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Associations between neighborhood characteristics and depression: a twin study

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Abstract

Background—Depression is an important contributor to the global burden of disease. Besides several known individual level factors that contribute to depression, there is growing recognition that neighborhood environment can also profoundly affect mental health. This study assessed associations between three neighborhood constructs – socioeconomic deprivation, residential instability, and income inequality – and depression among adult twin pairs. The twin design is used to examine the association between neighborhood constructs and depression, controlling for selection factors (i.e., genetic and shared environmental factors) that have confounded purported associations.

Methods—We used multilevel random-intercept Poisson regression among 3738 same-sex twin pairs from a community-based twin registry to examine the association between neighborhood constructs and depression. The within-pair association controls for confounding by genetic and environmental factors shared between twins within a pair, and is the main parameter of interest.

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Contributors: HCC and GD formulated the original research questions and designed the study. HCC and GD were responsible for and provided the data. Critical input from WB, SAAB, JW, and RM refined the research questions, methods, and analyses as part of HCC's doctoral dissertation. HCC analyzed the data with guidance from JW and a consultant. HCC drafted the manuscript with critical input and feedback on all aspects of data interpretation and subsequent manuscript versions from all authors.

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Models were adjusted for individual-level income, education, and marital status, and further by neighborhood-level population density.

Results—When twins were analyzed as individuals (between twin association), all neighborhood constructs were significantly associated with depression. However, only neighborhood socioeconomic deprivation showed a significant within-pair association with depression. A ten-unit within-pair difference in neighborhood socioeconomic deprivation was associated with 6 percent greater depressive symptoms (1.06, 95% CI: 1.01, 1.11); the association did not substantially change in adjusted models.

Conclusion—This study provides new evidence linking neighborhood socioeconomic deprivation with greater depression. Future studies should employ longitudinal designs to better test social causation versus social selection.

INTRODUCTION

Depression is a considerable public health problem. Among adults in the U.S., the prevalence of diagnosed depression is approximately 8%, and antidepressants are the most frequently prescribed drug.[1–4] Healthcare utilization and loss of productivity due to depression cost society up to $97 billion annually.[1]

It is well accepted that individual-level factors such as socioeconomic status and social isolation influence depressive symptoms by affecting behaviors, moods, and neuroendocrine stress responses, and by modifying gene expression through epigenetic processes.[56] There is, however, growing recognition that neighborhood-level characteristics also contribute to poor mental health risk, independent of individual-level characteristics.[7] Three neighborhood constructs of particular interest are socioeconomic deprivation, residential instability, and income inequality.

These constructs affect mental health through multiple pathways. Neighborhood socioeconomic deprivation may lead to negative perceptions of neighborhood quality and fear of crime and victimization, preventing the creation of social ties,[89] and can impact the quality of neighborhood infrastructure and local amenities including parks and recreation facilities and healthcare services.[10–12] Similar to neighborhood deprivation, residential instability, or the extent to which residents remain in the neighborhood over time, may impede the formation of social ties.[913] Income inequality, defined as an unequal distribution of income among a population, decreases the public services and amenities offered if those with higher incomes withdraw from participation in such services; decreases the sense of civic fairness and justice; and increases perceived loss of autonomy and helplessness in the face of obstacles, discrimination, and victimization.[1415]

Despite positive findings in previous studies, support for the association between these neighborhood factors and mental health outcomes is limited by concerns of bias due to individual self-selection into neighborhoods. Traditional observational studies address this concern by explicitly measuring and adjusting for variables that are thought to drive self-selection; however, it is not possible to measure all variables associated with selection into neighborhoods.[16] Because residential self-selection can be driven by genetic and childhood

upbringing factors,[17] the twin study design partially addresses this bias.[18] Twins reared together share both their genes and their upbringing, but are frequently discordant in behavior and location of residence in later life. It is therefore possible to investigate associations between neighborhood characteristics and health outcomes while controlling for much of the confounding that would otherwise limit inference in an observational study among unrelated individuals.[1819]

The aim of this study was to examine the associations between depression and neighborhood deprivation, residential instability, and income inequality, controlling for confounding by shared genetic and childhood environment factors. We hypothesized that more advantaged neighborhood characteristics would be associated with less depressive symptoms.

METHODS

Participants

This study used a cross-sectional analysis of data from the Washington State Twin Registry (formerly the University of Washington Twin Registry), a community-based sample of adult twins who had been raised together. Construction of the registry has been described elsewhere.[20] Briefly, each twin completes a recruitment survey upon enrollment, and a follow-up survey providing information on sociodemographic, lifestyle behavior, and physical and mental health-related outcomes. Additionally, each twin's residential address is geocoded and linked to a variety of environmental factors. All procedures were reviewed and approved by the university's institutional review board.

All twins in the study were from same-sex pairs. Using standard questions about childhood similarity, twins were categorized as either identical (monozygotic, MZ) or fraternal (dizygotic, DZ). Compared to DNA-based methods, these questions have been shown to have greater than 90% accuracy at identifying zygosity.[21]

A total of 7476 twins (3738 pairs) were included in the study. The majority (70%) were MZ twins. Most lived in Washington State (74%); however, twins lived in the District of Columbia and all 50 states except Delaware. Approximately 78 percent of twins lived in a different census tract from their cotwin.

Exposure Measures

All neighborhood exposures were measured at the census tract level. Neighborhood socioeconomic deprivation was measured by the Singh Index, which used principal components analysis to combine 2010 census data on education, employment, income and income disparity, poverty, characteristics of the home, and home, vehicle, and telephone ownership.[22] Greater deprivation is represented by higher index scores.

Both residential instability and income inequality were derived from the 2010 American Community Survey (ACS) five-year estimates. Residential instability was operationalized as the percentage of the population in a given census tract who had moved into owner-occupied units within the previous five years. Income inequality was measured by the Gini index. The

Gini index ranges from 0 to 1; higher values represent more unequal distributions where the majority of income is earned by a small proportion of the population.

Because of the considerable difference in scale between the outcome measure and neighborhood deprivation and residential instability, the two neighborhood exposures were rescaled for the analysis (divided by 10).

Outcome Measure

Depression was measured by the 2-item Patient Health Questionnaire (PHQ-2).[23] The PHQ-2 is a shorter version of the 9-item scale (PHQ-9), and measures self-reported depressive symptoms through questions about the two cardinal symptoms from the PHQ-9: depressed mood and the inability to experience pleasure. Respondents were asked how often in the last 4 weeks they had been bothered by either symptom (0 not at all; 1 several days; 2 more than half the days; 3 nearly every day). Responses were then summed to create a scale of symptom severity. The measure has been validated in other populations using the DSM-IV as the gold standard, and has shown substantial rater agreement when compared to a mental health professional interview ($\kappa = 0.62$).[23] While the longer 9-item scale is more commonly used in research on neighborhood effects,[24] the PHQ-2 has shown acceptable validity compared to the PHQ-9.[25]

Covariates

Traditional confounders of age, sex, and race/ethnicity are inherently controlled for in the twin model, and so not included as covariates in this analysis, except as potential effect modifiers in sensitivity analysis described below. At the individual-level, we decided *a priori* to include annual household income, education, and marital status. At the census tract level, we included population density (people/square mile).

Statistical analysis

To evaluate associations between the neighborhood exposures and depressive symptoms, we used a multi-level random intercept model with the outcome modeled as a Poisson distribution. This is a particular case of the non-linear mixed effects model. Random intercepts at the census tract and twin-pair level were included to account for the correlation between twins within a pair and between individuals within the same census tract.

We first estimated the phenotypic association by regressing depression on the neighborhood exposures, treating each individual as a singleton instead of a member of a twin pair. This model assumes that the average difference in outcome associated with a given difference in exposure is the same for twins within a pair as for unrelated individuals. Thus, although the model accounts for the correlation in the data through the use of random intercepts for twin pair and Census tract, it does not provide the within-pair estimates that inherently adjust for shared genetic and environmental characteristics.

Second, to estimate the within-pair associations, we used the model shown in equation 1:[26]

$$\log(\lambda_{ij}) = \beta_0 + \beta_B * x_i + \beta_W * (x_{ij} - x_i) + \beta_3 * g_z + \beta_4 * g_z * (x_{ij} - x_i) + \mu_{k[ij]} + \mu_I; \quad (1)$$

where y_{ij} represents the risk of depression for twin *j* in pair *i* as a function of the mean neighborhood exposure of twin-pair *i*, x_i, and each individual twin's deviation from their twin-pair mean, $(x_{ij} - x_i)$. Pair zygosity, g_z, is coded 0 for MZ twins and 1 for DZ twins, and $\mu_{k[ij]}$ and μ_i are random intercepts for census tract and twin pair, respectively.

Due to the nature of the twin model, the within-pair association for MZ twins (β_W) is not subject to confounding by genetic or shared childhood environment factors. When exponentiated, it can be interpreted as the ratio of depressive symptoms associated with a one-unit difference in neighborhood exposure within a MZ twin pair, conditional on the mean neighborhood exposure of the twin-pair. The between-pair coefficient, β_B, represents the extra variation in depression due to differences between twin pairs.

The inclusion of an interaction term for zygosity can assist in making inferences about genetic confounders. The within-pair difference for MZ twins is β_W; for DZ twins it is $\beta_W + \beta_4$. Because MZ twins share all their genes and DZ twins share only half their genes, if the within-pair association for MZ twins is significantly different from that for DZ twins ($\beta_4 \neq 0$), this is suggestive of genetic confounding in the observed association. If the two within-pair associations were not significantly different, however, we removed zygosity from the model, simplifying the model to equation 2:[27]

$$\log(\lambda_{ij}) = \beta_0 + \beta_B * x_i + \beta_W * (x_{ij} - x_i) + \mu_{k[ij]} + \mu_i. \quad (2)$$

In this instance, however, we still present results stratified by zygosity in addition to the main results of Equation 2.

We first regressed depression only on the neighborhood exposure (Model A). Each subsequent model included the potential confounders; first the individual-level covariates of income, education, and marital status (Model B); and then these individual-level covariates as well as neighborhood-level population density (Model C). Models were fit using the lme4 package in R.[28]

We conducted two sensitivity analyses to further explore the association between these neighborhood characteristics and depression. First, for any neighborhood characteristics that showed a statistically significant within-pair association with depression, we used interaction terms to test age (years) and sex (male/female) as effect modifiers. There are substantial differences in the prevalence of depression by both age and sex, and so we wanted to explore the potential for the association between various neighborhood characteristics and depression to vary based on these factors.

Second, we conducted the same analysis limited to twins who were discordant for depression. We defined this as twins who had a within-pair difference in PHQ-2 score of at

least 3 (N=318 individuals, 159 pairs). A score of 3 or greater on the PHQ-2 is commonly used to indicate depression; limiting to twins with a within-pair difference of at least 3 results in a study sample where one twin would be categorized as depressed and the other would not.

RESULTS

Table 1 gives select characteristics of the 7476 twins included in the study. The majority were female (66%), and the study sample was overwhelmingly non-Hispanic White (92%). Most respondents had greater than a high school education (82%) and were married or living with a partner (56%). Eight percent of the sample scored a three or greater on the PHQ-2, indicating the presence of diagnosable depression. Approximately 14% of the sample moved residential locations within the past 5 years.

Phenotypic models

All neighborhood exposures were significantly associated with depressive symptoms in the phenotypic models (data not shown). The interaction terms with zygosity were not significant, and were removed from the models. A ten-unit difference in Singh Index was associated with approximately 6 percent greater depressive symptoms (1.06; 95% CI: 1.03, 1.13); a ten-unit difference in residential instability was associated with approximately 3 percent greater depressive symptoms (1.03; 95% CI: 1.00, 1.04); and a completely unequal income distribution (Gini Index value of 1) was associated with approximately 78 percent greater depressive symptoms compared to complete income equality (Gini Index value of 0) (1.78; 95% CI: 1.01, 3.13).

Within-Between twin models

Only neighborhood deprivation showed significant within-pair associations in the within-between models. The interaction term with zygosity was not significant in the neighborhood deprivation model; thus, we used equation 2 to assess the association with depression. In the unadjusted model, a ten-unit difference in neighborhood deprivation was associated with nearly 6 percent greater depressive symptoms (1.06, 95% CI: 1.01, 1.11), conditional on the mean deprivation score for the twin pair; this association did not substantially change when adjusting for individual and neighborhood-level covariates (Table 2). Individuals in the 75th percentile of neighborhood deprivation (Singh Index = 101.9) had on average 12 percent greater depressive symptoms (1.12, 95% CI: 1.02, 1.23) than those residing in the 25th percentile of neighborhood deprivation (Singh Index = 81.6).

Although the interaction term with zygosity was not significant in the neighborhood deprivation model, we present the fully-adjusted model, stratified by zygosity, in Table 3. DZ twins had a larger within-pair association between neighborhood deprivation and depression than did MZ twins (1.10, 95% CI: 1.05 to 1.14; vs. 1.03, 95% CI 1.00, 1.06).

There were no significant within-pair associations for residential instability or income inequality.

Sensitivity Analyses

We did not find any significant interaction between neighborhood deprivation and age or sex (data not shown).

Results for the fully adjusted neighborhood deprivation model limited to twin pairs discordant for depression is given in Table 4. The within-pair association between neighborhood deprivation and depression symptoms is substantially greater in this model; adjusting for individual and neighborhood-level covariates, a ten-unit difference in neighborhood deprivation was associated with 20 percent greater depressive symptoms (1.20, 95% CI: 1.14 to 1.26), conditional on the mean deprivation score for the twin pair.

DISCUSSION

The results of this study support the hypothesis that greater neighborhood socioeconomic deprivation is associated with greater depression, but do not provide evidence linking residential instability or income inequality to depression. The results of the sensitivity analysis limiting to twins discordant for depression further adds to our understanding of the complexity of the associations between neighborhood deprivation and depression. Among twins where one member of the pair is depressed and the other is not, the magnitude of the association between neighborhood deprivation and depression becomes much greater compared to the entire study population.

Results from previous studies of neighborhood deprivation and depression are mixed.[7,29,30] A 2008 review of the literature found eleven of twenty-two community-based studies showed a significant association between neighborhood deprivation and depression among adults after controlling for individual-level characteristics,[29] while a subsequent review of the literature published between January 2009 and January 2010 found two of five studies showed significant associations.[7] One potential explanation for the observed difference in study results is differences in operationalizing neighborhood deprivation. While measures of neighborhood deprivation are commonly derived from administrative data, variables may be single indicators (e.g. percent of families living in poverty) or combinations of multiple indicators (e.g. percent of families living in poverty, percent female-headed households, and percent of individuals with a high school diploma/GED).[29] The inclusion of these different aspects of neighborhood deprivation will affect results if they influence depression through different mechanisms. However, without testing specific theories or causal pathways, it is not possible to determine if contradictory conclusions are due to differences in study design and methodology or to the absence of important mechanisms from specific studies.[7]

Despite positive findings with neighborhood deprivation, there was no association between depression and residential instability or income inequality. There has not been much previous research on mental health and residential instability; however, our results are inconsistent with other published studies.[9,31,32] One possible explanation is our use of a single indicator as a measure of instability. Previous studies have created more comprehensive measures by combining percent moved in the last five years with factors such percent of residents with home ownership, percent living in apartment buildings, and percent vacant households.[9,31,32] Further, we looked only at residential instability of the

current neighborhood, whereas residential instability may be more etiologically relevant during childhood.[32]

Our finding of no association between income inequality and depression is also inconsistent with previous studies.[3334] We conceptualized income inequality at the neighborhood level, while other studies have used state- or country-level measures. Depending on the proposed mechanism, the level of the measure chosen can obscure the association. If income inequality affects health primarily through decreased government services, inequality at the city- or state-level may be the most relevant. Alternatively, if income inequality erodes social cohesion and contributes to social disorder, the neighborhood (census tract) would be a more appropriate level.[3435]

While the Gini index is the most commonly used measure of income inequality, and previous research suggests that the choice of measure will not substantially change the results,[36] it is possible that a different measure would give different results.[35] Finally, our negative results related to income inequality may be explained by the threshold effect, where adverse health effects appear only after the neighborhood reaches a certain threshold in income inequality.[34] Despite the lack of consistency with previous studies regarding depression and income inequality, the robust study design and methods employed provides strong evidence to support the lack of association found in the present study.

Strengths and limitations

An important strength of this study is the use of a large community-based sample of twins raised together, which controls for confounding due to shared genetic and childhood environment factors. Early-life socioeconomic status predicts socioeconomic status in adulthood, and the characteristics of the neighborhood in which a child is born and raised are strongly correlated with those of the neighborhood in which they will live as adults. By additionally adjusting for select individual-level sociodemographic characteristics, this study can overcome some of the concerns regarding residential self-selection that limit the ability to draw causal inference from observational studies. Because it is neither practical nor ethical to randomize individuals to different neighborhood environments, a genetically-informed twin model is the best approximation to an experimental design.[1826]

The twin design, however, does not inherently account for other factors that can affect self-selection into neighborhoods. For example, we were unable to adjust for general neighborhood preference or selection factors such as wanting to live close to work or within a certain school’s catchment area. A further limitation is the cross-sectional study design; while the underlying hypothesis in our study is that neighborhood characteristics affect health (social causation), previous studies have shown that individual health can affect neighborhood choice (social selection).[37] Despite this concern, prior research suggests that, while social selection may be an important factor for explaining the association between socioeconomic factors and some mental disorders like schizophrenia, social causation is the more relevant mechanism for depression.[38]

A further limitation is the use of census tracts presents to represent neighborhoods. Selecting neighborhood boundaries would ideally be driven by theoretical considerations instead of

methodological ones. However, the availability and consistency of boundaries over time make census tracts a widely used operationalization of neighborhood in the United States. Additionally, census tracts are designed to be economically homogenous, decreasing concerns that individual heterogeneity may obscure results.[39] Further, state and local governments may allocate resources based on these administrative areas, and this can impact the experience of the individuals residing in them.[40]

Finally, the lack of racial diversity in the sample limits generalizability to other populations. There was, however, substantial diversity of income, and while the twins in the Registry may not be representative of the U.S. population as a whole, they are generally representative of residents of Washington State.

Conclusion

The results of this study suggest that greater neighborhood socioeconomic deprivation is associated with more depressive symptoms. Future studies should employ longitudinal designs to better test social causation versus social selection. Longitudinal designs would also allow for assessing the trajectory of depression and empirically testing proposed pathways and theories.

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Thumbnail Sketch

What is already known on this subject?

Depression contributes to the global burden of disease. Several known individual level factors, such as socioeconomic status, contribute to depression. However, neighborhood level factors are gaining appreciation for their contributions to mental health.

What this study adds?

This study assessed the associations between neighborhood factors, including area level socioeconomic deprivation, residential instability and income inequality, and depression among a large sample of adult twin pairs. The twin sample controls for confounding of the association between neighborhood factors and depression by shared genetic and childhood environment factors. Using this model, the results provide evidence to support the concept that neighborhood factors are associated with depression, even when controlling for known individual level factors as well as shared genetic and childhood environment factors.

Table 1

Select characteristics of 7476 adult twins (3738 pairs) in the Washington State Twin Registry, 2009–2013.

	Mean	SD
Age	41.0	17.1
Gini index	0.40	0.07
Population density	4,243.7	7,772.9
Singh Index	89.1	20.6
PHQ-2*	0.81	1.24
	N	**%**
Male	2,582	34.5
White	6,910	92.4
Hispanic	303	4.1
Income		
<$60,000	3,528	47.2
≥$60,000	3,944	52.8
Education		
Less than HS	195	2.6
HS grad	1,169	15.6
Some college	2,663	35.6
Bachelors or more	3,449	46.1
Marital status		
Single	2,395	32.0
Living as married	4,169	55.8
Previously married	912	12.2
*PHQ-2**		
0	4427	59.2
1	1251	16.7
2	1197	16.0
3	246	3.3
4	190	2.5
5	67	0.9
6	98	1.3

* The 2-item Patient Health Questionnaire; used to measure depressive symptoms.

Continuous variables shown as mean + standard deviation and categorical variables as counts (N) and percentages.

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Table 2

Associations between neighborhood deprivation and depressive symptoms* among 7476 adult twins (3738 pairs) in the Washington State Twin Registry, 2009–2013.

	Model 1		Model 2		Model 3	
	exp(β)	**95% CI**	**exp(β)**	**95% CI**	**exp(β)**	**95% CI**
Singh Index						
Between-pair	1.06	(1.03 to 1.20)	1.02	(0.99 to 1.06)	1.02	(0.99 to 1.06)
Within-pair	1.05	(1.01 to 1.11)	1.05	(1.01 to 1.09)	1.05	(1.01 to 1.10)
Income			0.92	(0.90 to 0.94)	0.93	(0.91 to 0.94)
Education			0.91	(0.86 to 0.97)	0.91	(0.86 to 0.97)
Marital status						
Single			1.00		1.00	
Living as married			0.78	(0.70 to 0.88)	0.78	(0.69 to 0.87)
Previously married			1.05	(0.91 to 1.21)	1.05	(0.91 to 1.21)
Population density†					1.01	(0.94 to 1.10)
Random Effects Variance						
Census tract	0.12		0.09		0.09	
MZ twins	0.74		0.66		0.67	
DZ twins	0.00		0.03		0.02	

*Measured by the 2-item Patient Health Questionnaire.

†Scaled to 10,000 people per square mile.

Model 1 unadjusted for covariates.

Model 2 adjusted for individual-level income, education, and marital status.

Model 3 adjusted for individual-level income, education, and marital status, and area-level population density.

CI, confidence interval.

Table 3

Zygosity-specific associations between neighborhood deprivation and depressive symptoms * among 7476 adult twins (3738 pairs) in the Washington State Twin Registry, 2009–2013.

	Monozygotic		Dizygotic	
	exp(β)	**95% CI**	**exp(β)**	**95% CI**
Singh Index				
Between-pair	1.02	(1.00 to 1.05)	1.02	(0.98 to 1.05)
Within-pair	1.03	(1.00 to 1.06)	1.10	(1.05 to 1.14)
Income	0.92	(0.91 to 0.93)	0.93	(0.91 to 0.95)
Education	0.93	(0.89 to 0.96)	0.88	(0.83 to 0.93)
Marital status				
Single	1.00		1.00	
Living as married	0.78	(0.73 to 0.84)	0.79	(0.71 to 0.88)
Previously married	1.02	(0.94 to 1.12)	1.11	(0.97 to 1.27)
Population density †	1.03	(0.97 to 1.10)	0.99	(0.94 to 1.05)

* Measured by the 2-item Patient Health Questionnaire.

† Scaled to 10,000 people per square mile.

CI, confidence interval.

Table 4

Associations between neighborhood deprivation and depressive symptoms[*] among 318 adult twins (159 pairs) in the Washington State Twin Registry with discordant depression scores, 2009–2013.

	exp(β)	95% CI
Singh Index		
Between-pair	0.99	(0.95 to 1.03)
Within-pair	1.20	(1.14 to 1.26)
Income	0.94	(0.92 to 0.96)
Education	0.96	(0.90 to 1.01)
Marital status		
Single	1.00	
Living as married	0.79	(0.71 to 0.89)
Previously married	1.04	(0.91 to 1.18)
Population density[†]	0.90	(0.80 to 1.01)

[*] Measured by the 2-item Patient Health Questionnaire.

[†] Scaled to 10,000 people per square mile.

CI, confidence interval.