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Neighborhood Social Resources and Depressive Symptoms: Longitudinal Results from the Multi-Ethnic Study of Atherosclerosis

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ABSTRACT *The ways in which a neighborhood environment may affect depression and depressive symptoms have not been thoroughly explored. This study used longitudinal data from 5475 adults in the Multi-Ethnic Study of Atherosclerosis to investigate associations of time-varying depressive symptoms between 2000 and 2012 (measured using the 20-item Center for Epidemiologic Studies Depression Scale (CES-D)) with survey-based measures of neighborhood safety and social cohesion (both individual-level perceptions and neighborhood-level aggregates) and densities of social engagement destinations. Linear mixed models were used to examine associations of baseline cross-sectional associations and cumulative exposures with changes over time in CES-D. Econometric fixed effects models were utilized to investigate associations of within-person changes in neighborhood exposures with within-person changes in CES-D. Adjusting for relevant covariates, higher safety and social cohesion and greater density of social engagement destinations were associated with lower CES-D at baseline. Greater cumulative exposure to these features was not associated with progression of CES-D over 10 years. Within-person increases in safety and in social cohesion were associated with decreases in CES-D, although associations with cohesion were not statistically significant. Social elements of neighborhoods should be considered by community planners and public health practitioners to achieve optimal mental health.*

KEYWORDS *Mental health, Depressive symptoms, Neighborhoods, Social environment, Built environment*

INTRODUCTION

Depression is one of the leading causes of disease burden worldwide.[1] A growing body of research has linked mental health outcomes to specific features of the neighborhood environment.[2,3] Research examining the pathways through which neighborhood features contribute to mental well-being has identified four key domains: (1) neighborhood social and economic makeup (e.g., age, socioeconomic status (SES), housing), (2) social support between neighbors, (3) access to necessary services, and (4) presence of green spaces and access to the natural environment.[4]

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Much of the current research on neighborhoods and mental health has focused on the first two domains. Significant work has investigated how neighborhood socioeconomic conditions[5–12] are associated with depression or depressive symptoms. Similarly, other work has examined the ways in which social characteristics (e.g., social cohesion, safety)[9,13–20] may be associated with depression or depressive symptoms. Cross-sectional and longitudinal studies have found that residents of neighborhoods with higher SES,[5–12,21] greater social cohesion,[9,13,14,16,18,20] and higher levels of safety[14,15,17–19,22] have fewer depressive symptoms and are protected from onset of depression. However, most of these studies are limited by the use of exposures from only one time point, restricting their ability to examine how changes in these environments may impact changes in depression. While one study examined how changes in neighborhood conditions are related to changes in CES-D, it was limited to only one US city.[20] Additionally, questions remain around the relative importance of perceived social environments and more objective measures of social environment. Studies indicate that perceived safety may have a stronger impact on walking than actual crime.[23,24] However, less work has been done to tease apart the separate influences of perceptions and objective neighborhood characteristics on depression or depressive symptoms.

The impact of physical environments on depression and depressive symptoms has been less studied than the other domains. Qualitative research supports the idea that physical features which promote a more cohesive social environment may provide some protection against depression in adults.[4] Most of the research on the physical environment, however, has focused on physical disorder or decay[18,25,26] or neighborhood characteristics that promote walking such as land use mix, street connectivity, public transportation, and residential density,[6,26,27] summary measures of walkability,[28] or quality of built environment.[29] Physical destinations that promote social engagement (e.g., recreation centers, religious institutions, restaurants and nightclubs) are strong candidates for explaining neighborhood clustering of depressive symptoms because they provide a space for social connections. Few studies have investigated how social engagement destinations may contribute to neighborhood variation in depressive symptoms. These studies reported no association, but were limited to cross-sectional analyses within one study area.[26,30] Thus, there remains a large gap in understanding the possible impact of these types of physical resources on mental well-being.

This study investigates the longitudinal association of features of neighborhood social environment with depressive symptoms. In order to contrast the influence of individual perceptions with those of more "objective" measures (as reflected by the aggregation of the perceptions of multiple neighbors), we examine both individual-reported and aggregated neighborhood-level measures of safety and social cohesion. To illuminate the potential role of physical amenities, we investigate social engagement destinations. A major advantage over prior work is the availability of both time-varying measures of exposures and depressive symptoms in multiple locations across the USA Using a longitudinal design, we investigate how long-term exposure to these characteristics and changes in these characteristics relate to changes in depressive symptoms. We hypothesize that persons living in neighborhoods with long-term exposures to higher levels of safety, social cohesion, and social engagement destinations will have a decrease or slower increase in depressive symptoms over time. We also hypothesize that increases in these domains will be associated with reductions in depressive symptoms. We hypothesize that perceptions will have a stronger influence than aggregated neighborhood-level measures. We also hypothesize that this relationship is modified by gender.

METHODS

Sample

The Multi-Ethnic Study of Atherosclerosis (MESA) is a longitudinal study of cardiovascular disease among adults aged 45–84 years in six cities (Forsyth County, NC; New York City, NY; Baltimore, MD; St Paul, MN; Chicago, IL; and Los Angeles, CA) in the USA The study recruited 6814 participants free of a history of clinically overt cardiovascular disease at baseline. Baseline assessment was conducted from 2000 to 2002, with four follow-up exams occurring at approximately 1.5–2-year intervals through April 2012.[31] Addresses were geocoded using TeleAtlas EZ-Locate web-based geocoding software.[32] The sample was restricted to those who participated in the MESA Neighborhood Ancillary Study (N = 6191), had addresses geocoded to the street (98.5 %) or zip code + 4 (0.1 %) extension level (N = 6163), and had data available for outcome, exposures, and covariates at baseline and at least one follow-up visit (N = 5475). The study was approved by the institutional review boards at each site and all participants gave written informed consent.

Depressive symptoms

The primary outcome was participants' depressive symptoms measured using the 20-item Center for Epidemiologic Studies Depression Scale (CES-D).[33] Each scale item is scored from 0 to 3, with a higher score representing more depressive symptoms; the score range is 0–60 points. CES-D was measured at all exams except exam 2. At each visit, an inventory of medications taken within the last 2 weeks was collected and antidepressant medications were defined as those including oxidase inhibitors, SSRIs, and tricyclic antidepressants. For persons taking antidepressant medications, the CES-D score was adjusted using a nonparametric imputation based on methods used elsewhere.[34] The algorithm replaced the score of a person on antidepressants with the mean of the CES-D score of all persons also using antidepressants who had the same or higher score within gender and race/ethnicity groups to account for possible differences in medication effect. For ease of interpretation and because violations of normality did not meaningfully affect inferences,[35] CES-D was examined as a continuous variable in the original metric in all analyses.

Neighborhood measures

Neighborhood characteristics, assessed as part of the MESA Neighborhood Study, included measures of geographic information systems (GIS) social engagement destinations, and survey measures of safety and social cohesion; both individual perceptions and neighborhood measures constructed by aggregating the reports of multiple neighbors.

Individual perceptions of neighborhood safety and social cohesion were collected from questionnaires. Safety (two items) was collected in 2003–2005 as part of exam 2 or 3 and exam 5 in 2010–2012. Social cohesion (four items) was collected at baseline and exam 5.[36] For both scales, participants were asked to describe the environment within a 20-min walk (approximately 1 mile) around their home on a five-point scale ranging from "strongly agree" to "strongly disagree." Values were reverse coded as necessary such that a higher score indicates safer and more cohesive environments. The means of the responses were derived and used as the individual perceptions of neighborhood safety and social cohesion, ranging from 1 to 5. Scales had acceptable internal consistency (Cronbach alpha 0.64–0.82).

To obtain neighborhood aggregate measures of safety and social cohesion, questionnaires were administered to a random sample of residents of selected census tracts in three of the MESA study sites (Baltimore, MD; Forsyth County, NC; and New York, NY) between January and August 2004 and all six study sites between August 2011 and May 2012. To increase sample size and reliability of scale estimates, responses from this sample were pooled with the MESA respondents to obtain neighborhood aggregate measures. By averaging across individuals, a more valid measure of the objective reality of the neighborhood is obtained. Scales based on a 1-mile buffer around residential addresses were created by taking the mean of the responses for all respondents living within a 1-mile radius and who answered all questions within the domain, excluding themselves (median number of respondents = 65).

GIS-based data on social engagement destinations, hereafter called "destinations" were obtained from the National Establishment Time Series (NETS) database from Walls & Associates[37] for years 2000–2010. Based on previous work, a total of 430 Standard Industrial Classification codes were selected as locations which may facilitate social interaction and promote social engagement.[38] These destinations include: participatory entertainment and physical activity (e.g., gyms, yoga, bowling, golf); cultural/intellectual (e.g., theaters, libraries, museums/galleries, social/political clubs); restaurants and night clubs; spiritual/religious (e.g., churches, synagogues, mosques); beauty salons and barbers; and gambling or coin operated entertainment (e.g., casinos, arcades). Destinations density (number per square mile) was created using ArcGIS 10.1 for 1-mile Euclidean buffers around each residential address and linked to each exam by calendar year.

Covariates

Covariates include baseline time-invariant measures of age, gender, race/ethnicity, education, duration of residence in the neighborhood, and study site and time-varying measures of household income, marital status, and neighborhood SES. Age, race/ethnicity, gender, education, and duration of residence were obtained by interviewer-administered questionnaire at baseline. Race/ethnicity was classified as Hispanic, non-Hispanic White, non-Hispanic Chinese, and non-Hispanic Black. Education was selected from eight categories, and a continuous measure in years was derived using the midpoint of the selected category. Income and marital status were obtained via interviewer-administered questionnaire at baseline and follow-up exams. Family income was selected from 14 categories, and a continuous measure was derived using the midpoint of the selected category. Marital status was dichotomized as "currently married or living with a partner" and "other." Neighborhood SES was developed using principle factor analysis of 16 census variables, which reflected aspects of education, occupation, household income and wealth, poverty, employment, and housing from Census 2000[39] and American Community Surveys 2005-2009[40] and 2007-2011[41] as described elsewhere.[42]

To ensure that the measure of destinations density was not just a proxy for overall development density, we adjusted for population density. Population density within a 1-mile buffer was calculated based on block-level census population from US Censuses 2000[39] and 2010[43] as described elsewhere.[44] Values for exams between 2000 and 2010 were interpolated using a linear estimate.

For all time-varying measures, missing information was imputed using the value from the exam closest in time. Since changes in the environment could be attributed to relocation between visits, and thus may confound associations of interest, we included an indicator of whether the participant moved between visits.

Statistical analyses

Descriptive analyses contrasted participant characteristics, neighborhood exposures, and CES-D scores by exam. A test for trend over time was conducted using unadjusted linear regression models for continuous variables and chi-square tests for categorical variables.

Linear mixed models were used to assess the associations of baseline cross-sectional exposures with CES-D, as well as, long-term cumulative exposures with trend in CES-D over time. The time-varying cumulative exposures are defined as the mean across all months from baseline to each follow-up examination. We modeled repeat measures of CES-D as a function of time since baseline, time-varying cumulative exposures, and their interactions (to assess whether changes over time were modified by cumulative exposures). The models included a random intercept and time slope to account for within individual correlation in responses and to allow the rate of change in CES-D to vary by individual. For adjustment purposes, models also included time-invariant age at baseline, gender, race/ethnicity, education, duration in neighborhood, and study site, as well as interactions of each with time; and time-varying income, marital status, moving status and population density.

In a second set of analyses, we used econometric fixed effects models[45] to assess the association of within-person changes in neighborhood exposures with within-person changes in CES-D. This approach estimates associations between exposures and outcome using only within-person variability. In so doing, it tightly controls for person-specific characteristics. The following covariates were included for adjustment purposes: time since baseline, time-varying income, marital status, moving status and population density and interactions between time since baseline and each of the following: age at baseline, gender, race/ethnicity, education, duration in neighborhood, and study site.

First, each exposure was analyzed in separate models. To test the joint effect of destinations with safety and social cohesion, three additional models were fitted which included destinations with (1) neighborhood aggregate safety and social cohesion, (2) individual perceptions of safety and social cohesion, and (3) both neighborhood aggregate and individual perceptions of safety and social cohesion. This modeling strategy allows us to understand the independent effects of physical destinations and the social environment variables, as well as the independent effects of individual perceptions and aggregate measures. The correlation between individual and neighborhood survey measures was 0.41 for safety 0.30 for social cohesion. Gender interactions were tested for all exposures and only retained if significant at the $P = 0.1$ level. In final models, only the gender interaction for destinations was retained. All exposures were mean centered and scaled for comparison so that a one-unit change represented a standard deviation (SD) difference. All covariates were mean centered to allow for interpretation of any interactions at the sample average. Sensitivity analyses were performed stratified by site for comparison with previous work in the New York study site[20] and also subset to those in the lowest 25th percentile of social cohesion for comparison to the New York study site. Additional sensitivity analyses were performed with buffer sizes of 0.5 mile and 3 miles for social engagement destinations, subset to only those participants never taking antidepressants during the study period, and subset to only those who never moved during the study period. Results are consistent and not presented. All analyses were conducted using SAS 9.3 (Cary, NC).

RESULTS

The mean age of participants at baseline ranged from 44 to 84 years with a mean of 61.7 years (SD = 10.1) and 47 % were male (Table 1). Participants were followed for a mean of 8.1 years (SD = 2.3) with a minimum of 2.6 and maximum of 11.2. At baseline, 40 % of the sample was non-Hispanic White, 27 % non-Hispanic Black, 21 % Hispanic, and 12 % non-Hispanic Chinese. Mean years of education was 13.3 years at baseline (SD = 3.9). The number of years resided in the neighborhood at baseline was 19.1 (SD = 14.2). Family income at baseline was $50,200 and increased slightly over time. The percent of persons currently married or living with a partner decreased over follow-up from 62 to 60 %. Population density decreased from 15,623 (SD = 19,290) persons per square mile to 14,634 (SD = 18,772). On average, neighborhood aggregated safety did not change over time (mean = 3.7 (SD = 0.4) at exam 1) and social cohesion increased slightly. Individual perceptions of safety and social cohesion increased slightly over time. The destinations density increased from 90.4 (SD = 117.4) to 117.6 (SD = 166.4) per square mile. At baseline, 7.3 % of the sample was taking an antidepressant medication which increased to 11.2 % by exam 5.

On average, depressive symptoms increased over time: 1.90 points in the CES-D scale over 10 years (95 % confidence interval (CI) 1.53, 2.27) for males and 0.95 (CI 0.57, 1.32) for females (Table 2). Higher safety and social cohesion were associated with lower CES-D at baseline for both the neighborhood aggregate and individual perceptions (mean differences: neighborhood safety −0.40 CI −0.65, −0.15; neighborhood social cohesion −0.33 CI −0.60, −0.05; individual safety −0.82 CI −1.04, −0.60; individual social cohesion −0.74 CI −0.96, −0.53, "single exposure models" Table 2). Greater destinations density was associated with lower CES-D for females at baseline (mean difference −0.48 CI −0.87, −0.10) but there was no association for males (*P* for gender interaction 0.0450). Long-term cumulative exposure to destinations, social cohesion, and safety were not associated with 10-year change in CES-D.

Associations of safety and social cohesion with CES-D at baseline were attenuated but persisted after adjustments for destinations. This was true for both individual perceived and neighborhood aggregate measures of safety and social cohesion (Table 2, columns labeled "mutual"). The association of destinations with CES-D at baseline was largely unchanged after adjustment for other neighborhood social factors. When all three measures were in the same model (individual perceptions, neighborhood aggregate, and destinations), both neighborhood aggregate measures were no longer associated with CES-D but individual perceptions were (mean differences: neighborhood safety −0.02 CI −0.32, 0.28; neighborhood social cohesion −0.13 CI −0.45, −0.20; individual safety −0.64 CI −0.88, −0.41; individual social cohesion −0.60 CI −0.83, −0.38).

In the fixed effects analyses (Table 3), a one SD unit within-person increase in individual perception of safety was associated with a 0.46-point decrease in CES-D (CI −0.66, −0.25) in the single variable models. Increases in individual perceptions of social cohesion were also associated with decreases in CES-D but the association was not statistically significant (−0.14 (CI −0.30, 0.02)). Neighborhood aggregate

TABLE 1 Selected characteristics of participants at baseline and follow-up exams. Multi-ethnic Study of Atherosclerosis, 2000–2012

	Exam 1	Exam 3	Exam 4	Exam 5	*P* for change over 10 years[a]
Sample (*N*)	5475	5149	4771	3790	
Time elapsed since baseline in years (mean (SD))	–	3.2 (0.3)	4.8 (0.3)	9.4 (0.5)	
Age (Mean (SD))	61.7 (10.1)	65.0 (10.0)	66.5 (9.9)	69.9 (9.4)	
Gender—male (%)	47.0 %	47.0 %	46.5 %	46.3 %	
Race/ethnicity (%)					
Non-Hispanic White	39.7 %	40.1 %	40.6 %	42.0 %	
Non-Hispanic Black	27.2 %	27.2 %	26.5 %	26.1 %	
Non-Hispanic Chinese	12.1 %	12.0 %	12.0 %	11.9 %	
Hispanic	20.9 %	20.6 %	20.9 %	20.0 %	
Length of time in neighborhood at baseline in years (mean (SD))	19.1 (14.2)	19.2 (14.2)	19.3 (14.1)	18.9 (13.6)	
Years of education (mean (SD))	13.3 (3.9)	13.3 (3.9)	13.3 (3.9)	13.6 (3.8)	
Family income (per $1000 mean (SD))	50.2 (34.2)	50.0 (34.6)	50.6 (34.8)	54.9 (35.6)	0.0004
Currently married/living with a partner (%)	62.4 %	62.1 %	63.0 %	60.2 %	0.0637
Moved since baseline (%)	–	10.4 %	16.2 %	23.6 %	<0.0001
Population density per square mile (mean (SD))	15622.9 (19290.0)	15528.0 (19338.4)	15509.5 (19366.9)	14634.4 (18771.5)	<0.0001
Study site (%)					
Forsyth County, NC	16.3 %	16.4 %	15.7 %	17.6 %	
New York, NY	16.4 %	16.4 %	16.6 %	15.8 %	
Baltimore, MD	15.1 %	14.9 %	15 %	13.9 %	
St Paul, MN	15.7 %	15.9 %	16 %	16.7 %	
Chicago, IL	17.8 %	17.9 %	18.2 %	19.8 %	
Los Angeles County, CA	18.8 %	18.4 %	18.6 %	16.1 %	
Neighborhood exposures					
Neighborhood-level safety scale (mean (SD)) [b]	3.66 (0.42)	3.67 (0.42)	3.66 (0.49)	3.70 (0.51)	0.0778
Neighborhood-level social cohesion scale (mean (SD))[b]	3.54 (0.26)	3.55 (0.27)	3.57 (0.31)	3.61 (0.32)	<0.0001
Individual perceived safety scale (mean (SD))[c]	3.76 (0.78)	3.76 (0.77)	3.76 (0.78)	3.83 (0.81)	<0.0001

TABLE 1 ***Continued***

	Exam 1	Exam 3	Exam 4	Exam 5	*P* for change over 10 years[a]
Individual perceived social cohesion scale (mean (SD))[c]	3.57 (0.57)	3.57 (0.57)	3.63 (0.58)	3.68 (0.58)	<0.0001
Density of social engagement destinations (mean (SD))[d]	90.4 (117.4)	98.9 (129.7)	110.3 (146.0)	117.6 (166.4)	<0.0001
Outcome					
Taking antidepressant (%)	7.3 %	9.2 %	9.9 %	11.2 %	<0.0001
CES-D[e] (mean (SD))	8.0 (7.9)	8.3 (8.4)	8.6 (8.6)	9.0 (8.2)	<0.0001

[a] *P* value for time-varying measures from unadjusted linear mixed regression model for continuous variables; chi-square for categorical variables

[b] Crude mean of respondents within 1 mile of participant based on questionnaire. Higher score indicates a better environment. Range 1–5

[c] Based on questionnaire. Higher score indicates a better environment. Range 1–5

[d] GIS-based density is count per square mile within a 1-mile buffer

[e] CES-D score adjusted for medication use using nonparametric method

TABLE 2 **Mean difference (95 % confidence interval (CI)) in CES-D at baseline and mean differences in 10-year change in CES-D associated with cumulative neighborhood exposures. Multi-ethnic Study of Atherosclerosis, 2000–2012**

		Single exposure models[a]	Mutual neighborhood-level[b] + GIS-based social engagement	Mutual individual-level[c] + GIS-based social engagement	Fully adjusted[d]
		Mean difference (95 % CI)	Mean difference (95 % CI)	Mean difference (95 % CI)	Mean difference (95 % CI)
Neighborhood-level safety[e]	Difference in CES-D at baseline	−0.40 (−0.65, −0.15)*	−0.28 (−0.57, 0.02)^		−0.02 (−0.32, 0.28)
	Difference in 10-year change in CES-D	0.23 (−0.05, 0.50)	0.14 (−0.20, 0.48)		0.27 (−0.10, 0.64)
Neighborhood-level social cohesion[e]	Difference in CES-D at baseline	−0.33 (−0.60, −0.05)*	−0.20 (−0.52, 0.13)		−0.13 (−0.45, 0.20)
	Difference in 10-year change in CES-D	0.25 (−0.06, 0.56)	0.17 (−0.21, 0.56)		0.19 (−0.19, 0.58)
Individual-level safety[e]	Difference in CES-D at baseline	−0.82 (−1.04, −0.60)*		−0.67 (−0.90, −0.44)*	−0.64 (−0.88, −0.41)*
	Difference in 10-year change in CES-D	−0.11 (−0.41, 0.18)		−0.07 (−0.38, 0.24)	−0.21 (−0.55, 0.14)
Individual-level social cohesion[e]	Difference in CES-D at baseline	−0.74 (−0.96, −0.53)*		−0.62 (−0.84, −0.39)*	−0.60 (−0.83, −0.38)*
	Difference in 10-year change in CES-D	−0.20 (−0.51, 0.11)		−0.16 (−0.48, 0.17)	−0.18 (−0.51, 0.14)
GIS-based social engagement destinations[f]	Female: difference in CES-D at baseline	−0.48 (−0.87, −0.10)*	−0.45 (−0.85, −0.05)*	−0.40 (−0.79, −0.01)*	−0.42 (−0.82, −0.03)*
	Male: difference in CES-D at baseline	−0.08 (−0.48, 0.32)	−0.06 (−0.47, 0.35)	−0.05 (−0.46, 0.35)	−0.08 (−0.49, 0.33)
	Female: difference in 10-year change	0.17 (−0.22, 0.55)	0.15 (−0.24, 0.55)	0.19 (−0.19, 0.58)	0.16 (−0.24, 0.55)

TABLE 2 ***Continued***

	Single exposure models[a]	Mutual neighborhood-level[b] + GIS-based social engagement	Mutual individual-level[c] + GIS-based social engagement	Fully adjusted[d]
	Mean difference (95 % CI)	Mean difference (95 % CI)	Mean difference (95 % CI)	Mean difference (95 % CI)
in CES-D				
Male: difference in 10 year change in CES-D	−0.26 (−0.64, 0.13)	−0.27 (−0.66, 0.13)	−0.24 (−0.63, 0.15)	−0.27 (−0.66, 0.12)

*$P < 0.05$; ^$P < 0.10$

Linear mixed effects models with random effects for person-level intercept and time slope. All models are adjusted for time-invariant baseline age, education, years lived in neighborhood, race/ethnicity, and gender and interactions of each with time and time-varying income, marital status, moving status, study site, and population density. Overall estimates from models without gender interactions; gender specific estimates from models with exposure and time by gender interactions. Mean change in CES-D over 10 years is 0.95 (0.57, 1.32) for females, 1.90 (1.53, 2.27) for males

[a]Each exposure in separate models

[b]Social engagement destinations and neighborhood-level safety and social cohesion modeled jointly

[c]Social engagement destinations and individual-level safety and social cohesion modeled jointly

[d]Social engagement destinations and neighborhood-level and individual-level safety and social cohesion modeled jointly

[e]For a 1 standard deviation increase in exposure

[f]Density per square mile within a 1-mile buffer; for a 1 standard deviation increase. *P* values for gender interactions: Single exposure model baseline = 0.045, cumulative average = 0.045; Mutual neighborhood-level model baseline = 0.056, cumulative average = 0.050; Mutual individual-level model baseline = 0.085, cumulative average = 0.042; Fully adjusted model baseline = 0.087, cumulative average = 0.046

TABLE 3 Mean changes in CES-D associated with within-person changes in exposures[a], Multi-Ethnic Study of Atherosclerosis, 2000–2012

		Single exposure models[b]	Mutual neighborhood-level[c]	Mutual individual-level[d]	Fully adjusted[e]
		Mean change (95 % CI)	Mean change (95 % CI)	Mean change (95 % CI)	Mean change (95 % CI)
Neighborhood-level safety[f]		−0.01 (−0.22, 0.20)	−0.11 (−0.35, 0.13)		−0.08 (−0.32, 0.16)
Neighborhood-level social cohesion[f]		0.11 (−0.05, 0.28)	0.15 (−0.04, 0.34)		0.16 (−0.03, 0.35)^
Individual-level safety[f]		−0.46 (−0.66, −0.25)*		−0.44 (−0.64, −0.24)*	−0.44 (−0.64, −0.24)*
Individual-level social cohesion[f]		−0.14 (−0.30, 0.02)^		−0.09 (−0.26, 0.07)	−0.10 (−0.26, 0.07)
Social engagement destinations[g]	Female	0.31 (−0.25, 0.86)	0.31 (−0.25, 0.86)	0.30 (−0.25, 0.86)	0.30 (−0.26, 0.86)
	Male	−0.38 (−0.99, 0.23)	−0.37 (−0.99, 0.24)	−0.37 (−0.98, 0.24)	−0.36 (−0.98, 0.25)

*$P < 0.05$; ^$P < 0.10$

[a]Estimated from econometric fixed effects models adjusted for time-invariant baseline age, education, years lived in neighborhood, race/ethnicity, study site, and gender interactions with time and time-varying income, marital status, moving status, and population density

[b]Each exposure in separate models

[c]Social engagement destinations and neighborhood-level safety and social cohesion modeled jointly

[d]Social engagement destinations and individual-level safety and social cohesion modeled jointly

[e]Social engagement destinations and neighborhood-level and individual-level safety and social cohesion modeled jointly

[f]For a 1 standard deviation increase in exposure

[g]Density per square mile within a 1-mile buffer; for a 1 standard deviation increase. *P* values for gender interactions: Single exposure model = 0.051; Mutual neighborhood-level model = 0.054; Mutual individual-level model = 0.057; Fully adjusted model = 0.060

safety, social cohesion, and destinations density were not significantly associated with within-person changes in CES-D. When mutually adjusting for individual perceptions of safety, social cohesion, and destinations, the associations remained largely unchanged.

DISCUSSION

In this multi-ethnic and geographically diverse sample, higher levels of safety and social cohesion (both individual perceptions and neighborhood aggregate measures) as well as higher levels of destinations were cross-sectionally associated with lower depressive symptoms (measured using CES-D). In mutually adjusted models, neighborhood aggregate measures of safety and social cohesion and destinations density remained associated with CES-D in the expected directions, but only the individual perceptions remained significantly associated with CES-D. On average, depressive symptoms increased over time in this sample. This increase was not modified by cumulative exposures to social environments. However, within-person increases in individual perceptions of safety and social cohesion over time were associated with decreases in depressive symptoms, although the association with social cohesion was not statistically significant. Changes in availability of destinations were not associated with changes in CES-D.

Our results were consistent with previous cross-sectional work which found that higher levels of perceived safety[14,15,17–19] and social cohesion[9,13,14,16–18] are associated with lower levels of depression prevalence and depressive symptoms. In models in which individual perceptions and neighborhood aggregated measures were adjusted for each other, only individual perceptions remained associated with CES-D. This is consistent with literature on safety and crime on walking[23,24] and highlights the importance of perceptions in mediating the impact of at least some neighborhood social factors. This suggests that how a person perceives their neighborhood may be especially important to CES-D, although it also raises the possibility of same source bias or reverse causation.

Little prior work has examined longitudinal associations of neighborhood social characteristics with changes in depressive symptoms. Our null findings regarding associations of cumulative exposure to social environments with trends over time in CES-D are consistent with previous work showing no relationship between a time-invariant neighborhood-level social environment score (safety, social cohesion) with incident depression.[14] This may be due to the greater importance of other, more proximal, influences on mental health. Alternatively, it is possible that individuals adjust to their long-term social environments and are thus only influenced by shorter-term changes. More work should attempt to tease apart the appropriate time frame and pathways linking neighborhood social environments to mental health.

In the fixed effects models, we did find that those experiencing short-term increases in individual perceived safety also experienced reductions in depressive symptoms, while individual social cohesion showed a marginal association in the expected direction. In prior work, we reported that neighborhood changes in safety, social cohesion, and aesthetic environment were related to simultaneous decreases in CES-D over a 7-year period at one of the MESA sites (New York) although findings were not statistically significant.[20] In these analyses including all MESA sites, changes in aggregate measures of safety were associated with changes in CES-D in the expected direction but associations were not statistically significant. Increases in social cohesion were associated with changes in CES-D were in the opposite direction, although not statistically significant. When we subset analyses to the New York site (not shown), the associations observed were consistent with those previously reported. This may be due to differences in initial starting levels of social cohesion as the social cohesion score was lower in New York at baseline (3.26) than the other sites (3.50–3.81). This is consistent with sensitivity analyses in other sites restricted to individuals reporting social cohesion below the 25th percentile, which showed results consistent to those previously reported (not shown). Changes that occur where social cohesion is initially lower may be more impactful on improving depressive symptoms than changes when cohesion is already high.

While previous work has identified destinations as an aspect of the physical environment that may link neighborhoods to mental well-being,[4] little work has been done using objective, GIS-based measures to examine this pathway. Cross-sectional studies investigating associations of the built environment with depressive symptoms have had mixed results with some reporting that higher walkability index,[28] urban density, and accessibility of public transport[26] are associated with lower depressive symptoms, while others found that land use mix, especially percent devoted to retail,[27] and quality of built environment[29] are associated with higher depressive symptoms. We focused on a measure of the physical environment that may be more directly related to social interactions. The destinations may be providing a space for individuals to interact with their friends and family, enabling them to maintain good mental health, or they may be acting as buffers, reducing the impact of negative life events by providing healthy coping mechanisms. Because destinations density is likely to be high in areas of dense development overall, which may be related to depression for other reasons, adjustment for overall density is important. Although other studies found no association with destinations with depressive symptoms,[26] we found that cross-sectional associations of destinations with CES-D differed by gender: a greater density of destinations was associated with lower CES-D score in females but not in males. This is consistent with previous work reporting that the associations of socioeconomic status[9,14] and overall walkability[28] with depressive symptoms differed by gender. However, there was no evidence that within-person changes in exposure to destinations resulted in changes in CES-D, raising the possibility that cross-sectional associations may be confounded.

Limitations and strengths

Destinations densities were based on commercial data and did not take into account quality, hours of operation, or cost. We also did not have information on whether the participants were using these destinations. Previous studies have examined the quality of commercial databases that suggest that there may be measurement error in facility counts.[38] Information on the relevant buffer size for these destinations is unknown. We used a 1-mile buffer size to correspond with the survey responses for safety and social cohesion. Results were not substantively different in sensitivity analysis with 0.5-mile or 3-mile buffers. The survey-based measures (both individual perceived and neighborhood aggregate) were only available for the sample at two time points. The assignment of these measures of the available data closest in time to visits where data was unavailable could lead to misspecification of the environment and reduce the amount of potential change that is actually occurring in these measures that we were unable to capture. Analyses performed using the two visits contemporaneous in time with the survey measures (exams 3 and 5) resulted in similar associations (data not shown).

We cannot rule out residual confounding due to unmeasured covariates although fixed effects rule out confounding by time-invariant person-specific factors. Loss to follow-up may lead to bias if differential by neighborhood social environment and depression. Although this study used a multi-ethnic and geographically diverse sample, it may not be generalizable to younger populations or those in other locations.

An important strength of our study is the rich longitudinal data across multiple sites and race/ethnic groups with information on multiple neighborhood measures over time. The analytical strategy we used allowed us to contrast the associations of CES-D with long-term cumulative exposures and short-term changes in exposures. The cumulative average models we used illustrate the associations of long-term trajectories with trends in CES-D, while the fixed effects models examine the associations of short-term changes in the environment with CES-D. Our work suggests that the change itself, especially for perceived safety, may have a larger impact on depressive symptoms than long-term stable exposures.

CONCLUSION

We found evidence that higher levels of perceptions of safety and social cohesion, and higher destinations densities were cross-sectionally associated with lower depressive symptoms. Within-person increases in safety and (although not statistically significant) in social cohesion were associated with decreases in depressive symptoms. While a myriad of factors may influence mental health, this work suggests that features of residential environments deserve further consideration.

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REFERENCES

1. WHO. *The global burden of disease. 2004 update*. World Health Organization (WHO), Geneva, Switzerland; 2008.
2. Blair A, Ross NA, Gariepy G, Schmitz N. How do neighborhoods affect depression outcomes? A realist review and a call for the examination of causal pathways. *Soc Psychiatry Psychiatr Epidemiol*. 2014; 49(6): 873–887.

3. Mair C, Diez Roux AV, Galea S. Are neighbourhood characteristics associated with depressive symptoms? A review of evidence. *J Epidemiol Community Health*. 2008; 62(11): 940–946. 948 p following 946.
4. O'Campo P, Salmon C, Burke J. Neighbourhoods and mental well-being: what are the pathways? *Health Place*. 2009; 15(1): 56–68.
5. Beard JR, Cerdá M, Blaney S, Ahern J, Vlahov D, Galea S. Neighborhood characteristics and change in depressive symptoms among older residents of New York City. *Am J Public Health*. 2009; 99(7):1308–14. doi:10.2105/AJPH.2007.125104.
6. Galea S, Ahern J, Nandi A, Tracy M, Beard J, Vlahov D. Urban neighborhood poverty and the incidence of depression in a population-based cohort study. *Ann Epidemiol*. 2007; 17(3): 171–179.
7. Gary-Webb TL, Baptiste-Roberts K, Pham L, et al. Neighborhood socioeconomic status, depression, and health status in the Look AHEAD (Action for Health in Diabetes) study. *BMC Public Health*. 2011; 11(1): 349.
8. Aneshensel CS, Wight RG, Miller-Martinez D, Botticello AL, Karlamangla AS, Seeman TE. Urban neighborhoods and depressive symptoms among older adults. *J Gerontol Ser B Psychol Sci Soc Sci*. 2007; 62(1): S52–S59.
9. Bassett E, Moore S. Gender differences in the social pathways linking neighborhood disadvantage to depressive symptoms in adults. *PLoS One*. 2013; 8(10): e76554.
10. Albor C, Uphoff EP, Stafford M, Ballas D, Wilkinson RG, Pickett KE. The effects of socioeconomic incongruity in the neighbourhood on social support, self-esteem and mental health in England. *Soc Sci Med*. 2014; 111: 1–9.
11. King K, Ogle C. Negative life events vary by neighborhood and mediate the relation between neighborhood context and psychological well-being. *PLoS One*. 2014; 9(4): e93539.
12. Wee LE, Yong YZ, Chng MW, et al. Individual and area-level socioeconomic status and their association with depression amongst community-dwelling elderly in Singapore. *Aging Ment Health*. 2014; 18(5): 628–641.
13. Gary TL, Stark SA, LaVeist TA. Neighborhood characteristics and mental health among African Americans and whites living in a racially integrated urban community. *Health Place*. 2007; 13(2): 569–575.
14. Mair C, Diez Roux AV, Shen M, et al. Cross-sectional and longitudinal associations of neighborhood cohesion and stressors with depressive symptoms in the multiethnic study of atherosclerosis. *Ann Epidemiol*. 2009; 19(1): 49–57.
15. Ziersch AM, Baum FE, MacDougall C, Putland C. Neighbourhood life and social capital: the implications for health. *Soc Sci Med*. 2005; 60(1): 71–86.
16. Bassett E, Moore S. Social capital and depressive symptoms: the association of psychosocial and network dimensions of social capital with depressive symptoms in Montreal Canada. *Soc Sci Med*. 2013; 86: 96–102.
17. Roh S, Jang Y, Chiriboga DA, Kwag KH, Cho S, Bernstein K. Perceived neighborhood environment affecting physical and mental health: a study with Korean American older adults in New York City. *J Immigr Minor Health*. 2011; 13(6): 1005–1012.
18. Mair C, Diez Roux AV, Morenoff JD. Neighborhood stressors and social support as predictors of depressive symptoms in the Chicago Community Adult Health Study. *Health Place*. 2010; 16(5): 811–819.
19. Wilson-Genderson M, Pruchno R. Effects of neighborhood violence and perceptions of neighborhood safety on depressive symptoms of older adults. *Soc Sci Med*. 2013; 85: 43–49.
20. Mair C, Diez Roux AV, Golden SH, Rapp S, Seeman T, Shea S. Change in neighborhood environments and depressive symptoms in New York City: the Multi-Ethnic Study of Atherosclerosis. *Health Place*. 2015; 32: 93–98.
21. Mair C, Diez Roux AV, Osypuk TL, Rapp SR, Seeman T, Watson KE. Is neighborhood racial/ethnic composition associated with depressive symptoms? The multi-ethnic study of atherosclerosis. *Soc Sci Med*. 2010; 71(3): 541–550.

22. Hernandez R, Kershaw KN, Prohaska TR, Wang PC, Marquez DX, Sarkisian CA. The cross-sectional and longitudinal association between perceived neighborhood walkability characteristics and depressive symptoms in older Latinos: the "inverted exclamation markCaminemos!" study. *J Aging Health*. 2015; 27(3): 551–568.
23. Evenson KR, Block R, Diez Roux AV, McGinn AP, Wen F, Rodriguez DA. Associations of adult physical activity with perceived safety and police-recorded crime: the Multi-Ethnic Study of Atherosclerosis. *Int J Behav Nutr Phys Act*. 2012; 9: 146.
24. Kerr Z, Evenson KR, Moore K, Block R, Diez Roux AV. Changes in walking associated with perceived neighborhood safety and police-recorded crime: the multi-ethnic study of atherosclerosis. *Prev Med*. 2015; 73: 88–93.
25. Latkin CA, Curry AD. Stressful neighborhoods and depression: a prospective study of the impact of neighborhood disorder. *J Health Soc Behav*. 2003; 44(1):34–44.
26. Melis G, Gelormino E, Marra G, Ferracin E, Costa G. The effects of the urban built environment on mental health: a cohort study in a large Northern Italian city. *Int J Environ Res Public Health*. 2015; 12(11): 14898–14915.
27. Saarloos D, Alfonso H, Giles-Corti B, Middleton N, Almeida OP. The built environment and depression in later life: the health in men study. *Am J Geriatr Psychiatr*. 2011; 19(5): 461–470.
28. Berke EM, Gottlieb LM, Moudon AV, Larson EB. Protective association between neighborhood walkability and depression in older men. *J Am Geriatr Soc*. 2007; 55(4): 526–533.
29. Galea S, Ahern J, Rudenstine S, Wallace Z, Vlahov D. Urban built environment and depression: a multilevel analysis. *J Epidemiol Community Health*. 2005; 59(10): 822–827.
30. Kubzansky LD, Subramanian S, Kawachi I, Fay ME, Soobader M-J, Berkman LF. Neighborhood contextual influences on depressive symptoms in the elderly. *Am J Epidemiol*. 2005; 162(3): 253–260.
31. Bild DE, Bluemke DA, Burke GL, et al. Multi-ethnic study of atherosclerosis: objectives and design. *Am J Epidemiol*. 2002; 156(9): 871–881.
32. TeleAtlas. USA_Geo_002 (Documentation for TeleAtlas products using Dynamap line files. Available at: http://www.geocode.com/documentation/USA_Geo_002.pdf. Accessed 8 Mar 2008.
33. Radloff L. The CES-D scale: a self-report depression scale for research in the general population. *Appl Psychol Meas*. 1977; 1: 385–401.
34. Hek K, Demirkan A, Lahti J, et al. A genome-wide association study of depressive symptoms. *Biol Psychiatry*. 2013; 73(7): 667–678.
35. Lumley T, Diehr P, Emerson S, Chen L. The importance of the normality assumption in large public health data sets. *Annu Rev Public Health*. 2002; 23: 151–169.
36. Mujahid MS, Diez Roux AV, Morenoff JD, Raghunathan T. Assessing the measurement properties of neighborhood scales: from psychometrics to ecometrics. *Am J Epidemiol*. 2007; 165(8): 858–867.
37. Walls & Associates L. National Establishment Time-Series (NETS) Database: database description. Available at: www.youreconomy.org/nets/NETSDatabaseDescription.pdf. Accessed 23 Jul 2008.
38. Hoehner CM, Schootman M. Concordance of commercial data sources for neighborhood-effects studies. *J Urban Health*. 2010; 87(4): 713–725.
39. Bureau of the Census USDoC. *Year 2000 STF1 and STF3*. Washington DC: Bureau of the Census; 2000.
40. Bureau of the Census USDoC. *American Community Survey 5-year small area estimates 2005–2009*. Washington DC: Bureau of the Census; 2010.
41. Bureau of the Census USDoC. *American Community Survey 5-year small area estimates 2007–2011*. Washington DC: Bureau of the Census; 2012.

42. Moore K, Diez Roux AV, Auchincloss A, et al. Home and work neighbourhood environments in relation to body mass index: the Multi-Ethnic Study of Atherosclerosis (MESA). *J Epidemiol Community Health*. 2013; 67(10): 846–853.
43. Bureau of the Census USDoC. *Year 2010 STF1*. Washington DC: Bureau of the Census; 2010.
44. Hirsch JA, Moore KA, Clarke PJ, et al. Changes in the built environment and changes in the amount of walking over time: longitudinal results from the multi-ethnic study of atherosclerosis. *Am J Epidemiol*. 2014; 180(8): 799–809.
45. Allison P. *Fixed effects regression methods for longitudinal data using SAS*. Cary, NC: SAS Institute Inc; 2005.