mixed/null findings (Richardson et al., 2015). Further, individual-level characteristics are known to affect and be affected by neighborhood. For neighborhood socioeconomic disadvantage, inadequate adjustment for individual-level SES is of concern given the correlations that exist between living in a neighborhood with similar socioeconomic position as individual SES (Xie, Hubbard, & Himes, 2020). All of the studies in the 2015 review, for instance, controlled for individual-level SES factors in some capacity, including income, poverty, education, and employment, although residual confounding may still be a concern (Richardson et al., 2015).

Finally, there is little existing research encompassing the entire U.S. with regards to the relationship between neighborhood socioeconomic disadvantage and depression. One 2021 study utilizing the 2014–2015 500 Cities Project found that affluence, a measure of neighborhood income, education, and home value, strongly associated with poor mental health across the U.S., however it did not focus on depression (Forthman, Colaizzi, Yeh, Kuplicki, & Paulus, 2021). Most findings have been restricted to specific study areas and sample demographics that do not reflect the diversity of the U.S. population (Blair et al., 2014; Julien et al., 2012; Kim, 2008; Mair et al., 2008; Richardson et al., 2015).

Therefore, the aim of this study is to examine the associations between neighborhood socioeconomic disadvantage using the measure Neighborhood Deprivation Index (NDI), wherein higher NDI indicates greater neighborhood socioeconomic deprivation, and severity of depression within a broadly representative, demographically diverse U. S. cohort. We hypothesized that NDI would associate with severity of depression, with living in a neighborhood with greater deprivation associating with greater severity of depression. In addition, we hypothesized that there would be stronger relationships between living with higher NDI and depressive severity among women and Black residents.

2. Materials and methods

2.1. Study sample

The study population is taken from the National Health and Nutrition Examination Survey (NHANES), a nationally representative survey of the noninstitutionalized U.S. population. It is conducted biannually by the Centers for Disease Control and Prevention (CDC). This study utilized NHANES data from the 2011–2012 and 2013–2014 surveys. Of the 11,329 adults aged 20 to 85, we excluded those that did not complete the depression screening instrument (n = 1636). We also excluded those with histories of chronic health conditions including cardiovascular disease (stroke, myocardial infarction, congestive heart failure, coronary artery disease, or angina) (n = 995), diabetes (n = 934), and cancer (n = 567) because chronic conditions are complex mediators and modifiers of the associations between NDI and depression (DeJean, Giacomini, Vanstone, & Brundisini, 2013; Ross & Mirowsky, 2008; Santiago et al., 2011; Wells et al., 1989). Those missing sociodemographic, lifestyle, and environmental covariates were also excluded (n = 889). For missing data, NHANES recommendations are to disregard missing data if less than 10% of responses for a given variable are missing, and analyses are acceptable without imputation or further adjustment ("Clean & Recode Data, 2013" CDC). The resulting final study sample was of 6308 U.S. adults.

Access to the restricted-use NHANES variable identifying participant census tract was required. Original data collection for NHANES was approved by the National Center for Health Statistics (NCHS) Research Ethics Review Board and all participants provided written informed consent. We submitted a proposal to the NCHS and use of restricted-use data was approved by the NCHS Ethics Review Board. Data files including the restricted-use participant census tract variable were accessed through the Research Data Center (RDC) to merge NHANES public-use files with public-use neighborhood-level data from the U.S. Census Bureau.

2.2. Neighborhood Deprivation Index

Neighborhood deprivation is a measure of area-level socioeconomic disadvantage that has been used to assess associations between individuals' health outcomes and the socioeconomic resources in their neighborhoods. 2010 U.S. Census data was used to create NDI for each U.S. census tract as previously published; NDI was constructed at the census tract-level for consistency with previous literature and because census block group does not have access to the same variables consistently at the national level (U.S Census Bureau; Powell-Wiley et al., 2020). Principal axis factoring identified variables for NDI from 13 income, wealth, education, employment/occupation, and housing 2010 U. S. Census variables. Variables were z-standardized for scale consistency

and reverse coded if necessary before factor analysis. After applying promax rotation in the factor analysis, factors with an Eigenvalue >1 and variables showing a loading score >0.4 were included. Cronbach's alpha was used to assess the consistency of each factor with alpha ≥0.7. Variables that loaded for NDI were median household income, median home value, the percentage of households below the federal poverty limit, the percentage of families receiving public assistance, the percent of female-headed households with children under 18, the percentage of households that own their home, the percentage that receive interest, dividends, or rental income, the percentage of individuals over 25 with a high-school diploma, and the percentage of individuals over 25 with a bachelor's degree. A sum of these variables was used as a continuous NDI score, with a higher score representing a more deprived, lower socioeconomic level neighborhood. A tertile form of the score consisting of low, medium, and high deprivation was then created at the census tract level.

2.3. Severity of depression

The presence and severity of depression during the 2011–2012 and 2013–2014 NHANES was assessed using the Patient Health Questionnaire-9 (PHQ-9). PHQ-9 scores, ranging from 0 to 27, were used to create a continuous score of depression severity and a binary outcome of Clinically Relevant Depression (CRD, PHQ-9 ≥10). CRD encompasses moderate to severe depression, with a PHQ-9 score of ≥10 having a sensitivity and a specificity of 88% for MDD (Kroenke, Spitzer, & Williams, 2001).

2.4. Covariates

Individual- and neighborhood-level characteristics were controlled in the analysis as they may confound, mediate, or modify the association between NDI and depression. Individual-level sociodemographic characteristics included participant's age (years), binary self-reported gender (woman/man), national origin (foreign-born, US-born), self-reported race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, Other), highest educational attainment (less than high school, high school diploma or equivalent, some college, college graduate), ratio of family income to poverty level using annual Department of Health and Human Services poverty guidelines (U.S. Census Bureau, 2007), and marital status (married/living with partner, never married/separated/widowed/divorced). Individual-level health-related behavioral factors included smoking status (current smoker, former smoker, never smoker), alcohol consumption (abstainers, moderate drinkers, heavy drinkers), dietary intake (based on the 2010 Healthy Eating Index [HEI] diet quality score (Guenther et al., 2013)), physical activity based on NHANES accelerometer data in MET-minutes per week (MET-min/wk) (Troiano et al., 2008; Tucker, Welk, & Beyler, 2011), BMI in kilograms per meter squared (kg/m^2), and antidepressant medication use within the past month (yes, no). Antidepressant use was considered since antidepressants may be prescribed for other mental and physical health conditions and may indicate characteristics such as health care access. Further, we assessed depressive severity from PHQ-9 response rather than medication or treatment. Moreover, antidepressant use may modify scores participants indicate on the PHQ-9. Neighborhood-level sociodemographic characteristics included urban/rural status, which was classified by the 2010 U.S. Census at the county-level.

2.5. Statistical analysis

For descriptive statistics, weighted means and standard errors of continuous variables and weighted percentages of binary variables were compared across NDI tertile using Proc Surveymeans and Proc Surveyfreq to account for NHANES complex sample design ("Module3: Weighting," CDC). Weighted participant characteristics were also compared across measures of depression severity (CRD, PHQ-9 score)

using descriptive statistics.

An intraclass correlation coefficient (ICC) was calculated from the intercept-only model for the continuous PHQ-9 score to evaluate the need for multilevel modeling due to the nesting of individuals within census tract. The ICC was 37.30%. As such, we used sequential multilevel modeling to assess the relationship between NDI and severity of depressive symptoms in U.S. adults. We conducted multilevel modeling using Proc Glimmix for both continuous and binary depression outcomes in SAS 9.14 (SAS Institute Inc., Cary, NC). Modeling in SAS cannot presently account for both multilevel models and weighted survey models. As such, we additionally utilized weight-scaling developed to address complex survey designs which can produce results comparable to multilevel modeling using Proc surveyregression and Proc surveylogistic for continuous and binary outcomes (Carle, 2009). Proc Glimmix and Proc Survey procedures yielded similar results. As such, we provide multilevel modeling in the results and weighted survey modeling as supplemental material.

Five sequential models were calculated to estimate the relationships between NDI tertile and continuous depressive score (i.e., PHQ-9 score) and between NDI tertile and binary depression severity outcome (i.e., CRD). Model 1 adjusted for demographic variables (age, gender, race/ethnicity, nativity, marital status). Model 2 added individual-level SES (education, income to poverty ratio). Module3 added lifestyle risk factors (smoking, alcohol consumption, dietary intake, physical activity). Model 4 added antidepressant medication use. Finally, Model 5 added county-level urban/rural classification by the Census. Beta estimates are provided for continuous depressive severity and odds ratios are provided for binary depressive severity.

In addition, we performed sensitivity analyses to test interactions by gender and race. Mixed significant gender and race interactions were observed. Therefore, the model results were further stratified by gender and race to clarify the relationships (Supplemental Table 1) (Ward et al., 2019).

3. Results

3.1. Descriptive statistics

Differences in weighted demographic characteristics were shown by NDI tertile (Table 1). U.S. adults living in neighborhoods with higher deprivation were more likely to be younger (p = 0.0019), non-white (p < 0.0001), have lower educational attainment (p < 0.0001), have lower poverty to income ratios (p=<0.0001), be born outside of the U.S. (p=<0.0001), not be married or partnered (p < 0.0001), have less healthful diets (p < 0.0001), have higher BMI (p < 0.0001), be current smokers (p < 0.0001), reach more MET-min/week of physical activity (p = 0.0019), be never or former drinkers rather than current drinkers (p = 0.0041), and live in rural environments (p = 0.0073). Residents of high deprivation neighborhoods additionally had higher continuous PHQ-9 scores (p < 0.0001).

Differences in weighted demographic characteristics were also shown by category of PHQ-9 severity (Table 2). Those with higher PHQ-9 scores were more likely to be women (p < 0.0001), have lower educational attainment (p < 0.0001), have lower poverty to income ratios (p < 0.0001), be U.S. born (p = 0.032), not be married or partnered (p < 0.0001), reach fewer MET-min/week of physical activity (p = 0.0066), have less healthful diets (p < 0.0001), have higher BMI (p < 0.0001), not be current drinkers (p < 0.0001), be current smokers (p < 0.0001), take antidepressants (p < 0.0001), and live in high deprivation neighborhoods (p < 0.0001). Similar results were found for those with CRD as those with higher PHQ-9 scores (Supplemental Table 2).

3.2. NDI and continuous depression

Living in medium compared to low deprivation neighborhoods for U.S. adults significantly associated with higher PHQ-9 scores among all

Table 1
Weighted means of NDI by participant characteristics, NHANES, 2011–2014 (n = 6308).

Characteristics	Low Neighborhood Deprivation		Medium Neighborhood Deprivation		High Neighborhood Deprivation		p-value for test of independence[a]
	% (SE) or Mean (SE)	N	% (SE) or Mean (SE)	N	% (SE) or Mean (SE)	N	
Age (years), mean (SE)	44.92 (0.66)	1960	43.93 (0.96)	1871	41.77 (0.51)	2477	**0.0019**
Gender, % (SE)							
Men	48.40 (1.16)	953	49.72 (1.19)	943	49.09 (1.19)	1196	0.68
Women	51.60 (1.16)	1007	50.28 (1.19)	928	50.91 (1.19)	1281	
Race/ethnicity, % (SE)							
Non-Hispanic White	78.94 (1.71)	1010	72.06 (2.70)	906	45.49 (4.69)	621	**<0.0001**
Non-Hispanic Black	4.95 (0.84)	241	9.37 (1.34)	349	19.99 (2.75)	820	
Hispanic	7.24 (1.03)	251	11.05 (1.69)	306	28.07 (3.75)	771	
Other	8.88 (1.10)	449	7.51 (0.89)	310	6.45 (0.81)	265	
Nativity, % (SE)							
US born	85.49 (1.43)	1390	85.28 (1.80)	1384	76.28 (2.25)	1705	**<0.0001**
Foreign born	14.51 (1.43)	570	14.72 (1.80)	487	23.72 (2.25)	772	
Marital status, % (SE)							
Married/partnered	69.51 (1.63)	1307	59.75 (2.05)	1083	52.62 (1.79)	1252	**<0.0001**
Never married, separated, divorced, or widowed	30.49 (1.63)	653	40.25 (2.05)	787	47.38 (1.79)	1225	
Education, % (SE)							
Less than High School	4.88 (0.63)	146	12.78 (1.17)	318	25.70 (1.48)	718	**<0.0001**
High School/GED	14.17 (1.14)	279	23.61 (1.56)	426	26.78 (1.72)	653	
Some college/associate degree	27.99 (1.23)	556	38.35 (1.46)	677	32.93 (1.38)	780	
College degree or above	52.96 (1.90)	979	25.26 (1.70)	450	14.59 (1.39)	326	
Poverty Income Ratio, mean (SE)	3.77 (0.08)	1960	2.85 (0.07)	1871	2.07 (0.08)	2477	**<0.0001**
Physical Activity (MET-min/week), mean (SE)	309.83 (17.05)	1960	365.31 (25.99)	1871	412.52 (24.17)	2477	**0.0019**
Dietary Intake, % (SE)							
Poor (<50 HEI-2010)	42.19 (1.82)	833	55.50 (1.42)	1019	60.11 (1.62)	1457	**<0.0001**
Intermediate/Ideal (≥50 HEI-2010)	57.81 (1.82)	1127	44.50 (1.42)	852	39.89 (1.62)	1020	
BMI (kg/m², mean (SE)	27.59 (0.20)	1960	28.76 (0.24)	1871	29.40 (0.20)	2477	**<0.0001**
Alcohol Consumption, % (SE)							
Never drinker	8.70 (2.51)	246	10.91 (1.31)	237	13.88 (0.86)	399	**0.0041**
Former drinker	9.27 (0.98)	215	11.59 (0.83)	262	14.25 (0.88)	385	
Current drinker	82.03 (3.30)	1499	77.51 (1.59)	1372	71.87 (1.35)	1693	
Tobacco Use, % (SE)							
Never smoker	63.85 (2.06)	1272	56.39 (1.73)	1051	54.61 (1.65)	1399	**<0.0001**
Former smoker	23.14 (1.80)	424	21.95 (1.75)	400	18.39 (1.09)	444	
Current smoker	13.02 (0.97)	264	21.66 (1.27)	420	26.99 (1.88)	634	
Taking Antidepressant Medication, % (SE)							
Yes	13.62 (1.33)	209	12.93 (1.47)	195	10.12 (1.24)	200	0.21
No	86.38 (1.33)	1751	87.07 (1.47)	1676	89.88 (1.24)	2277	
Urban/Rural Classification, % (SE)							
Urban	89.16 (2.77)	1791	74.37 (3.81)	1502	88.24 (3.72)	2281	**0.0073**
Rural	10.85 (2.77)	169	25.63 (3.81)	369	11.76 (3.72)	196	
PHQ-9 Score	2.34 (0.11)	1960	2.95 (0.13)	1871	3.42 (0.17)	2477	**<0.0001**

Abbreviations: NDI, Neighborhood Deprivation Index; PHQ-9, Patient Health Questionnaire-9; HEI, Healthy Eating Index; NHANES, National Health and Nutrition Examination Survey.

[a] Boldface indicates statistical significance (p < 0.05).

individuals prior to adjustment (β = 0.49, SE = 0.16, p = 0.0019), but not after adjusting for socioeconomic characteristics or full adjustment (β = −0.05, SE = 0.16, p = 0.78; β = 0.004, SE = 0.14, p = 0.98). There was an association between NDI and PHQ-9 score among those in high compared to low deprivation neighborhoods for U.S. adults prior to adjustment (β = 0.89, SE = 0.15, p < 0.0001), but not after adjusting for socioeconomic characteristics or full adjustment (β = 0.04, SE = 0.16, p = 0.47; β = 0.10, SE = 0.15, p = 0.51) (Table 3).

When stratifying for gender and race/ethnicity, association with higher PHQ-9 score was seen among women (β = 0.60, SE = 0.22, p = 0.0066) and non-Hispanic Whites (β = 0.59, SE = 0.23, p = 0.011) living in medium deprivation neighborhoods, and among women (β = 1.06, SE = 0.21, p < 0.0001), men (β = 0.70, SE = 0.18, p = 0.0001), non-Hispanic Whites (β = 1.53, SE = 0.29, p < 0.0001), and non-Hispanic Blacks (β = 0.84, SE = 0.32, p = 0.0097) living in high deprivation neighborhoods. The models were not statistically significant after adjusting for individual-level SES and full adjustment. Similar results were seen for weighted survey modeling as for multilevel modeling (Supplemental Table 3).

3.3. NDI and binary depression

Individuals living in neighborhoods with high deprivation had higher odds of CRD (OR = 1.35, 95% CI = 1.20–1.51) (Table 4). These odds lost significance, however, after adjusting for individual-level SES and after full adjustment (OR = 1.00, 95% CI = 0.88–1.13; OR = 0.98, 95% CI = 0.86–1.12). When stratifying for gender and race/ethnicity, significantly higher odds of CRD were seen in unadjusted models among women (OR = 1.34, 95% CI = 1.14–1.58), men (OR = 1.40, 95% CI = 1.16–1.69), non-Hispanic Whites (OR = 1.59, 95% CI = 1.33–1.91), and non-Hispanic Blacks (OR = 1.53, 95% CI = 1.14–2.05) living in high compared to low deprivation neighborhoods. These odds lost significance after adjusting for individual-level SES and fully adjusting for covariates. Similar results were seen for survey modeling as for multi-level modeling (Supplemental Table 4).

Individuals living in medium deprivation neighborhoods had nonsignificant odds of CRD prior to adjustment (OR = 1.13, 95% CI = 0.99–1.28) and after full adjustment (OR = 0.92, 95% CI = 0.80–1.05) (Table 4). Prior to adjustment, non-Hispanic Whites (OR = 1.20, 95% CI

Table 2

Weighted means of categorical PHQ-9 score by participant characteristics, NHANES, 2011–2014 (n = 6308).

Characteristics	Overall		PHQ-9 Depression Score								p-value[a]
			0-4 None/Minimal		5-9 Mild		10-14 Moderate		15-27 Severe		
	% (SE) or Mean (SE)	N	% (SE) or Mean (SE)	N	% (SE) or Mean (SE)	N	% (SE) or Mean (SE)	N	% (SE) or Mean (SE)	N	
Age (years), mean (SE)	43.67 (0.43)	6308	43.80 (0.48)	4908	42.98 (0.87)	902	43.44 (0.93)	305	43.54 (1.35)	193	0.51
Gender, % (SE)											
Men	49.02 (0.78)	3092	51.36 (0.85)	2549	42.19 (2.14)	369	34.07 (2.83)	102	39.43 (4.54)	72	**<0.0001**
Women	50.98 (0.78)	3216	48.64 (0.85)	2359	57.81 (2.14)	533	65.93 (2.83)	203	60.57 (4.54)	121	
Race/ethnicity, % (SE)											
Non-Hispanic White	66.76 (2.52)	2546	67.37 (2.56)	1968	63.43 (3.00)	354	65.75 (4.40)	130	66.95 (4.94)	94	0.071
Non-Hispanic Black	10.84 (1.20)	1410	10.22 (1.10)	1068	13.91 (1.91)	232	13.36 (1.98)	73	9.79 (2.24)	37	
Hispanic	14.68 (1.81)	1328	14.44 (1.87)	1020	15.78 (1.96)	194	14.58 (2.96)	68	16.35 (3.68)	46	
Other	7.73 (0.65)	1024	7.98 (0.70)	852	6.88 (0.90)	122	6.31 (1.31)	34	6.91 (2.39)	16	
Nativity, % (SE)											
US born	82.66 (1.33)	4479	82.03 (1.32)	3418	83.77 (1.73)	668	86.18 (2.61)	235	89.38 (3.17)	158	**0.032**
Foreign born	17.34 (1.33)	1829	17.98 (1.32)	1390	16.23 (1.73)	235	13.82 (2.61)	70	10.62 (3.17)	35	
Marital status, % (SE)											
Married/partnered	61.41 (1.29)	3643	64.50 (1.32)	2976	52.73 (2.35)	454	43.56 (3.60)	134	44.35 (3.89)	79	**<0.0001**
Never married, separated, divorced, or widowed	38.59 (1.29)	2665	35.50 (1.32)	1932	47.27 (2.35)	448	56.44 (3.60)	171	55.65 (3.89)	114	
Education, % (SE)											
Less than High School	13.58 (1.18)	1182	12.34 (1.23)	853	15.93 (1.74)	184	21.89 (3.05)	88	24.19 (3.64)	57	**<0.0001**
High School/GED	20.88 (1.08)	1358	19.99 (0.99)	1009	23.22 (2.88)	224	20.65 (2.34)	64	34.65 (4.84)	61	
Some college/associate degree	32.68 (1.00)	2013	31.71 (1.11)	1537	37.64 (3.13)	316	37.63 (3.22)	103	28.86 (4.09)	57	
College degree or above	32.85 (1.75)	1755	35.96 (1.71)	1509	23.22 (2.69)	178	19.83 (3.43)	50	12.30 (3.15)	18	
Poverty Income Ratio, mean (SE)	2.98 (0.08)	6308	3.14 (0.08)	4908	2.53 (0.09)	902	2.04 (0.16)	305	1.93 (0.19)	193	**<0.0001**
Physical Activity (MET-min/ week), mean (SE)	357.87 (14.52)	6308	363.46 (16.47)	4908	374.10 (28.39)	902	276.40 (40.50)	305	255.38 (40.50)	193	**0.0066**
Dietary Intake, % (SE)											
Poor (<50 HEI-2010)	51.70 (1.31)	3309	49.17 (1.35)	2456	58.08 (1.96)	523	68.39 (3.26)	207	65.73 (3.95)	123	**<0.0001**
Intermediate/Ideal (≥50 HEI-2010)	48.30 (1.31)	2999	50.83 (1.35)	2452	41.92 (1.96)	379	31.61 (3.26)	98	34.27 (3.95)	70	
BMI (kg/m²), mean (SE)	28.50 (0.15)	6308	28.21 (0.16)	4908	29.39 (0.26)	902	29.89 (0.46)	305	29.99 (0.64)	193	**<0.0001**
Alcohol Consumption, % (SE)											
Never drinker	10.94 (1.28)	882	11.25 (1.38)	713	9.28 (1.35)	107	7.22 (1.33)	32	15.80 (4.16)	30	**<0.0001**
Former drinker	11.49 (0.65)	862	10.67 (0.59)	632	10.95 (1.07)	127	20.06 (3.47)	63	22.99 (4.14)	40	
Current drinker	77.58 (1.77)	4564	78.08 (1.78)	3563	79.77 (2.12)	668	72.71 (4.00)	210	61.21 (3.61)	123	
Tobacco Use, % (SE)											
Never smoker	58.76 (1.17)	3722	61.92 (1.25)	3040	50.48 (1.85)	474	38.31 (3.39)	127	41.86 (4.92)	81	**<0.0001**
Former smoker	21.34 (1.09)	1268	21.35 (1.17)	989	21.09 (2.03)	175	21.06 (2.59)	65	22.92 (3.83)	39	
Current smoker	19.89 (1.09)	1318	16.73 (0.89)	879	28.43 (2.21)	253	40.64 (3.38)	113	35.22 (3.29)	73	
Taking Antidepressant Medication, % (SE)											
Yes	12.35 (0.65)	604	8.45 (0.55)	298	21.40 (1.74)	146	36.34 (4.49)	85	40.59 (4.43)	75	**<0.0001**
No	87.65 (0.65)	5704	91.55 (0.55)	4610	78.60 (1.74)	756	63.66 (4.49)	220	59.41 (4.43)	118	
Urban/Rural Classification, % (SE)											
Urban	84.30 (1.87)	5574	83.59 (1.89)	4321	86.74 (2.47)	808	88.34 (2.07)	276	86.32 (3.83)	169	0.078
Rural	15.70 (1.87)	734	16.41 (1.89)	587	13.26 (2.47)	94	11.66 (2.07)	29	13.68 (3.83)	24	
Neighborhood Deprivation Tertiles, % (SE)											
Low Deprivation	38.98 (3.43)	1960	41.67 (3.49)	1620	28.83 (3.68)	227	29.68 (4.88)	71	26.37 (4.58)	42	**<0.0001**
Medium Deprivation	30.97 (1.98)	1871	30.47 (1.93)	1459	34.08 (3.34)	275	29.49 (3.37)	77	32.63 (4.88)	60	
High Deprivation	30.05 (3.46)	2477	27.85 (3.30)	1829	37.10 (4.71)	400	40.83 (4.84)	157	41.00 (5.81)	91	

Abbreviations: NDI, Neighborhood Deprivation Index; PHQ-9, Patient Health Questionnaire-9; HEI, Healthy Eating Index; NHANES, National Health and Nutrition Examination Survey; SE, Standard Error.

[a] Boldface indicates statistical significance (p < 0.05).

= 1.01–1.44) living in medium deprivation neighborhoods had significant odds of CRD; after full adjustment, these odds lost significance. However, women living in medium deprivation neighborhoods had nonsignificant odds of CRD (OR = 1.09, 95% CI = 0.91–1.30) prior to adjustment. After adjusting for individual-level SES (OR = 0.77, 95% CI = 0.64–0.94) and after full model adjustment (OR = 0.80, 95% CI = 0.66–0.98), women living in medium deprivation neighborhoods had significantly lower odds of CRD compared to low deprivation neighborhoods. Similar results were seen for weighted survey modeling as for multilevel modeling (Supplemental Table 4).

4. Discussion

In this study, the relationship between neighborhood socioeconomic deprivation and depression severity was assessed using a large,

nationally representative sample of the U.S. population. Ultimately, we found that individual-level SES attenuated the relationship between NDI and depression severity, with models either experiencing loss of significance or significant change in directionality after adjustment for individual-level SES. These changes were consistent for continuous and binary measures of depression. These results further contribute to mixed and null results that have been found in the associations between neighborhood-level socioeconomic deprivation and depression among smaller cohorts and subsamples of the U.S. population, while emphasizing the role of individual-level SES in the relationship between neighborhood socioeconomic disadvantage and depression (Blair et al., 2014; Julien et al., 2012; Kim, 2008; Mair et al., 2008; Richardson et al., 2015).

Table 3

Association between NDI and continuous PHQ-9 score, NHANES, 2011–2014 (n = 6308)[a].

Characteristic	Unadjusted		Model 1		Model 2		Model 3		Model 4		Model 5	
	β (SE)	p-value[b]	β (SE)	p-value	β (SE)	p-value	β (SE)	p-value	β (SE)	p-value	β (SE)	p-value
Overall sample (n=6308)												
Low NDI (ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Medium NDI	0.49 (0.16)	**0.0019**	0.45 (0.16)	**0.0037**	0.04 (0.15)	0.79	−0.05 (0.15)	0.73	−0.03 (0.14)	0.84	0.004 (0.14)	0.98
High NDI	0.89 (0.15)	**<0.0001**	0.84 (0.16)	**<0.0001**	0.12 (0.16)	0.47	0.04 (0.16)	0.78	0.09 (0.15)	0.5534	0.10 (0.15)	0.51
Women (n=3216)												
Low NDI (ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Medium NDI	0.60 (0.22)	**0.0066**	0.51 (0.22)	**0.018**	0.09 (0.22)	0.68	−0.10 (0.21)	0.62	−0.06 (0.20)	0.77	−0.06 (0.20)	0.76
High NDI	1.06 (0.21)	**<0.0001**	0.93 (0.22)	**<0.0001**	0.12 (0.22)	0.60	−0.06 (0.21)	0.78	0.01 (0.21)	0.97	0.02 (0.21)	0.91
Men (n=3092)												
Low NDI (ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Medium NDI	0.37 (0.19)	0.058	0.33 (0.20)	0.10	−0.11 (0.19)	0.56	−0.12 (0.19)	0.51	−0.02 (0.18)	0.91	−0.01 (0.18)	0.96
High NDI	0.70 (0.18)	**0.0001**	0.73 (0.22)	**0.0008**	−0.002 (0.22)	0.99	−0.02 (0.22)	0.94	0.11 (0.21)	0.61	0.11 (0.21)	0.59
Non-Hispanic White (n=2546)												
Low NDI (ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Medium NDI	0.59 (0.23)	**0.011**	0.45 (0.23)	**0.045**	−0.09 (0.22)	0.68	−0.08 (0.20)	0.71	−0.04 (0.21)	0.84	0.02 (0.21)	0.93
High NDI	1.53 (0.29)	**<0.0001**	1.35 (0.28)	**<0.0001**	0.46 (0.28)	0.10	0.38 (0.26)	0.14	0.36 (0.27)	0.19	0.38 (0.27)	0.16
Non-Hispanic Black (n=1410)												
Low NDI (ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Medium NDI	0.40 (0.37)	0.28	0.37 (0.36)	0.31	−0.04 (0.35)	0.92	−0.07 (0.34)	0.84	−0.15 (0.33)	0.65	−0.16 (0.33)	0.63
High NDI	0.84 (0.32)	**0.0097**	0.66 (0.34)	**0.050**	−0.09 (0.33)	0.78	−0.15 (0.32)	0.64	−0.16 (0.31)	0.61	−0.16 (0.31)	0.61
Hispanic (n=1328)												
Low NDI (ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Medium NDI	0.13 (0.43)	0.76	0.13 (0.41)	0.75	−0.004 (0.41)	0.99	−0.13 (0.40)	0.75	−0.44 (0.40)	0.2684	−0.44 (0.40)	0.27
High NDI	0.27 (0.36)	0.45	0.23 (0.35)	0.52	−0.20 (0.38)	0.59	−0.29 (0.38)	0.44	−0.26 (0.37)	0.49	−0.26 (0.37)	0.49
Other (n=1024)												
Low NDI (ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Medium NDI	0.45 (0.40)	0.26	0.35 (0.38)	0.36	−0.08 (0.40)	0.85	−0.11 (0.36)	0.76	−0.20 (0.32)	0.52	−0.21 (0.32)	0.51
High NDI	−0.01 (0.34)	0.97	−0.17 (0.34)	0.62	−0.72 (0.37)	**0.049**	−0.70 (0.34)	**0.039**	−0.60 (0.32)	0.060	−0.60 (0.32)	0.060

Abbreviations: NDI, Neighborhood Deprivation Index; PHQ-9, Patient Health Questionnaire-9; NHANES, National Health and Nutrition Examination Survey; SE, Standard Error.

[a] Estimates were adjusted for complex survey MEC weights.

[b] Boldface indicates statistical significance (p < 0.05).

4.1. Strengths and limitations

The broadly representative, demographically diverse U.S. cohort utilized for this study strengthens the validity of our findings and may provide more generalizability than previous literature. This study examined severity of depression using the validated PHQ-9 provided by NHANES (Kroenke et al., 2001). Neighborhood socioeconomic deprivation was measured using NDI, which is a validated measure of neighborhood-level socioeconomic disadvantage (Powell-Wiley et al., 2020). Finally, our models were strengthened by adjustment for both individual- and neighborhood-level covariates.

Several limitations are present in this study. We were unable to consider NDI as a continuous variable in accordance with NHANES confidentiality requirements. Reporting minimum, maximum, or the difference of an external continuous variable in its exact form could lead to the disclosure of tracts visited by NHANES. An approximated version was thus derived from collapsed tertiles of the continuous NDI variable. However, these do not provide exact NDI values for participants and could miss detailed information surrounding variation in NDI.

Additionally, the study sample had limitations. The sample excluded participants missing data for NDI, depression, and covariates. This could introduce bias in the sample if such variables were not missing at random. However, missing covariate data did not represent a large proportion of the study cohort (<5%).

In analyzing associations, we were unable to assess causality due to exposure, outcome, and sample design. NHANES allows for only cross-sectional analysis. For the exposure, since NDI is an external variable, participant neighborhood experiences such as length of residency were not provided, which could have enabled dose-response evaluation. For the outcome, the PHQ-9 scale asks individuals about their depression severity for the past two weeks, during which a depressive episode may not have occurred. We were thus unable to assess the directionality and the relationship between neighborhood deprivation and depression severity, which was further complicated by attenuation by individual SES.

4.2. Future study

The relationship between individual- and neighborhood-level socioeconomic disadvantage is complex. Correlations exist between the two, with greater correlation existing between individual and neighborhood socioeconomic measures in large metropolitan and suburban areas of the US (Xie et al., 2020). This relationship may be clarified with context for past and current individual- and neighborhood-level

Table 4

Association between NDI and odds of CRD, NHANES, 2011–2014 (n = 6308)[a].

Characteristic	Unadjusted		Model 1		Model 2		Model 3		Model 4		Model 5	
	OR (CI[b])	p-value[c]	OR (CI)	p-value	OR (CI)	p-value	OR (CI)	p-value	OR (CI)	p-value	OR (CI)	p-value
Overall sample (n=6308)												
Low NDI (ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Medium NDI	1.13 (0.99, 1.28)	0.077	1.11 (0.97, 1.26)	0.12	0.93 (0.81, 1.06)	0.26	0.89 (0.78, 1.02)	0.10	0.90 (0.79, 1.04)	0.15	0.92 (0.80, 1.05)	0.21
High NDI	1.35 (1.20, 1.51)	**<0.0001**	1.33 (1.18, 1.51)	**<0.0001**	1.00 (0.88, 1.13)	0.99	0.96 (0.85, 1.09)	0.52	0.98 (0.86, 1.12)	0.78	0.98 (0.86, 1.12)	0.77
Women (n=3216)												
Low NDI (ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Medium NDI	1.09 (0.91, 1.30)	0.34	1.06 (0.88, 1.26)	0.55	0.88 (0.73, 1.06)	0.18	0.77 (0.64, 0.94)	**0.010**	0.79 (0.65, 0.96)	**0.019**	0.80 (0.66, 0.98)	**0.029**
High NDI	1.34 (1.14, 1.58)	**0.0003**	1.30 (1.10, 1.54)	**0.0022**	0.96 (0.80, 1.15)	0.68	0.89 (0.74, 1.07)	0.21	0.90 (0.74, 1.08)	0.24	0.90 (0.75, 1.08)	0.25
Men (n=3092)												
Low NDI (ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Medium NDI	1.22 (0.99, 1.50)	0.064	1.21 (0.98, 1.48)	0.076	1.01 (0.81, 1.23)	0.95	1.00 (0.81, 1.23)	0.99	1.04 (0.84, 1.30)	0.72	1.05 (0.84, 1.31)	0.66
High NDI	1.40 (1.16, 1.69)	**0.0006**	1.40 (1.14, 1.72)	**0.0011**	1.05 (0.85, 1.30)	0.65	1.05 (0.85, 1.29)	0.68	1.08 (0.87, 1.34)	0.49	1.07 (0.86, 1.33)	0.55
Non-Hispanic White (n=2546)												
Low NDI (ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Medium NDI	1.20 (1.01, 1.44)	**0.044**	1.17 (0.98, 1.40)	0.085	0.93 (0.76, 1.13)	0.43	0.90 (0.74, 1.10)	0.29	0.91 (0.74, 1.12)	0.38	0.95 (0.78, 1.16)	0.61
High NDI	1.59 (1.33, 1.91)	**<0.0001**	1.52 (1.27, 1.82)	**<0.0001**	1.09 (0.89, 1.32)	0.40	1.02 (0.83, 1.25)	0.87	1.01 (0.82, 1.24)	0.96	1.01 (0.82, 1.24)	0.95
Non-Hispanic Black (n=1410)												
Low NDI (ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Medium NDI	1.23 (0.88, 1.71)	0.23	1.20 (0.87, 1.66)	0.28	1.06 (0.76, 1.49)	0.73	1.07 (0.76, 1.49)	0.70	1.05 (0.74, 1.50)	0.78	1.03 (0.73, 1.47)	0.85
High NDI	1.53 (1.14, 2.05)	**0.0045**	1.45 (1.08, 1.95)	**0.014**	1.13 (0.83, 1.54)	0.45	1.12 (0.81, 1.53)	0.49	1.17 (0.84, 1.63)	0.35	1.15 (0.83, 1.60)	0.39
Hispanic (n=1328)												
Low NDI (ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Medium NDI	0.91 (0.65, 1.28)	0.58	0.90 (0.65, 1.25)	0.53	0.86 (0.61, 1.22)	0.39	0.79 (0.56, 1.12)	0.18	0.79 (0.55, 1.14)	0.21	0.76 (0.52, 1.12)	0.16
High NDI	1.07 (0.81, 1.42)	0.63	10.5 (0.80, 1.38)	0.74	0.90 (0.67, 1.21)	0.49	0.86 (0.65, 1.16)	0.33	0.92 (0.68, 1.25)	0.58	0.90 (0.66, 1.24)	0.52
Other (n=1024)												
Low NDI (ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Medium NDI	1.11 (0.73, 1.67)	0.62	1.06 (0.74, 1.53)	0.74	0.86 (0.59, 1.25)	0.42	0.80 (0.56, 1.17)	0.25	0.80 (0.54, 1.17)	0.25	0.80 (0.54, 1.17)	0.25
High NDI	1.06 (0.68, 1.65)	0.80	1.03 (0.68, 1.54)	0.89	0.76 (0.51, 1.12)	0.16	0.70 (0.47, 1.06)	0.010	0.71 (0.47, 1.07)	0.11	0.72 (0.48, 1.08)	0.11

Abbreviations: NDI, Neighborhood Deprivation Index; CRD, Clinically Relevant Depression; NHANES, National Health and Nutrition Examination Survey; OR, Odds Ratio; CI, Confidence Interval.

[a] Estimates were adjusted for complex survey MEC weights.

[b] 95% confidence interval.

[c] Boldface indicates statistical significance (p < 0.05).

socioeconomic disadvantage, such as by getting more person-centered data regarding length of residence. For instance, data from the Moving to Opportunity has shown that low-income individuals randomized to receive housing-mobility vouchers who moved from high-poverty to lower-poverty neighborhoods had long-term improvements in adult physical and mental health after 10–15 years (Ludwig et al., 2012). Another type of person-centered data to consider is activity space, or the spatial area within which people move during daily life. A 2017 study of the Los Angeles Family and Neighborhood Survey found that higher SES residents have larger and more geographically diverse activity spaces, indicating they may have more options for movement, and that lower SES residents are more likely to share smaller, similar routine activity locations; further, increased neighborhood-SES inequality associated with more limited activity spaces (Browning, Calder, Krivo, Smith, & Boettner, 2017). Additionally, with details such as length of residence or spatial movement, changes over time in individual-level SES and neighborhood-level deprivation can be considered. Neighborhood

deprivation is often measured at one time point, but some neighborhoods may undergo rapid change from gentrification, urban development, and urban regeneration which residents may live through and which may relate to their SES and health (Schnake-Mahl, Jahn, Subramanian, Waters, & Arcaya, 2020).

Further, study design may clarify the interplay between individual and neighborhood socioeconomic disadvantage. Having follow-up responses from longitudinal studies could not only provide details such as length of residence, but would also allow for directionality to be assessed between individual or neighborhood socioeconomic status and health conditions. Randomized experiments and natural studies are also possible. For instance, housing voucher programs performed in academic and governmental contexts have allowed for studies of how movement between neighborhoods may result in health changes among low income individuals – although these studies have often been limited to low income individuals and urban settings and affected by economic and racial segregation (Deng, 2007; Ellen, 2020; Ludwig et al., 2012).

Greater understanding of these temporal factors may enable us to tease out the interplay between individual and neighborhood factors on depression.

Although our analysis of higher neighborhood deprivation as associating with depression did not yield significant findings, other neighborhood-level variables such as objective and perceived physical and social environment may still associate with depression. Although neighborhood socioeconomic disadvantage is one of the most investigated of neighborhood variables, it has shown less consistent results in relation to depression than other neighborhood variables, namely neighborhood social environment and structural/built environment (e. g. socioeconomic composition, racial composition, built environment) (Julien et al., 2012; D.; Kim, 2008; J.; Kim, 2010; Mair et al., 2008). As with studies of neighborhood socioeconomic disadvantage, studies of other neighborhood variables and depression have utilized a variety of neighborhood measures, have defined neighborhood exposures at different geographic levels, have largely been restricted to specific study areas and sample demographics, and have been cross-sectional (Blair et al., 2014; Julien et al., 2012; D.; Kim, 2008; Mair et al., 2008; Richardson et al., 2015). While we were unable to assess the effect of perceptions of neighborhood as the data are not collected by NHANES, some physical and social environment measures could be assessed with census data in future studies.

In addition, we provided stratified analyses by gender and race/ethnicity. Living in medium deprivation neighborhoods associated with lower odds of CRD among women after adjustment for individual-SES. These results may indicate a stress-resilience mechanism among women living with certain deprivation levels or that a different factor attenuates the association for U.S. women at certain deprivation levels. Neighborhood socioeconomic disadvantage has been found to positively associate with or have null association with depression among women after controlling for individual characteristics (Blair et al., 2014; Julien et al., 2012; Kim, 2008; Richardson et al., 2015). Although studies have not exhibited negative associations, some have investigated other neighborhood- and individual-level variables which may confound or mediate the relationship of neighborhood socioeconomic disadvantage to depression for women. As such, other variables may have a protective effect against or act in conjunction with neighborhood socioeconomic disadvantage on depression among women. For instance, measures of social environment such as neighborhood social support (Buu et al., 2011) (Mair, Roux, & Morenoff, 2010), lower social disorder (Cutrona et al., 2005), and social cohesion (Wilmot & Dauner, 2017) have related to lower depression in women. Individual-level factors may also protect against the impact of neighborhood socioeconomic disadvantage on depression among women. Although adjusted for, remnants of individual SES confounding may still attenuate the relationship between neighborhood socioeconomic disadvantage and depression in women. Given the results of this study and past literature, both individual- and neighborhood-level factors may influence depressive symptoms in women, and the ways that these factors interact should be considered in future study.

5. Conclusions

After controlling for and individual- and neighborhood-level characteristics, living in a neighborhood with high deprivation compared to low deprivation did not associate with severity of depression among a nationally representative sample of U.S. adults. Living in a neighborhood with medium deprivation compared to low deprivation associated with lower odds of CRD among U.S. adult women after adjustment. The relationship between neighborhood deprivation and depression may be attenuated by individual-level SES, supporting a need to further examine other physical and social neighborhood environment factors that may relate to depression severity by gender and in racially- and ethnically-diverse and geographically-diverse populations.

Ethics statement

Use of NHANES data was approved by the NCHS Research Ethics Review Board and all participants provided written informed consent. This study was exempted from human subjects review by the NIH Office for Human Subjects Research Protection. Data access was provided and confidential data was managed by RDC of the CDC. To maintain participant confidentiality, the participant census tract variable used to merge public-use NHANES and U.S. Census Bureau data is only available through the RDC by approval of the NCHS Research Ethics Review Board.

Data sharing statement

Deidentified participant data is publicly available on the NHANES website (https://wwwn.cdc.gov/Nchs/Nhanes/). Data from the 2010 U. S. Census used to create NDI by U.S. Census tracts is publicly available on the U.S. Census Bureau website (https://data.census.gov/cedsci/). To maintain participant confidentiality, the participant census tract variable used to merge public-use NHANES and U.S. Census Bureau data is only available through the RDC by approval of the NCHS Research Ethics Review Board.

Authors' contributions

S.J.N. contributed conceptualization, data curation, formal analysis, investigation, methodology, and writing - original draft. T.M.P–W. contributed conceptualization, funding acquisition, investigation, methodology, project administration, resources, software, supervision, validation, and writing - review & editing. K.T. contributed investigation, methodology, validation, and writing - review & editing. S.D.L. contributed conceptualization, methodology, validation, and writing - review & editing. S.E.C. contributed conceptualization, data curation, methodology, and writing - review & editing. N.F. contributed data curation and writing - review & editing. Y.B., N.P.V., K.C., M.R.A., and J. N.C. contributed writing - review & editing.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2022.101111.

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