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Pathways Linking Census Tract Typologies with Subjective Neighborhood Disorder and Depressive Symptoms in the Black Women's Experiences Living with Lupus (BeWELL) Study

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Abstract

Depression is a common comorbidity among Black women with systemic lupus erythematosus (SLE), an understudied autoimmune disease characterized by major racial and gender inequities. Research is needed that examines how area-level factors influence risk of depression in this population. Latent profile analysis revealed four neighborhood typologies among metropolitan Atlanta, Georgia census tracts that participants (n=438) in the Black Women's Experiences Living with Lupus (BeWELL) Study were living in: Integrated/High-SES, Moderately Segregated/Mid-SES, Highly Segregated/Mid-SES, and Highly Segregated/Low-SES. Structural equation models indicated that highly segregated census tracts were associated with the greatest levels of

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depression via increased subjective assessments of neighborhood disorder. Policies that invest in segregated areas and address physical and social aspects of the environment that contribute to neighborhood disorder may promote mental health among Black women with SLE.

Keywords

systemic lupus erythematosus; depression; racial residential segregation; neighborhood disorder; structural racism; latent profile analysis

Systemic lupus erythematosus (SLE) is a chronic autoimmune condition that involves several organ systems and unpredictable periods of disease activity that wax and wane [1]. Symptoms of SLE are heterogeneous and potentially debilitating, such as chronic pain, fatigue, face and skin rashes, ulcers, hair loss, and joint and chest pain [1]. Up to 262,000 people in the US live with SLE and Black women have the highest prevalence rate [2–5]. Black women are also burdened with faster disease progression, worse disease outcomes (including mortality) and at earlier ages than White women [6, 7]. Recent evidence suggests racial disparities in disease outcomes are widening, including in the prevalence of lupus comorbidities, such as depression, which has been associated with worse disease outcomes [8–12]. It is estimated that 24–35% of people living with SLE are diagnosed with major depressive disorder, making it one of the most common comorbid conditions observed in SLE patients [13–15]. The etiology of depression within SLE is complex and manifold, including clinical, inflammatory, and psychosocial mechanisms as well as their interactions [7, 16]. Growing evidence suggests that qualitatively unique psychosocial stressors experienced by Black Americans may contribute to racial disparities in SLE severity, which may be partly driven by comorbid depression [7, 17, 18]. For example, psychosocial stressors related to trauma, racism, and their intersections with gender—all risk factors for depression—have been associated with disease incidence and worse outcomes among women with SLE [17, 19–23]. Chronic exposure to psychosocial stress can produce elevated levels of inflammation which cause or exacerbate depressive symptoms, in turn accelerating the SLE disease course [24–28]. Given that Black women are more likely than White women to experience chronic psychosocial stress throughout the lifecourse, the comorbid occurrence of depression with SLE may hasten disease progression for Black women and contribute to racial SLE disparities [29–32].

Neighborhood factors and area-level characteristics, including aspects of the physical, service, and social environment (e.g., quality of the built environment, neighborhood poverty, and neighborhood disorder) are associated with mental health outcomes [33, 34]. For example, census tract poverty and various aspects of physical and social disorder (vandalism, crime, low social cohesion) have been associated with greater risk and severity of depression [35–37]. The inequitable allocation of these neighborhood health-promoting versus health-damaging factors are structured and reinforced by racial residential segregation. Racial residential segregation is characteristic of major metropolitan areas in the US, and has been intentionally designed by meso-level actors to maintain White supremacy [38, 39]. One major consequence has been the creation of predominantly Black

neighborhoods that on average have greater systematic disadvantages compared to White neighborhoods [38, 40].

There is a paucity of research on neighborhood-level factors and their association with depression specifically among people living with SLE. Prior research on SLE and neighborhood characteristics is limited and most empirical studies focus on associations between area-level poverty and outcomes of organ damage and mortality [41, 42]. For example, geographic variation in SLE incidence and mortality are concentrated in areas with high rates of poverty and high proportions of racial and ethnic minorities [44]. Recent qualitative work identified that fear of crime and exposure to neighborhood disorder is a stressor in the lives of SLE patients, particularly for those living in areas of concentrated poverty [45]. Aspects of neighborhood disorder, such as crime, physical decay, and low social cohesion have also been associated with depressive symptoms and poorer SLE outcomes among patients living in Egypt [46]. Taken together, this evidence suggests that contextual neighborhood attributes, including racial residential segregation and poverty concentration, are linked to area-level stressors that may partially account for racial SLE disparities through mental health mechanisms [75]. However, there are few studies that examine this relationship, and research among Black women is particularly sparse.

Emerging methods in area-level research have begun to incorporate neighborhood-centered techniques which address methodological limitations of more traditional variable-centered approaches [47, 48]. Latent profile analysis (LPA) is one method that can be used to identify practically meaningful and distinct groupings of types of neighborhoods based on heterogeneity in objective area-level characteristics [49]. Past studies have used LPA to identify neighborhood typologies based on various area-level indicators, such as socioeconomic disadvantage, alcohol availability, food environments, green space, and air pollution [49].

Black and White Americans reside in qualitatively distinct neighborhoods largely due to the legacy and persistence of racial residential segregation, concurrent economic segregation, and contemporary racial discrimination in housing and lending [38, 40]. In the current study, we: (1) use LPA to identify distinct census tract typologies that Black women with SLE live in; and (2) examine associations between census tract typologies, subjective neighborhood disorder, and depressive symptoms. We hypothesize that participants living in tract typologies associated with greater perceived neighborhood disorder will report more depressive symptoms.

Methods

Sample

Data are from the Black Women's Experiences Living with Lupus (BeWELL) Study. Details of the BeWELL sample have been previously described [19]. Briefly, the BeWELL Study consists of 438 Black women living in metropolitan Atlanta, GA with validated SLE based on guidelines set by the American College of Rheumatology (4 criteria or three criteria with documented diagnosis by board-certified rheumatologist) [50]. Participants were recruited from April 2015 to May 2017 from the Georgians Organized Against Lupus

(GOAL) cohort. The GOAL cohort was largely derived from the Georgia Lupus Registry (GLR), a population-based SLE registry funded by the Centers of Disease Control and Prevention [2, 51]. The GLR was designed to estimate the incidence and prevalence of SLE in Atlanta, GA and ascertained cases from various sources including hospitals, health care providers, state and regional laboratories, and electronic medical records [2]. In addition to the assessment of psychosocial factors, SLE outcomes, and other health conditions, the BeWELL Study geocoded participant addresses to US census tracts in metropolitan Atlanta.

Variables

Area-Level—Sociodemographic and socioeconomic data on Atlanta Metropolitan Statistical Area (MSA) census tracts were obtained from American Community Survey five-year estimates (2014–2018) [52]. The following tract-level socioeconomic indicators were matched to geocoded participant addresses and used to characterize latent tract typologies: (1) *percent poverty*, measured as the percent of individuals living at or below the federal poverty threshold; (2) *percent unemployment* is the percent of individuals who are unemployed and actively looking for employment; (3) *percent on Supplemental Nutritional Assistance Program* (SNAP) is the percent of individuals receiving federal assistance or SNAP; and (4) *percent with a high school degree or less* measured as the percent of individuals without any post-secondary education.

The evenness dimension of *racial residential segregation* was assessed using divergence scores which quantify the difference between Black-White racial composition at the tract-level to the broader Atlanta MSA [53]. Divergence values for individual tracts range from 0 (no segregation) to a maximum value dependent on the proportions of each group in the MSA. Greater relative divergence within an MSA indicates that a single race predominates the tract above and beyond the average MSA tract. We use the following formula to calculate divergence values for tract i in the BeWELL sample:

$$D_i = \sum_{m=1}^M \pi_{im} \log \frac{\pi_{im}}{\pi_m}$$

where π_{im} is race m 's proportion of the total Black-White population in tract i , and π_m is race m 's proportion of the overall Black-White MSA population [53]. Values of D_i do not indicate the racial composition of census tracts, only their divergence from the racial composition of the overall MSA. *Percent of Black individuals* at the census tract-level was used to examine the racial composition of census tracts; when used for participants all residing within a single MSA, it is considered to be an indicator of racial isolation [54].

Individual-Level

Subjective Neighborhood Disorder.: Items measuring subjective neighborhood disorder were from the Perceived Neighborhood Disorder Scale [55]. Four items assessed neighborhood *social disorder*. Example items are: “There are too many people hanging around on the streets near my home” and “There is a lot of crime in my neighborhood”.

Participants indicated their agreement to each item, with response choices ranging from 1 (strongly disagree) to 5 (strongly agree). We examined the mean score across items ($\alpha=.90$).

Physical disorder: Physical disorder was measured using six items that assessed physical conditions of participants' neighborhoods, including the presence of graffiti, abandoned buildings, vandalism, and cleanliness. We examined the mean of response choices, which also ranged from 1 (strongly disagree) to 5 (strongly agree) ($\alpha=.88$).

Depressive Symptoms.: Six items from the Patient-Reported Outcomes Measurement Information System (PROMIS) Short Form v1.0 - Depression 6a instrument were used to assess depressive symptomology [56, 57]. PROMIS short-form instruments for depression were developed by the National Institutes of Health, are validated, precise, and reliable measures, and have been correlated with other established measures, such as the Center for Epidemiological Studies Depression (CES-D) Scale [58]. Participants reported how frequently they experienced feeling the following in the past seven days: worthless, helpless, depressed, hopeless, like a failure, and unhappy. Response options ranged from "never" (1) to "always" (5). Scores were summed and converted to standardized *T*-Scores, where a *T*-score of 50 and a standard deviation of 10 represents the general population average for depressive symptoms. *T*-Scores range from 38.4–80.3 with higher scores indicating greater depressive symptoms.

Covariates.: Demographic covariates were age in years and SLE duration in years. Socioeconomic covariates included categories of educational attainment (less than high school, high school degree, some college or associates/technical degree, bachelor's or graduate or professional degree), work status (full time, part time, out of labor force, or unable to work), insurance status (public, private, or none), and income-to-poverty ratio measured continuously. Health-related covariates included body mass index (measured continuously as weight (kg) divided by height (m^2)), smoking status (current vs. not current), and the following categories of current SLE medication use, each measured dichotomously (yes vs. no): steroids, hydroxychloroquine, and immunomodulators.

Analytic Strategy—There were a total of 257 census tracts represented in the sample. Most (89.0%) of the census tracts in the sample included only one or two participants (Mean=1.7, max=5) which is insufficient clustering for use of multilevel models [59]. Hence, census-derived variables were examined as individual-level variables. Descriptive statistics and bivariate correlations for all study variables were examined prior to conducting analyses. Individual-level missing data was minimal (<1% for any study variable) and accounted for using Full Information Maximum Likelihood (FIML) estimation within *Mplus* Version 8 [60, 61].

Latent profile analysis (LPA) was used to identify subgroups or typologies of census tracts based on the covariance structure of four continuous tract-level socioeconomic characteristics (percent poverty, high school degree or less, SNAP, and unemployment) and two indicators of racial residential segregation (divergence and percent Black). LPA models of increasing number of profiles (1–6) were conducted to identify the best fitting solution. The following fit indices were used to evaluate models: Bayesian Information Criteria

(BIC), sample-size adjusted BIC (ABIC), entropy, and a parametric bootstrapped likelihood ratio test (BLRT). The smallest values of BIC and ABIC and highest entropy values are considered to represent the best fitting model [48]. Elbow plots of BIC and ABIC values were examined to illustrate relative gains in model fit of additional profiles [62]. The BLRT statistically compares the fit of k vs $k-1$ profile solutions, with a significant ($p<.05$) BLRT indicating the higher-profile solution represents a better fit of the data [48]. In addition to fit indices, theory in neighborhoods and health guided decisions to identify conceptually meaningful profiles and select a model of best fit [48].

ANOVA and chi-square tests examined whether census tract typologies significantly differed on sociodemographic and socioeconomic characteristics, subjective social and physical neighborhood disorder, and depressive symptoms. The most likely typology assignments were then merged with individual-level participant data for structural equation models (SEM). First, a measurement model was specified which indexed the two measures of perceived neighborhood factors as a latent construct of subjective neighborhood disorder. Standardized factor loadings for the measurement model were evaluated for measurement quality and good model fit ($CFI>.95$; $RMSEA<.10$, $p<.0001$; $SRMR<.10$) [63]. Next, a structural model was specified to assess direct and indirect effects between tract typologies, subjective neighborhood disorder, and depressive symptoms. Standard errors for indirect effects were estimated using the Delta method in *Mplus*. SEM estimates for paths linking census tract typologies to subjective neighborhood disorder, census tract typologies to depressive symptoms, and subjective neighborhood disorder to depressive symptoms adjusted for all covariates. Post-hoc sensitivity analyses were conducted to compare model estimates using FIML versus listwise deletion for observations with missing individual-level data on any study variable ($n=7$), and to test the direction of indirect effects modeled in primary analyses.

Results

Descriptive Statistics

Means and correlations among study variables in Table 1. Participants in the sample were an average of 46.8 years old ($SD=12.3$) with a mean disease duration of 16.0 years ($SD=10.4$). The mean depression T -Score for our sample was 51.7 ($SD=9.9$) which is 1.7 units greater than the average for the US general population ($M=50$, $SD=10$).

Characteristics of census tracts represented in the BeWELL Study and the broader Atlanta MSA are also presented in Table 1. With the exception of percent of individuals with a high school degree or less, significant mean differences exist between tracts in BeWELL and the Atlanta MSA. Compared to all populated tracts in the Atlanta MSA ($n=948$), tracts in the BeWELL sample ($n=257$) have significantly higher rates of poverty, SNAP recipients, and unemployment. Tracts in the BeWELL sample also have, on average, greater divergence scores and higher proportions of Black individuals compared to the MSA, indicating that BeWELL participants live in more segregated census tracts than the average Atlanta resident.

Latent Profile Analysis Results

Results from the LPA indicated that a 4-profile solution best characterized census tracts in the BeWELL sample (Table 2). Posterior probabilities ranged from .94 to .95 indicating high concordance in the likelihood of latent profile membership. Although the 5- and 6-profiles solution had lower BIC and ABIC, higher entropy, and significant BLRT, these profiles were not conceptually distinct from one another (i.e., additional racially integrated and mid-SES typologies). Therefore, we determined that the 4-profile solution best characterized the sample and represented unique neighborhood typologies.

The first latent tract profile of the 4-profile solution was defined by several indicators of socioeconomic affluence and racially integrated demographics (29.9% Black, divergence=0.08) (Table 3). We named this tract typology Integrated/High-SES. The second profile indicated moderate socioeconomic disadvantage and a significantly higher percent of Black individuals compared to Profile 1 (44.1% Black, divergence=0.13). We named this typology Moderately Segregated/Mid-SES. The third tract profile was also characterized by moderate levels of socioeconomic disadvantage but was predominantly Black and racially segregated (86.0% Black, divergence=0.63). We classified this tract typology as Highly Segregated/Mid-SES. The final latent profile had a similar racial composition as Profile 3 (predominantly Black (84.7%) and racially segregated (divergence=0.62)), but had significantly greater socioeconomic disadvantage relative to other profiles. This tract typology was described as Highly Segregated/Low-SES. Figure 1 depicts standardized mean values for all indicators across unique tract typologies.

Of the 257 tracts in the sample, Highly Segregated/Mid-SES tract typologies were most prevalent (33.9%), followed by Integrated/High-SES (28.8%), Highly Segregated/Low-SES (20.2%), and Moderately Segregated/Mid-SES typologies (17.1%). Participants in the BeWELL Study (n=438) primarily lived in census tracts characterized as Highly Segregated/Mid-SES (47.0%), followed by Integrated/High-SES (19.4%) and Moderately Segregated/Mid-SES (18.5%). The remaining 15.1% of BeWELL participants lived in tracts classified as Highly Segregated/Low-SES.

Table 3 presents results of ANOVA and chi-square tests which indicated that Highly Segregated/Low-SES tracts had significantly higher rates of socioeconomic disadvantage compared to other typologies. In contrast, Integrated/High-SES tracts had significantly lower rates of socioeconomic disadvantage compared to all other typologies. There were significant, yet inconsistent, differences in most socioeconomic characteristics between Highly Segregated/Mid-SES and Moderately Segregated/Mid-SES tracts typologies. For instance, Highly Segregated/Mid-SES tracts had higher percent unemployment, but lower percent of individuals with up to a high school degree compared to the Moderately Segregated/Mid-SES tract typology.

Mean perceived social and physical disorder was lowest in Integrated/High-SES tracts (M=1.29, SD=0.43; M=1.23, SD=0.43, respectively) and highest in Highly Segregated/Low-SES tracts (M=2.11, SD=0.82; M=1.98, SD=0.64). There were similar levels of mean perceived social and physical disorder across Moderately Segregated/Mid-SES (M=1.60, SD=0.73; M=1.50, SD=0.67) and Highly Segregated/Mid-SES tracts (M=1.79, SD=0.74;

M=1.66, SD=0.56). Participants in Integrated/High-SES tracts had the highest individual-level income-to-poverty ratio (M=2.63, SD=1.84), were most likely to have at least some college education (89.4%) and work full-time (38.8%), and were least likely to be uninsured (5.9%). Women who lived in Highly Segregated/Low-SES tracts reported the lowest income-to-poverty ratio (M=1.42, SD=1.26) and were most likely to have a high school degree or less (39.2%), be unable to work (65.4%), and be uninsured (14.8%). Mean levels of depressive symptoms did not significantly differ across tract typologies ($F=0.71$, $p=0.54$). Additional descriptive statistics for participant-level variables across tract typologies are presented in Table 3.

Structural Equation Model Results

Measurement model factor loadings for perceived social and physical disorder that indexed the latent construct of neighborhood disorder were 0.850 and 0.826 ($p<.0001$), respectively, indicating high measurement quality [63].

Initial models examined standardized direct path coefficients of tract typologies predicting subjective neighborhood disorder and depressive symptoms, separately (Fig. 2 and Table 4). Subsequent models tested indirect effects of the relationship between tract typologies and depressive symptoms through subjective neighborhood disorder (Table 5). Highly Segregated/Low-SES was the referent group for Integrated/High-SES estimates, and Integrated/High SES served as the referent group for all other typologies. Direct and indirect path estimates for additional referent group combinations are included as supplementary material (Tables S1–S6).

Direct Effects.—Model fit is good (RMSEA=0.02; CFI=0.98; SRMR=0.02) [63]. Relative to Integrated/High-SES tracts, both Highly Segregated/Low-SES ($\beta=0.495$, SE=0.059, 95% Confidence Interval (CI)=0.384, 0.624) and Highly Segregated/Mid-SES tracts ($\beta=0.402$, SE=0.052, 95% CI=0.302, 0.504) were most strongly associated with subjective neighborhood disorder after adjusting for demographic, socioeconomic, and health-related covariates. Integrated/High-SES tracts were associated with less subjective neighborhood disorder ($\beta=-0.332$, SE=0.040, 95% CI=-0.412, -0.254) compared to Highly Segregated/Low-SES tracts. Moderately Segregated/Mid-SES tracts were associated with higher subjective neighborhood disorder ($\beta=0.184$, SE=0.053, 95% CI=0.088, 0.314) than Integrated/High-SES tracts, but less disorder compared to both Highly Segregated/Mid-SES ($\beta=-0.104$, SE=0.057, 95% CI=-0.215, -0.006) and Highly Segregated/Low-SES tracts ($\beta=-0.272$, SE=0.067, 95% CI=-0.414, -0.154) (Tables S2–S3). Subjective neighborhood disorder was positively associated with depressive symptoms ($\beta=0.134$, SE=0.062, 95% CI=0.021, 0.259). No significant direct effects between tract typologies and depressive symptoms were found.

Indirect Effects.—Standardized estimates for indirect paths between tract typologies, subjective neighborhood disorder, and depressive symptoms are presented in Table 5. Integrated/High-SES tracts were indirectly associated with fewer depressive symptoms through decreased subjective neighborhood disorder, relative to Highly Segregated/Low-SES tracts ($\beta=-0.040$, SE=0.020, 95% CI=-0.088, -0.007). Compared to Integrated/High-SES

tracts, all other typologies were indirectly associated with greater depressive symptoms through increased exposure to subjective neighborhood disorder. Specifically, both Highly Segregated/Low-SES ($\beta=0.066$, $SE=0.032$, 95% $CI=0.013$, 0.144) and Highly Segregated/Mid-SES tracts ($\beta=0.054$, $SE=0.026$, 95% $CI=0.012$, 0.120) were indirectly associated with elevated depressive symptoms via subjective neighborhood disorder. Moderately Segregated/Mid-SES tracts were also associated with greater depressive symptoms through subjective neighborhood disorder ($\beta=0.025$, $SE=0.014$, 95% $CI=0.005$, 0.063) compared to Integrated/High-SES tracts. In comparison to Highly Segregated/Low-SES tracts, all other tract typologies were associated with less depressive symptomology through subjective neighborhood disorder (Table S6).

Sensitivity Analyses

Results did not substantively differ when comparing models estimated using FIML ($n=438$) to models estimated using listwise deletion ($n=431$). Standardized estimates for FIML models were nearly identical to models using listwise deletion and did not meaningfully alter the interpretation of results. Post-hoc sensitivity analyses tested an alternative causal pathway (e.g., Tract Typology \rightarrow Depressive Symptoms \rightarrow Subjective Neighborhood Disorder). Indirect effect estimates were nonsignificant and provide support for the causal order of effects presented in the main analyses (Table S7).

Discussion

The objectives of this study were to identify latent typologies of metropolitan Atlanta, GA census tracts that BeWELL Study participants live in and examine subjective neighborhood disorder as a pathway linking tract typologies to depressive symptomology. We identified four unique tract typologies based on sociodemographic and socioeconomic characteristics: 1) Integrated/High-SES, 2) Moderately Segregated/Mid-SES, 3) Highly Segregated/Mid-SES, and 4) Highly Segregated/Low-SES. Most of the Black women in our sample (62.1%) lived in a highly segregated tract typology, reflecting the stark racial residential segregation in Atlanta, GA. An overwhelming majority of individuals living in those tracts are Black ($M=85\%$), which significantly diverges from the percent of the Black population in the overall Atlanta MSA (33.9%). We found that participants who live in highly segregated census tracts are at greatest risk of depression through their increased exposure to neighborhood disorder, compared to racially integrated tracts. This was also the case for moderately segregated tracts, albeit to a lesser degree. These findings could offer partial explanation for racial disparities in SLE outcomes given that depression is a risk factor for disease severity among Black women [8–11].

An important conclusion from our study is that structural racism, in the form of racial residential segregation, shapes area-level socioeconomic resources, exposure to neighborhood disorder, and subsequent risk of depression among Black women in our sample. Racial residential segregation and neighborhood disadvantage is the intentional byproduct of institutional gatekeepers (e.g., lenders, politicians, executives, police and courts) who perpetuate the political economy of racial capitalism by shaping access to opportunity and resources based on the reification of race [39, 64]. Thus, the underlying

cause of area-level socioeconomic disadvantage and neighborhood disorder observed in our sample is the action and inaction of these meso-level actors [39].

Participants living in Integrated/High-SES tract typologies reported less subjective neighborhood disorder which was associated with fewer depressive symptoms compared to moderately and highly segregated tracts. Among the highly segregated tract typologies, women in moderate SES tracts reported lower levels of neighborhood disorder compared to those living in low SES tracts, in concordance with prior research [65–68]. High levels of physical disorder (e.g., abandoned buildings, graffiti, litter) and social disorder (e.g., lack of trust, fear of crime, and hostility and conflict) may trigger or worsen depressive symptomology through stress-mediated pathways [37, 69]. Perceptions of neighborhood disorder also reduce predictability and controllability in neighborhoods, and can lead to residents feeling a lack of control which is a risk factor for depression [36]. These unique sources of stress should be considered in context of our sample of Black women with SLE who face inherent stressors of disease management, unpredictability of disease course, and racism [70]. Living in neighborhoods with high physical and social disorder may proliferate concurrent stressors and increase risk of experiencing depressive symptoms [35, 36, 71], which can lead to heightened disease activity through multiple pathways, such as compromised disease management [30, 72, 73, 74].

Our findings are consistent with the relatively few studies that have examined associations between sociocontextual factors and health outcomes among SLE patients. Low social cohesion and poor neighborhood aesthetics have been associated with depressive symptoms and adverse SLE outcomes, and general perceived stress has been shown to partially account for the association between high area-level poverty and increased SLE-related organ damage and mortality [10, 39, 47, 48]. Our study advances this line of research and provides evidence for the significance of racial residential segregation and subjective neighborhood conditions in shaping risk of depression—a common comorbidity in SLE—specifically among Black women.

Notably, despite relatively similar area-level socioeconomic characteristics and levels of perceived social and physical disorder, tracts in the moderately segregated middle-class typology were associated with fewer depressive symptoms compared to highly segregated middle-class tracts. These results suggest that in metropolitan Atlanta, GA, additional structural deficits that accompany high levels of segregation and which stem from meso-level factors promote neighborhood disorder [38, 76]. For example, aspects of the service environment (e.g., presence of parks, recreational facilities, and green space; access to healthcare; healthy food availability) may contribute to heightened or reduced neighborhood disorder but were not captured with the indicators (i.e., area-level SES) used in the LPA. An important direction for future research will involve defining neighborhoods with more comprehensive and encompassing measures of neighborhood social, physical, and service environment.

Structural equation models did not indicate direct associations between tract typologies and depressive symptoms, nor did we observe statistical differences in mean levels of depression across typologies. These findings should be interpreted in the unique geographic context of

Atlanta which has many affluent Black neighborhoods relative to other large metropolitan areas in the US. As such, there are several health-promoting resources associated with predominantly Black neighborhoods in Atlanta, such as Black political power, high quality Black educational institutions, and social capital, which are not as salient in other highly segregated cities [40, 77, 78]. Heterogeneity in these factors across tract typologies in the BeWELL Study may explain the lack of a direct association between typologies and depressive symptoms. For instance, health-protective characteristics of living in a racially homogeneous neighborhood may offset risk factors for depressive symptoms caused by neighborhood disorder. In contrast, racially integrated neighborhoods may mitigate risk of depression through reduced neighborhood disorder but increase exposure to risk factors for depression, such as racial discrimination [79].

Results from our study suggest that efforts to address neighborhood context, including both area-level socioeconomic deprivation and neighborhood disorder, should be considered as part of a comprehensive effort to improve mental health among Black women living with SLE [35, 80]. Effective solutions for addressing these issues and promoting health equity occur at the structural level [81]. For example, recent evidence suggests that interventions that address over-policing and police violence may reduce subjective neighborhood disorder among Black women [82]. The enactment and strict enforcement of laws prohibiting housing discrimination and racial residential segregation may reduce the concentration of Black women with SLE in high-disorder neighborhoods. Housing vouchers that facilitate transitions from segregated to integrated neighborhoods are considered a cost-effective approach to reduce exposure to neighborhood disorder and promote mental health [83–86]. Similarly, homeownership, affordable housing, and anti-racist tenant agreements may reduce exposure to psychosocial stress associated with neighborhood disorder [87, 88]. Economic and public investment towards urban planning, land use, and quality housing in primarily Black communities also reduces social and physical disorder, and is beneficial to the mental health of neighborhood residents [89–94]. At the clinician-level, SLE-providers should screen for depressive symptoms and discuss mental health services if needed. Clinicians should also leverage the political power of professional medical associations to advocate for evidence-based policies that reduce physical and social neighborhood disorder and invest in racially segregated communities.

Limitations

This study used cross-sectional data and results should not be interpreted with causality. Our data does not allow us to distinguish the extent to which sociocontextual factors cause depressive symptoms or how an SLE diagnosis forces Black women to live in segregated neighborhoods with high levels of disorder, which therefore exacerbates poor mental health. However, post-hoc analyses of alternative indirect pathways provide support for the direction of effects in this study, and our results are consistent with past longitudinal studies on neighborhood socioeconomic conditions, subjective neighborhood disorder, and mental health outcomes that provide more robust causal interpretations [34, 95]. Our findings are limited to census tracts represented in the BeWELL Study throughout metropolitan Atlanta and may not be generalizable to other regions or populations, including rural areas and predominantly Black affluent neighborhoods. Compared to all tracts in the Atlanta MSA,

tracts in the BeWELL sample had higher rates of socioeconomic disadvantage and greater residential segregation. Furthermore, the use of census tracts to describe participant “neighborhoods” is a limitation as census tracts are relatively large (approximately 4,000 residents/tract) and obscure within-tract heterogeneity in area-level characteristics. Future analyses should examine contextual factors, depression, and SLE at more finite levels and in non-urban geographies.

Indicators used in latent profile analyses were limited to sociodemographic and socioeconomic characteristics. There are likely other area-level characteristics, such as aspects of the service environment, that affect mental health and the SLE disease course which should be incorporated in forthcoming studies. Future research should also examine area-level mechanisms that link protective factors associated with living in a predominately Black neighborhood to depression. Another limitation is the self-reported nature of neighborhood disorder and depressive symptoms. However, subjective neighborhood assessments have been highly correlated with objective measures [96], and our measure of depressive symptoms is reliable and validated for epidemiologic research [57].

These limitations should be considered in context of the study’s methodological strengths. Our sample of 438 Black women with validated SLE was derived from an enumerated population-based registry and is among the largest to examine areal-level sociocontextual factors and depression—an important consideration given Black women are most burdened yet underrepresented in existing areal-level SLE research. Latent profile analysis enabled us to identify unique configurations of segregation and SES census tract typologies that exist among Black women living with SLE in metropolitan Atlanta. This approach represents another methodological strength and advances area-level SLE research. Rather than examining area-level characteristics singularly, as in multivariable regression analysis, latent profile analysis allows for the simultaneous examination of multiple conceptually important influences on health [49].

Conclusions

This study addresses gaps in SLE research on area-level factors and depression, an outcome that by itself is important for those living with the disease, but which also has been shown to increase disease severity, and potentially may have a role in widening racial disparities in SLE outcomes. Our findings reveal nuances in the types of geographies that Black women living with SLE reside in, and how these are related to neighborhood disorder and depressive symptoms. Racial residential segregation—a pernicious facet of structural racism—may shape exposure to neighborhood disorder and subsequent depression, which is a risk factor for accelerated disease progression. Findings from this study highlight potential policy interventions, such as investment in racially segregated neighborhoods, to reduce neighborhood disorder and advance equitable health outcomes for Black women with SLE.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- Neighborhood disorder is a product of structural racism and residential segregation
- Perceived neighborhood disorder was associated with greater depression
- Structural racism and neighborhood factors may contribute to depression in lupus

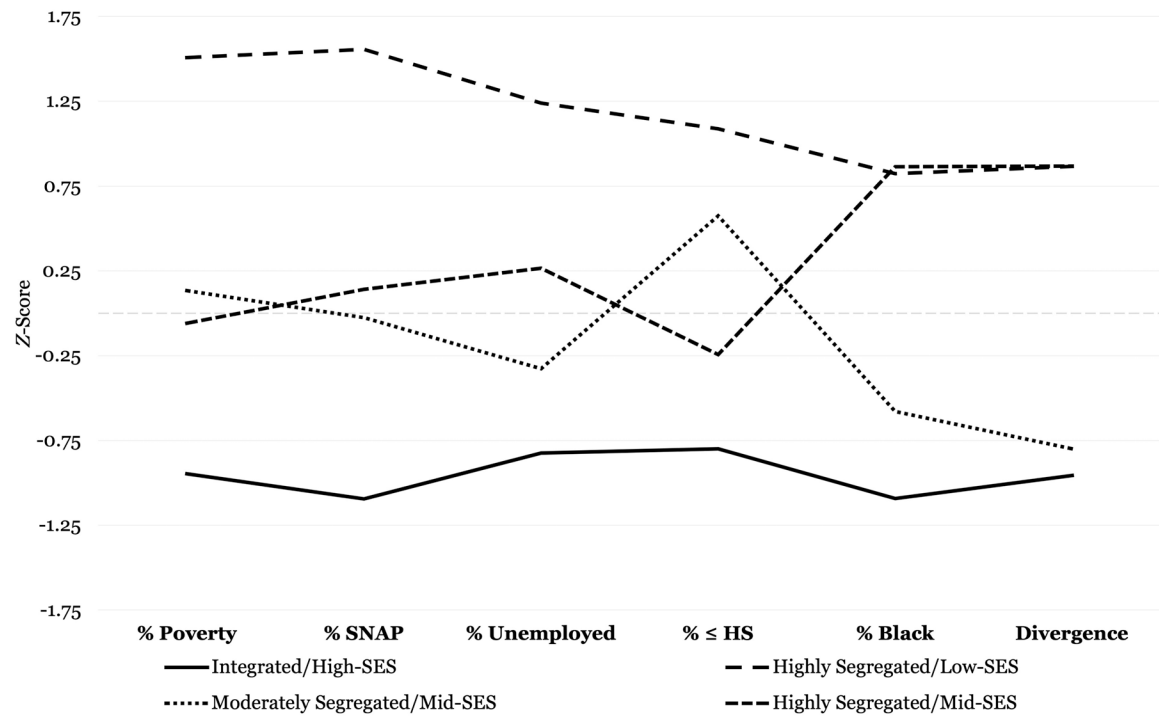


Figure 1.
Standardized means of census tract characteristics for latent tract typologies in the BeWELL Study (n=257).

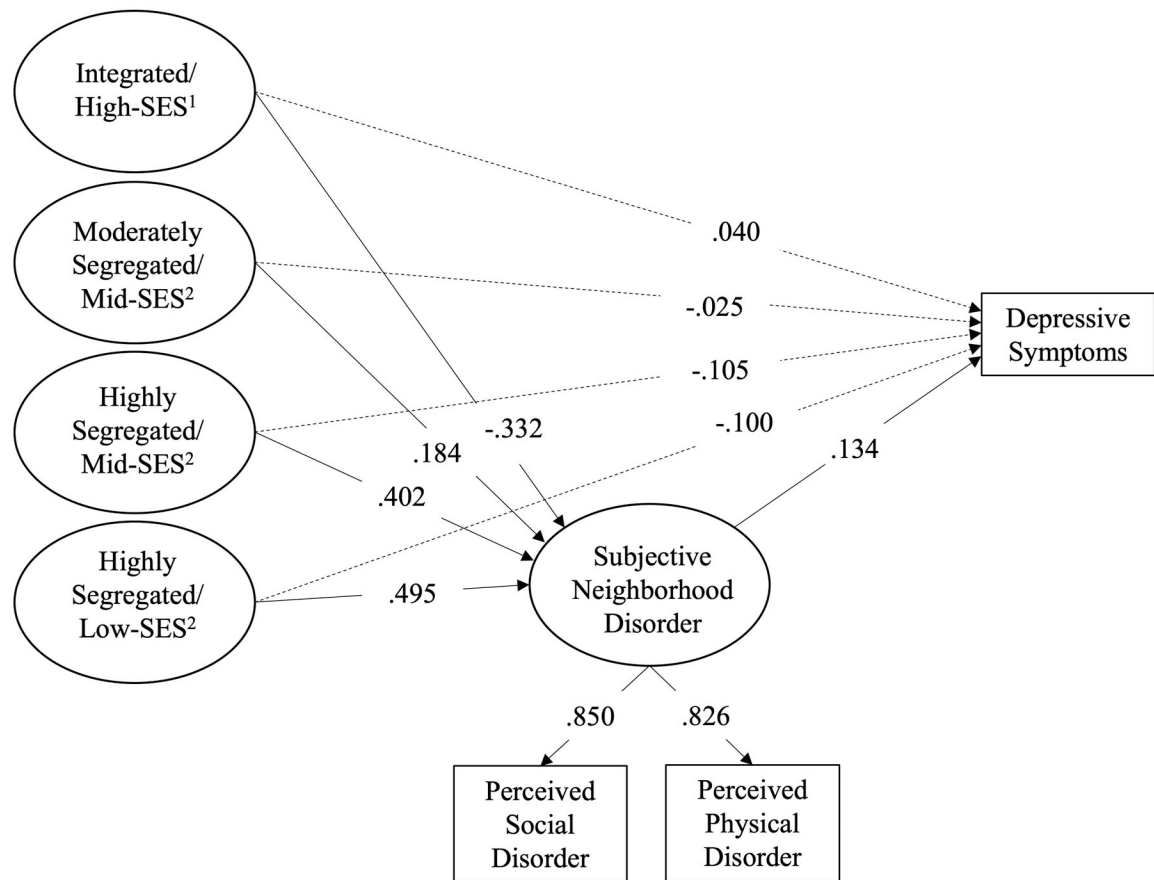


Figure 2.

Structural equation model of standardized direct effects among census tract typologies, subjective neighborhood disorder, and depressive symptoms in the BeWELL Study (n=438). Model Fit: RMSEA=0.02, CFI=0.98, SRMR=0.02. Notes: Estimates are adjusted for all sociodemographic, socioeconomic, and health-related covariates. Solid lines indicate significant association at $p < .05$.

¹referent: Highly Segregated/Low-SES ²referent: Integrated/High-SES.

Descriptive Statistics and Bivariate Correlations of Main Study Variables in the BeWELL Study ($N_{\text{tracts}} = 257$) and Atlanta, GA Metropolitan Statistical Area (MSA) ($N_{\text{tracts}} = 948$)

	BeWELL		Atlanta MSA		1	2	3	4	5	6	7	8	9
	Mean	SD	Mean	SD									
Individual-Level (n=438)													
1) Depression T-Score	51.70	9.85	-	-	-	-	-	-	-	-	-	-	-
2) Subjective Social Disorder	1.73	0.75	-	-	0.14	-	-	-	-	-	-	-	-
3) Subjective Physical Disorder	1.61	0.62	-	-	0.12	0.70	-	-	-	-	-	-	-
Tract-Level													
4) Percent Poverty	20.67	12.20	15.34	11.39	0.06	0.30	0.35	-	-	-	-	-	-
5) Percent High School	12.85	7.64	11.90	9.14	-0.01	0.21	0.26	0.66	-	-	-	-	-
6) Percent SNAP	19.86	11.72	13.41	11.23	0.02	0.33	0.36	0.83	0.65	-	-	-	-
7) Percent Unemployed	10.20	5.36	7.47	4.78	0.02	0.30	0.33	0.62	0.38	0.71	-	-	-
8) Percent Black	61.15	28.79	33.91	29.99	-0.01	0.31	0.33	0.37	0.13	0.55	0.61	-	-
9) Divergence	0.37	0.30	-	-	-0.02	0.31	0.34	0.36	0.12	0.54	0.59	0.89	-

Note: bolded correlations are significant at $p < .05$

Table 2.

Model Fit Statistics for Latent Profile Analyses of Census Tract Characteristics in the BeWELL Study (n=257)

Profile Size	Profile Proportions	BIC	ABIC	Entropy	BLRT
1	1.00	10005.5	9967.4	-	-
2	.52/.48	9301.3	9241.0	0.956	0.000
3	.46/.37/.16	9125.1	9042.6	0.921	0.000
4	.34/.29/.20/.17	8995.4	8890.8	0.901	0.000
5	.30/.23/.18/.14/.15	8909.0	8782.1	0.914	0.000
6	.23/.21/.18/.16/.14/.09	8851.8	8702.8	0.910	0.000

Table 3.

Tract-Level and Participant Characteristics by Tract Typology in the BeWELL Study

Variable	Typology 1			Typology 2			Typology 3			Typology 4			F or χ^2	P	
	Integrated/ High-SES			Moderately Segregated/Mid-SES			Highly Segregated/Mid-SES			Highly Segregated/Low-SES					
	(N _{tracts} = 74)			(N _{tracts} = 52)			(N _{tracts} = 87)			(N _{tracts} = 44)					
	(N _{participants} = 85)			(N _{participants} = 66)			(N _{participants} = 206)			(N _{participants} = 81)					
	M	SD		M	SD		M	SD		M	SD		M	SD	
Tract-Level															
Percent Poverty	9.09 _a	4.70		22.50 _b	7.45		20.02 _b	7.92		39.28 _c	8.16		168.59	<.0001	
Percent High School	6.81 _a	4.01		17.55 _b	7.42		10.94 _c	3.86		21.22 _d	7.53		79.18	<.0001	
Percent SNAP	7.09 _a	3.98		19.86 _b	5.67		21.47 _b	6.23		38.17 _c	6.77		281.41	<.0001	
Percent Unemployed	5.74 _a	2.20		8.48 _b	3.58		11.64 _c	3.59		16.90 _d	5.82		89.27	<.0001	
Percent Black	29.90 _a	15.96		44.14 _b	16.44		85.99 _c	8.75		84.72 _c	13.43		298.57	<.0001	
Divergence	0.08 _a	0.08		0.13 _a	0.11		0.63 _b	0.16		0.62 _b	0.20		291.42	<.0001	
Participant-Level															
Depressive Symptoms T-Score [*]	51.50	10.55		52.67	9.93		51.11	9.28		52.63	10.52		0.71	0.5400	
Perceived Physical Disorder	1.23 _a	0.43		1.50 _b	0.67		1.66 _b	0.56		1.98 _c	0.64		25.32	<.0001	
Perceived Social Disorder	1.29 _a	0.43		1.60 _b	0.73		1.79 _b	0.74		2.11 _c	0.82		20.3	<.0001	
Age (years)	45.51 _{ab}	12.08		43.68 _b	11.51		48.65 _a	12.13		46.17 _{ab}	13.09		3.40	0.0178	
Disease Duration (years)	14.98	9.77		14.62	8.86		16.81	10.91		15.87	10.67		1.08	0.3556	
Income-Poverty Ratio	2.63 _a	1.84		1.68 _b	1.35		2.08 _{bc}	1.75		1.42 _b	1.26		8.47	<.0001	
Education (n, %)													43.81	<.0001	
< High School	5	5.88		6	9.09		11	5.37		15	18.52				
High School	4	4.71		13	19.70		42	20.49		20	20.69				
Some College	35	41.18		33	50.00		94	45.85		35	43.21				
College Degree	41	48.24		14	21.21		58	28.29		11	13.58				
Work Status (n, %)															
Full-time	33	38.82		16	24.24		56	27.18		20	24.69		18.93	0.0257	
Part-time	10	11.76		11	16.67		26	12.62		7	8.64				
Out of labor force	6	7.06		0	0.00		15	7.28		1	1.23				

Variable	Typology 1			Typology 2			Typology 3			Typology 4			F or χ^2	P
	Integrated/ High-SES			Moderately Segregated/Mid-SES			Highly Segregated/Mid-SES			Highly Segregated/Low-SES				
	M	SD	(N _{tracts} = 74) (N _{participants} = 85)	M	SD	(N _{tracts} = 52) (N _{participants} = 66)	M	SD	(N _{tracts} = 87) (N _{participants} = 206)	M	SD	(N _{tracts} = 44) (N _{participants} = 81)		
Unable to work	36	42.35		39	59.09		109	52.91		53	65.43		23.09	0.008
Insurance Status (n, %)														
Private	43	50.59		20	30.30		79	38.35		15	18.52			
Public	37	43.53		41	62.12		101	49.03		54	66.67			
Uninsured	5	5.88		5	7.58		26	12.62		12	14.81			
BMI	28.83	7.24		30.91	8.89		31.04	8.40		31.07	7.72		0.50	0.6843
Current Smoker (n, %)	12	14.29		7	10.61		27	13.17		19	23.46		6.14	0.1049
Steroid Use (n, %)	48	56.47		39	59.09		116	56.31		41	50.62		1.21	0.7513
Hydroxychloroquine Use (n, %)	67	78.82		51	77.27		136	66.02		65	80.25		9.28	0.0258
Immunosuppressant Use (n, %)	40	47.06		27	40.91		93	45.15		35	43.21		0.66	0.8828

Note: the F-statistic is presented for results of one-way ANOVAs for continuous dependent variables. The χ^2 statistic is presented for results of chi-squared tests for categorical dependent variables. Means that do not share subscripts differ by $p < .05$.

* T-scores are in reference to the general U.S. population, which has mean of 50 and standard deviation of 10.

Table 4.

Direct effects among tract typologies, subjective neighborhood disorder, and depression in the BeWELL Study (n=438).

Tract Typology	Standardized Path Coefficients					
	Subjective Neighborhood Disorder			Depressive Symptoms		
	β	SE	95% CI	β	SE	95% CI
Integrated/High-SES ¹	-0.332	0.040	(-0.412, -0.254)	0.072	0.056	(-0.033, 0.185)
Moderately Segregated/Mid-SES ²	0.184	0.053	(0.088, 0.314)	-0.025	0.062	(-0.142, 0.095)
Highly Segregated/Mid-SES ²	0.402	0.052	(0.302, 0.504)	-0.105	0.072	(-0.258, 0.029)
Highly Segregated/Low-SES ²	0.495	0.059	(0.384, 0.624)	-0.100	0.064	(-0.273, 0.036)

Note: Estimates adjusted for all sociodemographic, socioeconomic, and health-related covariates.

¹ referent: Highly Segregated/Low-SES,

² referent: Integrated/High-SES

Table 5.

Indirect effects among tract typologies, subjective neighborhood disorder, and depressive symptoms in the BeWELL Study (n=438).

Indirect Paths	Standardized Path Coefficients		
	β	SE	95% CI
Integrated/High-SES ¹ →Neighborhood Disorder→Depressive Symptoms	−0.040	0.020	(−0.088, −0.007)
Moderately Segregated/Mid-SES ² →Neighborhood Disorder →Depressive Symptoms	0.025	0.014	(0.005, 0.063)
Highly Segregated/Mid-SES ² →Neighborhood Disorder→Depressive Symptoms	0.054	0.026	(0.012, 0.120)
Highly Segregated/Low-SES ² →Neighborhood Disorder→Depressive Symptoms	0.066	0.032	(0.013, 0.144)

Note: Estimates adjusted for all sociodemographic, socioeconomic, and health-related covariates.

¹referent: Highly Segregated/Low-SES,

²referent: Integrated/High-SES