ARE CANOPY COVER AND WALKABILITY ASSOCIATED WITH DEPRESSION IN LOW INCOME ADULTS?

By

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A THESIS

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CERTIFICATE OF APPROVAL

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Abstract

Background: Depressive disorders are disabling and prevalent in low-income populations. Improving our understanding of the role of neighborhood environmental factors on depression may suggest modification of specific built environment characteristics that can protect against depression. Canopy cover and walkability are two neighborhood characteristics which may be prevent depressive symptoms, although few studies have examined these associations. We hypothesize that canopy cover and walkability influence depressive symptoms through common causal pathways. Our study aims to help untangle these relationships by considering canopy cover and walkability together.

Methods: We use a large study population of low-income adults who completed extensive mail and in-person surveys between 2008 and 2010 (n=4121; Portland Metropolitan Area, Oregon). Depression screening used the Patient Health Questionnaire-2. Using geocoded residential locations, we calculated exposure to walkability and canopy cover within 0.25 miles of each study participant's home. Neighborhood walkability was calculated from density of business, street intersection, and population. Percent canopy cover was calculated using satellite imagery. The association between neighborhood walkability, canopy cover and depression was analyzed using gender-stratified logistic regression models controlling for relevant individual- and neighborhood-level covariates.

Results: No association was observed between canopy cover and depression in adjusted models in women (OR=1.00, 95% CI: 0.99-1.01) or men (OR= 1.00, 95% CI: 0.99-1.02). Walkability was not related to depression in women (highest vs lowest quartile: OR=1.14, 95% CI: 0.85-1.52). However, in men there was some indication the odds of depression may be elevated in the third (3rd vs 1st quartile: OR= 1.35, 95% CI: 0.96-1.91) but not fourth (4th vs 1st quartile: OR= 0.99, 95% CI: 0.67-1.46) walkability quartile.

Conclusion: Canopy cover was not associated with depression in low-income adults in the Portland Metropolitan Area. Moderately high walkability may be associated with higher odds of depression in men but not women.

BACKGROUND

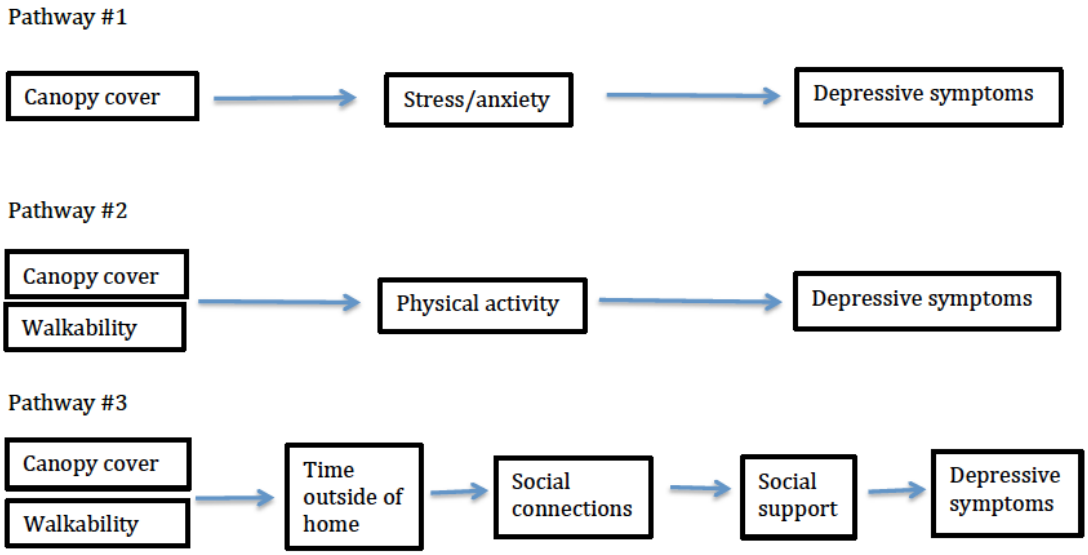
In 2004, the World Health Organization declared depression the leading cause of disease burden, as measured by disability-adjusted life years, in middle and high income countries such as the United States.[1] Depression can lead to absenteeism, decreased productivity, and short-term disability in the workplace [2] and can precipitate onset of chronic conditions as well as adversely affect treatment outcomes for asthma, arthritis, cardiovascular disease, cancer, diabetes, and obesity.[3] In the United States about 16.2% of U.S. adults have a history of depression,[4] and 9.1% of U.S. adults meet the criteria for current depression.[5] In 2008, the Behavioral Risk Factor Surveillance System (BRFSS) found 7.1% of Oregon adults report depressive symptoms (thoughts, moods, or behaviors that inform a diagnosis of depression).[5]

The social stress model is commonly used to evaluate the sociology of mental health disorders.[6] It posits that stressful life events and chronic life difficulties cause emotional stress, which may contribute to poor mental health, especially among people lacking adequate social support.[6] Since as far back as 1939 when Faris and Durham found substance use and schizophrenia associated with high poverty areas,[7] neighborhood environment has been considered a factor which could influence mental disorders.[6] Neighborhood environment, broadly categorized as the physical and social environment, may function as stressors or buffers of stress which impact depression.[8]

Physical environment characteristics that may promote mental health include cafes or restaurants (through social interaction) or parks and exercise facilities (through physical activity).[8] Social environment characteristics associated with greater risk of depression include delinquency,[9] drug use,[9] crime,[9,10] poverty,[9,11] female-headed households,[10] and residential instability.[12] Neighborhood socioeconomic level, usually calculated as an index encompassing many socioeconomic indicators, may be associated with higher risk of depression[6,11,13] although some studies have not found this association.[14,15]

Neighborhood canopy cover and walkability may also impact depression or depressive symptoms. There are at least three potential pathways in which canopy cover and walkability could decrease depressive symptoms: (1) Stress and anxiety may be decreased by proximity to canopy cover,[16,17] and reduction in stress can protect against depressive symptoms.[8] (2) Physical activity may be promoted by high canopy cover[18-20] and high walkability.[21,22] Physical activity can reduce stress and risk of depression.[23] In this pathway, physical activity mediates the relationship between canopy cover and depression, as well as walkability and depression. (3) Canopy cover[24] and walkability may both increase time outside of the home. Time outside of the home can increase social connections and may improve social support,[25] and social support can be protective against stress and depressive symptoms.[26] Figure 1 provides of a diagram of the conceptual framework for the association between canopy cover, walkability, and depressive symptoms.

Figure 1: Conceptual framework of the association between canopy cover, walkability, and depressive symptoms



Canopy Cover

Contact with nature has a positive effect on mood, physiological stress, and better self-perceived health.[27] Experimental studies show exposure to green spaces can have a restorative effect on individuals by increasing positive emotions and attention [28,29] and decreasing blood pressure [29] and anger.[29]

Three studies have examined the association between depressive symptoms or depression and proximity to green space or canopy cover. In 2002, Weich and colleagues examined the association between depression and several built environment characteristics in electoral wards in London. After adjustment for relevant individual-level covariates, people living in areas with few private gardens had a borderline significantly higher prevalence of depression.[30] In 2009, a large-scale exploratory study of Dutch individuals conducted by Maas et al examined a

possible association between canopy cover and 24 health conditions.[27] The study found a lower prevalence of anxiety and depression in people who lived in areas with more green space within a 1 km radius of residence, and this relationship was more pronounced in people of lower SES.[27] In 2012, Miles et al examined the association between acreage of green space within a study participant's census tract (which was categorized into three levels) and depressive symptoms in Miami residents. After controlling for individual-level variables and neighborhood socioeconomic level, less green space was borderline significantly associated ($p<0.1$) with increased depressive symptoms.[31]

These three existing studies have some methodological weaknesses. Two of the three studies were exploratory in nature, with no *a priori* hypothesis. These two studies did not control for neighborhood social or physical environment which may influence depressive symptoms.[8] In fact, the authors of the Dutch study note that neighborhood-level SES is an important confounder which future research should examine.[27] The third study by Miles and colleagues had an *a priori* hypothesis and controlled for neighborhood socioeconomic level. However, amount of green space near study participant's residence was split into three categories leading to much imprecision which may have resulted in inadequate power.[31] Due to the small number of studies on this topic, as well as the methodological limitations of existing studies, more research is warranted.

Walkability

Two studies have examined the association between walkability and depressive symptoms. The first study, conducted in the U.S., found a link between higher walkability and lower depression in older men but not older women after controlling for individual-level confounders.[32] The second study involved older Australian men and examined the association between walkability and its components (street connectivity, residential density, and mixed land use) and depressive symptoms.[33] After controlling for relevant confounders (including neighborhood socioeconomic level), walkability, street connectivity, and residential density were not associated with depression.[33] However, men living in areas with many retail stores had significantly *higher* odds of depression.[33]

These two studies put forth mixed evidence that neighborhood walkability may be associated with depressive symptoms. Both studies have some methodological weaknesses, which may explain the inconsistent results. The U.S. study did not control for neighborhood socioeconomic level, which may be associated with depressive symptoms.[34] Additionally, both studies may have erroneously adjusted for chronic health conditions, which may in fact be a mediator and not a confounder in the relationship between walkability and depressive symptoms. Mediation would occur if walkability affects chronic health conditions and chronic health conditions lead to a change in depressive symptoms. Adjustment for mediating variables will underestimate the relationship between exposure and outcome.[35] Another potential pathway could be that depression and walkability work together to affect chronic health conditions; in this instance adjustment for

common causes would lead to collider bias. In either case, adjustment for chronic health conditions would not be appropriate.

Potential inter-relationships

Canopy cover may have a different effect on depressive symptoms depending on neighborhood socioeconomic level. Canopy cover may be protective against depressive symptoms due to increasing social interactions through increased time outside of the home, reducing stress and anxiety, and increasing physical activity. Yet, low socioeconomic status areas may have higher crime,[36] and crime and fear of crime can produce stress and anxiety.[37] Therefore, increased time outside of the home in areas of low socioeconomic status may not be stress-free and restorative, and therefore canopy cover may not reduce the risk of depression in low SES neighborhoods. Due to the shared pathways between canopy cover and walkability, this same rationale can be applied to walkability as well. Walkability may have weaker protective effects on depressive symptoms in areas of low socioeconomic status than in areas of high socioeconomic status.

In addition, canopy cover and walkability may be correlated. For instance, areas with less population density, such as suburban areas, may have high canopy cover and low walkability, which would lead to a negative correlation. Due this possible correlation, examination of both characteristics simultaneously may help tease out if one or both characteristics are associated with depressive symptoms.

Summary & Study Goal

In summary, depressive disorders are prevalent in the United States, particularly in low socioeconomic groups. Improving our understanding of the role of neighborhood environmental factors on depression may support development of community environmental interventions that ameliorate depressive symptoms. To date, the few studies which explored the relationship between walkability, canopy cover and depressive symptoms have had some methodological limitations. To our knowledge, no study has examined the joint effects of walkability and canopy cover on depressive symptoms.

The goal of our study was to test the hypothesis that canopy cover and walkability are protective against depression, after accounting for both individual- and neighborhood-level characteristics. We tested the interactions between (1) neighborhood deprivation and canopy cover and (2) neighborhood deprivation and walkability.

MATERIALS AND METHODS

Data Sources

Study data were from two related studies, the Oregon Health Study and the Social Determinants of Health Study. Study data were linked to provide comprehensive health behavior, medical and built environment characteristics on low-income adults living in the Portland metropolitan area who completed a mail survey in 2008 or 2009 and an in-person interview in 2009 or 2010.

The Oregon Health Study (OHS) is a large-scale natural experiment whose goal was to determine the influence of Medicaid acquisition on health outcomes among low-income adults living in Oregon. Detailed recruitment for this study is outlined in Allen et al [38] and Finkelstein et al.[39] In 2008, the Oregon Health Plan opened a reservation list and lottery for uninsured adults who wished to receive publically financed medical care (Medicaid). To qualify, individuals were between the ages of 19 and 64; were Oregon residents; were U.S. citizens or legal residents; were not otherwise eligible for Medicaid; had no health insurance in at least 6 months; had income below the federal poverty level; and had assets less than $2000.[39] People who did not meet these selection criteria were not eligible for the study, [39] resulting in 72,803 eligible individuals. Of these, 29,411 people "won" the lottery and were offered health insurance. From the remaining 43,392 individuals who were not offered health insurance, 28,318 randomly selected "controls" were identified. In total, 57,729 individuals were invited to complete three mail surveys about their health behaviors and health status. Our study uses responses from the third mail survey offered between June and August 2009.

The recruitment protocol of the mail survey involved three mail attempts. If surveys were returned as undeliverable, efforts were made to find updated addresses using commercial address databases and the post office, and if a phone number was available a phone call was attempted as well. A $5 cash incentive was offered, and respondents were entered into a drawing to win $200.[39] Additionally, a subset of 30% of non-respondents were targeted for additional follow-up by

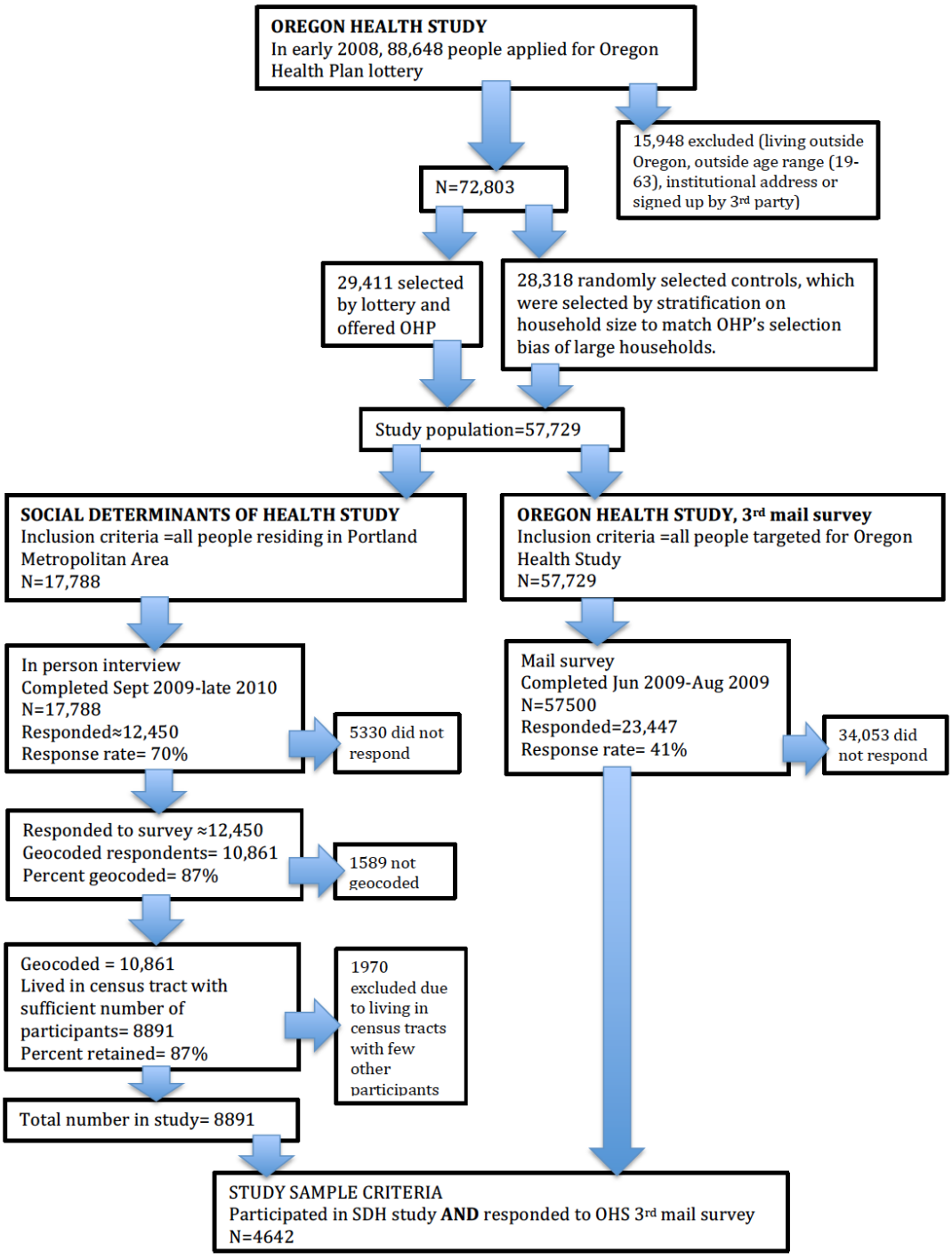
additional mailings, incentives, phone contact and more comprehensive address tracking.[39] Overall, this survey was completed by 23,447 Oregon residents (41%).

The Social Determinants of Health (SDH) Study aims to assess the impact of neighborhood environment characteristics on health conditions and behaviors. Individuals invited to participate in the Oregon Health Study who also lived in the Portland metropolitan area were invited to take part in the SDH Study. Participants completed an in-person interview and health exam between August 2009 and October 2010. The home location that was current during the interview was geocoded and linked to extensive information on street condition, crime, food availability, census-level socioeconomic data, and land use information. A total of 17,778 people were targeted for this study, and approximately 12,450 participated (70%). Some participants were excluded due to unsuccessful geocoding or were "trimmed" because they lived in census tracts with few other participants, resulting in a study population of 8891.

All participants included in the Social Determinates of Health Study who also completed the 3rd mail survey as part of the Oregon Health Study were considered for inclusion. A total of 4246 individuals met this criteria and were included in the analysis. Figure 1 on the next page presents a flowchart of the process for selection of the study sample.

The median mail survey completion date was August 2009, and the median in-person survey completion date was April 2010. Therefore, typically there was an eight month time lag between completion of the health questionnaire from the mail survey and home location ascertainment during the in-person interview.

Figure 1. Flowchart of study participant selection.



Human Subjects Protections

Primary data collection was approved by Providence Health and Services' Institutional Review Board. Data protection procedures complied with HIPPA guidelines, ensuring that information remained protected and confidential. For this study, patient information, including census tract of residence, were de-identified. Enclosed with the mail survey was information explaining the study and assurance that the respondent's identify would be kept confidential. Participants were informed they did not need to respond to the survey and that answering the survey would not impact any health benefits. This secondary data analysis was deemed not human subjects research by OHSU's Institutional Review Board and was approved as exempt.

Variables

Study variables were calculated by a number of different methods as described below. Table 1 below shows the study variables and categories.

TABLE 1. Variables used in analysis

Variable	Categories
Primary analysis	
Depression (primary outcome)	Depressed vs Not depressed
Canopy cover (primary exposure)	Continuous
Walkability index (primary exposure)	Quartiles
Age	18-29, 30-44,45-60, >60
Race/ethnicity	Black, Hispanic , white, other race (American Indian, Asian, Pacific Islander, other, multi-racial)
Education completed	Less than H.S. degree, H.S. diploma or GED, H.S. diploma or GED,Vocational or 2 year degree, 4 year degree
Employment	Not working, working < 20 hours/week, working 20-29 hours/week, working 30 > hours/week
Living status	Living alone, living with partner (including people who may also live with other adults or children), living with other adults and/or children
Percent below household poverty limit (FPL)	Continuous
Neighborhood deprivation index (NDI)	Continuous
Sensitivity analysis	
History of depression	Ever diagnosed with depression vs Never diagnosed with depression
Taking depression or anxiety medication	Have taken vs Have not taken depression or anxiety medication in last 6 months
Physical health (number of days in last 30 physical health was not good)	Continuous
Physical activity	More active, Less active, or About as active as people same age and gender

Depressive symptoms were measured by the Patient Health Questionnaire 2 (PHQ-2), a two-item depression screening questionnaire which assesses depressed mood and inability to experience pleasure in order to screen for probable depression. For each question, answers range from "not at all" (0) to "nearly every day" (3); thus 2-item composite scores ranged from 0 to 6. We used a score of 3 or higher to categorize people as depressed, although a cut-point of 2 or higher is sometimes also used. Using a score of 3 or higher to determine depression has a sensitivity of 83% and a specificity of 92% for major depression, whereas a cut-point of 2 or higher has a sensitivity of 93% and a specificity of 74%.[40] Therefore, using a score of 3 or higher will result in more true negatives and is a more conservative approach for classifying depression.

Neighborhood measures

Exposure to canopy cover and walkability was calculated using study participants' geocoded addresses to create a 0.25 mile Euclidean buffer around each home. Neighborhood deprivation index was calculated at the census-tract level.

A. Percent canopy cover (primary exposure)

Percent canopy cover is measured using Landsat TM digital satellite imagery from August 27, 1998 which was collected by the Metro Data Resource Center and collated into the Regional Land Information System.[41] Satellite data measures canopy cover at the pixilated level. Canopy cover was divided into 25 x 25 meter grid cells. Based on the pixelated data, each grid cell was classified into four canopy

cover categories: 0-25%, 26-50%, 51-75% or 76-100% canopy cover.[42] Study participants' geocoded addresses were overlaid with the canopy cover data, and percentage of canopy cover within a 0.25 mile radius for each study participant's home was calculated.

B. Walkability (primary exposure)

Calculation of a walkability index score was modeled after the work of Frank and colleagues.[43] Their study developed a walkability index using residential density, street connectivity and land-use mix (higher land use mix is a more even distribution of residential, commercial, and office buildings) to predict amount of physical activity as measured by study participants' accelerometers. After normalizing variables, equations with varying weights were attempted until a formula was developed which explained the greatest variation in minutes of walking: Walkability index= (6 x z-score of land-use mix) + (z-score of net residential density) + (z-score of intersection density)

Our walkability index calculations were very similar to, but not identical to, the calculation of Frank and colleagues. Our walkability index was calculated using publically available data collated into the Regional Land Information System.[41] Intersection, population, and business density within a 0.25 mile buffer of each study participant's geocoded home was used to calculate the index. Street intersection density was calculated by summing the total number of intersections, population density was calculated as total population per acre, and business density was calculated from businesses commonly used as destinations for trips. Of note,

our calculations used density of businesses commonly used as destinations whereas Frank and colleagues used land-use mix measurements. These data were normalized, and the following equation was used to calculate a walkability index for each study participant's home:

> Walkability index= (6 x z-score of business density) + (z-score of residential density) + (z- score of intersection density)

For analysis, walkability was split into four quartiles due to the non-linear association between walkability and depression and the inability to identify an appropriate transformation. Splitting walkability into four quartiles is also consistent with how the variable was treated in the initial validation study by Frank and colleagues.[43]

C. Neighborhood Deprivation Index (neighborhood-level control variable)

The neighborhood deprivation index (NDI) provides a composite score quantifying the socioeconomic level in each census tract. The index was computed based on the methods outlined in Messer et al.[44] Variables were supplied by the American Community Survey, a publicly available yearly survey which provides information similar to the decennial census. Due to the small numbers of people interviewed in some census tracts, we used aggregate data from 2005-2009. Nineteen important socioeconomic variables (such as percent of female-headed households and percent of adults without a high school diploma) were considered for inclusion in the index. Using principle component analysis, variables with factor

loadings above 0.250 were considered for the index. Variables with factor loadings above 0.250 were further assessed to determine if their lower 95% confidence interval was below the median 95% confidence interval of all considered variables. Variables with high factor loadings with a lower 95% confidence interval below the median 95% confidence interval would indicate a high degree of sampling variability, and for this reason variables which met this condition were excluded. Eight variables had factor loadings above 0.250, and none of the variables had lower 95% confidence intervals below the median 95% confidence interval. A predicted NDI score using the retained variables was computed for each census tract and used as the measure of neighborhood deprivation.

The final NDI consisted of the following variables: percent males and females with less than a high school diploma; percent households with more than 1 person per room; median home value; percent households in poverty; percent households with less than $30,000 of income a year; percent males in management, professional or related occupations; percent females in management, professional or related occupations; and percent Hispanic. The loading values of variables used in the final index are shown in Appendix 1.

Individual-level control variables

The following individual-level variables are included in the analyses as potential confounders based on prior research which has shown them to be important predictors of depression: lower income,[4,45] lower education,[45,46] unemployment,[4] not married,[4,45] and middle age.[4,45,46] Additionally, African

Americans may be at higher risk of depression.[47] Race was collapsed into four categories to achieve adequate cell counts. Age was split into clinically relevant categories used by Kessler and colleagues [4] due to the non-linear relationship between depression and age. Additionally, a few variables were included in sensitivity analyses but were not included in the primary model. These variables include history of depression, taking depression or anxiety medications, number of days in last month physical health was not good, and physical activity. Table 1 shows the variables and categories used in the primary and sensitivity analyses.

The mail surveys were completed over a 1 year period, and time of year may impact exposure to canopy cover and may influence depressive symptoms.[48] Although proposed as a control variable, the time of year the survey was completed was not included in analysis. All surveys were mailed between June 25th, 2009 and August 14th, 2009, and surveys were returned between June 29th, 2009 and March 16th, 2010 (median date of survey return = August 21st, 2009). Because all surveys were distributed in summer and the median date of completion was also in summer, we did not create a seasonal variable. Adjusting for surveys turned in late may inadvertently adjust for another correlated variable, such as organization, motivation or even depressed mood.

STATISTICAL ANALYSES

Descriptive statistics

First, summary statistics were calculated for all study variables including the primary outcome (depression), primary exposures (canopy cover and walkability), and potential confounders (age, race, education, employment, living status, percentage below federal poverty limit, and neighborhood deprivation index). Summary statistics including mean, median, and standard deviation were calculated for each variable and frequency distribution was calculated for categorical variables. Percent of missing information was assessed. Adequate cell counts (>5) for all categorical variables at each level of depression (yes/no) were verified. Continuous variables were split into quintiles to verify there were an adequate number of depressed and non-depressed individuals across the range of values when examining the crude associations.

Due to unstable estimates between the extreme values of some variables and the outcome (depression) in the full model, a few continuous values were capped at certain cut-points, and values beyond that cut-point were reassigned the upper or lower capped values. The following variables were capped at the following levels: FPL above the 99.5th percentile (300%), percent canopy cover above the 99th percentile (56.3%), and NDI below and above the 1st and 99th percentiles.

Logistic regression models

We created logistic regression models to examine the association between walkability, canopy cover and depression. Primary exposures (canopy cover, walkability) were treated as individual-level variables because they are measured within respondent-specific neighborhoods. Because neighborhood characteristics may impact risk of depression differently in men and women,[25,32] and some individual-level characteristics including income, [49] education,[50] and marital status[50] may affect risk of depression differently in men and women, analysis was stratified by gender (either men or women).

First, unadjusted models determined the crude association between the outcome, depression, and primary exposures.

We used a manual backward deletion strategy to create multivariate models. This was accomplished by adding the primary exposures (walkability, canopy cover), outcome (depression) and all considered confounders to the initial model. Confounding variables were considered for elimination from the full model if their exclusion did not change the beta coefficient estimate between the primary exposures and primary outcome more than 10%. The confounding variable's influence on the beta coefficients was assessed by eliminating confounding variables one at a time from the full model and comparing the coefficient estimates with and without the confounding variable. The variable with the least influence on the beta coefficients was eliminated first. This procedure was repeated until only variables which change at least one of the primary exposures' beta coefficients more than

10% were included in the model. Appendix 2 and 3 provide details of the model building process.

Proper scaling of continuous variables was assessed in both unadjusted and adjusted models by checking the assumption that the linearity of the logit of each continuous variable was met. In the unadjusted models, the linearity of the logit was assessed graphically using the "lowess" function in Stata. If a non-linear relationship was apparent, inclusion of higher order terms (squared, cubed), variable transformations (e.g., natural log), or splitting variables into categories was explored. Higher order terms were formally tested using likelihood ratio tests. Scaling of continuous variables was also assessed in the provisional adjusted model by plotting the estimated coefficients versus the estimated quintile coefficients, which were calculated by splitting the continuous variable into quintiles and re-running the full model (Men's full model: $\pi(x) = \beta_0 + \beta_1 canopy\ cover + \beta_2 walkability + \beta_3 age + \beta_4 NDI + \beta_5 employment + \beta_6 race + \beta_7 living\ status + \beta_8 FPL;$ Women's full model: $\pi(x) = \beta_0 + \beta_1 canopy\ cover + \beta_2 walkability + \beta_3 age + \beta_5 employment + \beta_6 race + \beta_7 living\ status + \beta_8 education).$

The interactions (canopy cover X NDI) and (walkability X NDI) were tested by adding them to the final model. These interactions were included in the model if their p-value was <0.1. This higher significance level was used based on Sander Greenland's recommendation that it may be best to have a significance level much higher than .05 when testing for interaction terms.[51]

Model diagnostics were performed to ensure the fit of the model and assess the impact of outliers. Model residuals including Cook's distance, change in Pearson correlation coefficient, and change in deviance were graphed against leverage and the predicted logistic probability of depression.

Clustering of our primary outcome (depression) within census tracts was tested to ensure a logistic regression model was appropriate. Although the study was not sampled by census tract, clustering could occur if large groups of individuals reside in certain census tracts. These observations would no longer be independent, although an OLS regression model treats them as such.[52] If much clustering is present, an OLS regression model could lead to an increased risk of type 1 error due to artificially narrow confidence intervals.[52] Tests for clustering indicated that the variance of the random effect term was not significant, which indicates that modeling random effects for census tracts is unnecessary.

Analyses were performed in Stata (Version 12; StataCorp, College Station, Texas).

Post-hoc analyses

Six sensitivity analyses and post-hoc power analyses were performed. The first analysis excluded people taking depression or anxiety mediations because these medications may blunt the influence of canopy cover or walkability on depression.

The second analysis re-categorized people who reported taking depression or anxiety medications in the last six months as depressed because people receiving medication for depression are likely depressed.

The third analysis adjusted for history of depression. We did not include history of depression in the primary model because history of depression may lead to inflation of the relationship between the outcome (current depression) and primary exposures (canopy cover and walkability).[53] This can occur when the following three conditions occur: (1) change in depressive symptoms has already occurred before baseline measurement of history of depression occurs (2) history of depression predicts current depressive symptoms, and (3) walkability and canopy cover are unaffected by history of depression.[53] Conditions 1 and 2 may be true, and it is plausible that condition 3 is true.

The fourth analysis added physical activity to the full, final model to assess if it partially explains the relationship between canopy cover, walkability and depression. As discussed in the background, physical activity may mediate the relationship between canopy cover and depression, as well as walkability and depression.

The fifth analyses added physical health to the full, final model to determine how inclusion of this variable may impact results. As discussed previously, physical health may mediate the relationship between canopy cover, walkability and depression, and therefore should not be included in analysis. However, the studies reviewed on walkability included physical health in their analysis (by controlling for

chronic health conditions), and for this reason we want to determine how inclusion of physical health may impact study findings.

The sixth analysis assessed the final model without NDI. Since we identified lack of control for neighborhood socioeconomic level as a major limitation of some studies, we sought to quantify how not controlling for this variable may impact our results.

Post-hoc power calculations were performed based on the observed associations found in the men and women's final models.

RESULTS

Table 2 shows gender-stratified summary statistics for study variables, including the primary outcome (depression), primary exposures (canopy cover and walkability), and potential confounders (age, race/ethnicity, education, employment, living status, FPL, NDI). Records were excluded from analysis if they did not include the outcome, depression, resulting in exclusion of 3% (n=116) of records. An additional 0.2% (n=9) of records were excluded due to missing gender information because analyses were stratified by gender. In total, 4121 records were included in analysis. For all variables except FPL, data was missing in less than 4% of participants; FPL was missing in 11% of records. As expected, we found a negative Spearman rank correlation between canopy cover and walkability ($r = -0.4049$, $p<.0001$); however, due to the large sample size it is unsurprising this correlation was significant

TABLE 2. Sociodemographic and neighborhood characteristics of study participants		
Characteristic	Men (N=1651) Mean (SD) or %	Women (N=2470) Mean (SD) or %
Screened positive for depression	33%	32%
NEIGHBORHOOD		
Canopy cover	26% (9.6%)	27% (9.3%)
Walkability index	1.3 (10.2)	-0.4 (5.4)
Neighborhood deprivation index	1.4 (2.0)	1.4 (2.0)
SOCIODEMOGRAPHIC		
Age		
18-29	17%	20%
30-44	34%	36%
45-60	42%	37%
>60	7%	7%
Race/ethnicity		
White	65%	64%
Black	10%	7%
Hispanic	14%	17%
Other race	11%	12%
Education completed		
Less than H.S. degree	17%	17%
H.S. diploma or GED	51%	43%
Vocational or 2 year degree	18%	26%
4 year degree	13%	14%
Employment		
Not working	57%	54%
Work < 20 hours/week	6%	11%
Work 20-29 hours/week	8%	11%
Work 30 > hours/week	29%	25%
Living status		
Alone	19%	17%
Partner[a]	41%	40%
Other adults and children	40%	43%
Percent of Federal Poverty Limit (FPL)[b] (mean)	73%	77%

[a]Includes people who may also live with other adults or children

[b]Calculated from self-reported income and household size.

Table 3 shows crude associations between depression and primary exposures and considered confounders. In the unadjusted model, canopy cover was not associated with depression in either men (OR=1.06, 95% CI:0.37-3.02, p=0.911) or women (OR=0.99, 95% CI: 0.99-1.00, p=0.275). The odds of depression appear to be highest in the third walkability quartile in both men (3rd vs 1st quartile: OR=1.22, 95% CI: 0.91-1.63) and women (3rd vs 1st quartile: OR=1.27, 95% CI: 1.00-1.61). In both men and women, employment, FPL, and not living alone were associated with lower odds of depression. Compared with those aged 18-29, older age, especially ages 45-60, was associated with higher odds of depression in men and women. Compared with whites, Hispanic men and women had significantly lower odds of depression, and Black women had significantly higher odds of depression. A four year degree was associated with lower odds of depression in women only.

TABLE 3. Crude association with depression						
	Men (N=1651)			Women (N=2470)		
Characteristic	OR	95% CI	p-value	OR	95% CI	p-value
NEIGHBORHOOD						
Canopy cover (primary exposure)	1.06	0.37, 3.02	0.911	0.99	0.99, 1.00	0.275
Walkability index (primary exposure)						
Quartile 1 (ref)	1.00	--	--	1.00	--	--
Quartile 2	1.09	0.82, 1.47	0.550	1.11	0.87, 1.41	0.413
Quartile 3	1.22	0.91, 1.63	0.183	1.27	1.00, 1.61	0.052
Quartile 4	1.15	0.86, 1.54	0.359	1.12	0.88, 1.43	0.347
Neighborhood deprivation index (NDI)	0.96	0.92, 1.02	0.170	1.00	0.96, 1.05	0.806
SOCIOEDEMOGRAPHIC						
Age						
18-29 (ref)	1.00	--	--	1.00	--	--
30-44	1.40	1.00, 1.96	0.052	1.49	1.15, 1.93	0.003
45-60	2.29	1.66, 3.17	<0.001	2.50	1.94, 3.22	<0.001
>60	1.64	1.02, 2.65	0.043	1.85	1.26, 2.72	0.002
Race/ethnicity						
White (ref)	1.00	--	--	1.00	--	--
Black	0.96	0.68, 1.36	0.827	1.58	1.15, 2.18	0.005
Hispanic	0.50	0.36, 0.71	<0.001	0.65	0.51, 0.83	0.001
Other race	0.95	0.68, 1.33	0.764	1.22	0.94, 1.58	0.140
Education completed						
Less than H.S. (ref)	1.00	--	--	1.00	--	--
H.S. diploma/ GED	0.90	0.68, 1.20	0.468	0.80	0.63, 1.02	0.076
Vocational/2 yr degree	0.81	0.58, 1.15	0.249	0.85	0.66, 1.11	0.236
4 yr degree	0.75	0.51, 1.09	0.133	0.45	0.33, 0.63	<0.001
Employment hrs per wk						
Not working (ref)	1.00	--	--	1.00	--	--
< 20 hours	0.56	0.35, 0.88	0.011	0.45	0.33, 0.61	<0.001
20-29 hours	0.45	0.30, 0.68	<0.001	0.43	0.32, 0.58	<0.001
30 > hours	0.26	0.20, 0.34	<0.001	0.36	0.29, 0.46	<0.001
Living status						
Alone (ref)	1.00	--	--	1.00	--	--
Partner[a]	0.38	0.29, 0.51	<0.001	0.55	0.43, 0.70	<0.001
Other adults or kids	0.66	0.50, 0.86	0.003	0.74	0.59, 0.94	0.012
Percent of Federal Poverty Limit (FPL)[b]	1.00	1.00, 1.00	<0.001	1.00	1.00, 1.00	<0.001

[a]Includes people who may also live with other adults or children
[b]Calculated from self-reported income and household size

Table 4 shows the association between depression, walkability, and canopy cover in the final adjusted models. Canopy cover was not associated with depression in either men (OR=1.00, 95% CI:0.99-1.02, p=0.458) or women (1.00, 95% CI: 0.99-1.01, p=0.508). Walkability was also not associated with depression in either men or women. There were positive, non-significant associations between higher walkability quartiles and depression in men and women, although these associations show no clear trend.

TABLE 4. Adjusted association between canopy cover, walkability, and depression

	Men[a] (N=1420)			Women[b] (N=2297)		
	OR	95% CI	p-value	OR	95% CI	p-value
Canopy cover	1.00	0.99, 1.02	0.458	1.00	0.99, 1.01	0.508
Walkability index						
Quartile 1 (ref)	1.00	--	--	1.00	--	--
Quartile 2	1.12	0.80, 1.57	0.515	1.20	0.92, 1.57	0.184
Quartile 3	1.35	0.96, 1.91	0.086	1.19	0.91, 1.57	0.204
Quartile 4	0.99	0.67, 1.46	0.947	1.14	0.85, 1.52	0.371

[a] adjusted for NDI, age, employment, race, living status, and FPL

[b] adjusted for age, employment, race, education, living status

Interactions between canopy cover and NDI as well as walkability and NDI were not significant at the p=0.1 level in either the women or men's models (see Appendix 4 for details), and therefore are not included in the final models. Interactions were tested (1) in the full, final model and (2) in the model with all considered confounders before the backwards deletion procedure.

Model diagnostics were performed. Four outliers were identified in the women's model, although removal of these four outliers had only a slight impact on the coefficient estimates. Therefore, these four outliers were included in the final

model. No outliers were identified in the men's model. The Hosmer-Lemeshow goodness of fit tests indicate the model was a good fit in both the women's (p=0.2432) and men's (p=0.4055) models. The area under the ROC curve was 0.6682 in women's model and 0.6804 in the men's model.

Post-hoc analyses

Six sensitivity analyses were conducted. Three of our analyses adjusted for potential confounders not included in our primary model (taking depression or anxiety mediations, history of depression, physical health), and inclusion of these confounding variables did not change study conclusions (results provided in Appendices A5-A7).

The fourth analysis added physical activity to the full, final model to assess if physical activity explained some of the association between canopy cover, walkability and depression (results provided in Appendix A8). However, since we did not find a protective association between either exposures and depression, assessment for a mediating variable is no longer appropriate. The fifth analysis re-categorized people who report taking depression or anxiety medications in the past six months as depressed (see table 5). This method resulted in classifying 41% of men and 45% of women as depressed. This analysis led to some changes in odds ratios, most notably in men the odds of depression were significantly higher in the third walkability quartile (OR=1.51, 95% CI: 1.08-2.10) when compared to the lowest walkability quartile.

Table 5. Sensitivity analysis categorizing people taking depression or anxiety medications in the past 6 months as depressed						
	Men[a] (N=1420)			Women[b] (N=2297)		
	OR	95% CI	Percent change from final model	OR	95% CI	Percent change from final model
Canopy cover	1.00	0.98, 1.01	-0.8%	1.00	0.99, 1.01	-0.8%
Walkability index						
Quartile 1 (ref)	1.00	--	--	1.00	--	--
Quartile 2	1.23	0.89, 1.70	+10%	1.12	0.88, 1.46	-6%
Quartile 3	1.51	1.08, 2.10	+12%	1.13	0.88, 1.46	-5%
Quartile 4	1.26	0.87, 1.82	+27%	1.11	0.85, 1.45	-3%

[a] adjusted for NDI, age, employment, race, living status, and FPL

[b] adjusted for age, employment, race, education, living status

The sixth analysis assessed the effect of NDI by comparing study results with and without NDI in the final model (see Appendix A9). Not controlling for NDI had little effect on odds ratio estimates in both the men and women's models.

Post-hoc power calculations were performed in SAS (Version 9.2; SAS Institute Inc., Cary, North Carolina). Ordinal variables could not be included in the calculations due to software limitations, and therefore the following variables were included: canopy cover, walkability, FPL, and NDI. For canopy cover, both the men and women's models had 5% power to detect odds ratios of 1.004 and 1.005, respectively. The low power to detect an association is expected due to the observed null association. For walkability, both the men and women's models had over 99% power to detect an odds ratio of 1.2.

DISCUSSION

Our study puts forth important information which may help untangle the complex relationship between canopy cover, walkability and depression. To our knowledge, this is the first study to examine these associations in low-income adults.

No association was observed between canopy cover and positive depression screening in either men or women, although the three prior studies reviewed on this topic found an association between canopy cover and depression.[27,30,31] As noted in the introduction, these studies had some methodological limitations. Two of the studies did not account for neighborhood physical or social environment,[27,30] and the third study, which controlled for neighborhood socioeconomic level, lacked precision due to splitting canopy cover exposure into three levels.[31] Our sensitivity analyses reveal neighborhood SES is not an important confounder in our study, so lack of control for this variable may not have greatly impacted the other studies' results. Therefore, the observed associations found in the three other studies may persist even if neighborhood SES was controlled for, which is counter to the results of our study which did not find an association. However, as discussed later in this section, our study has a number of limitations which may have affected this conclusion.

This study found no association between walkability and positive depression screening in women, which is consistent with the one prior study on this association.[32] In men, there is some indication the odds of depression may be higher

in the third quartile of walkability (3rd quartile vs 1st quartile: OR= 1.35, 95% CI: 0.96-1.91, p=0.086); this association was statistically significant when men taking depression or anxiety medication in the last 6 months were re-categorized as depressed (3rd quartile vs 1st quartile: OR=1.51, 95% CI: 1.08-2.10, p=0.015).

These results add to the mixed findings in the two other reviewed studies which examined these associations in men. One reviewed study found walkability to be protective against depression,[32] while the more comprehensive study by Saarloos and colleagues did not find an association between overall walkability and depression.[33] As with our results, Saarloos et al found the odds of depression was higher in more walkable areas, and the highest odds of depression was observed in the third quartile of walkability (3rd quartile vs 1st quartile: OR=1.23, 95% CI: 0.85-1.80).[33] The stronger estimated effect of walkability on depression in men may be due to women being more apt to seek treatment for depression, which may leave men more susceptible to neighborhood environmental factors.[32]

The Saarloos study may provide some clues to explain the counterintuitive results observed between depression and walkability in men. Although Saarloos and colleagues did not find a significant association between walkability and depression, there was a significant association between areas whose primary land use designation was retail stores and higher odds of depression (OR= 1.40, 95% CI: 1.04-1.90).[33] Because our study's walkability index weights business density six times more strongly than residential density or intersection density, our results may be driven by business density. If so, both our study and the Saarloos study indicate business density may underlie the positive association between walkability and

depression. One potential explanation for this association is pointed out by Saarloos: retail stores may lead to more strangers to the neighborhood, [54] which may increase stress and decrease social interaction with neighbors. [55,56] Perhaps the third walkability quartile has high business density, yet lower intersection and population density; intersection and population density would both facilitate social interactions which may protect against depression.[26] Therefore, areas in the third quartile of walkability may have some characteristics which increase risk of depression (high business density) yet lack characteristics which protect against depression (intersection and population density). Examination of each of the walkability index components (residential density, business density, intersection density), such as the analysis conducted by Saarloos, may shed light on this association.

Future research and public health implications

This study provides a number of interesting results which could guide future research. First, the positive association between depression and high walkability in men deserves closer consideration. One potential research area could examine the individual components of walkability (business, intersection, and population density) to reveal which component may help explain this counterintuitive association.

Another potential area of research could account for variations in individual-level exposure to canopy cover and walkability. Neighborhood exposure to canopy cover and walkability was approximated by measuring the amount of these exposures within a quarter mile buffer of participants' homes. Exposure to canopy

cover experienced by an individual may vary widely depending on individual behaviors (biking, walking, sitting outside, gardening) or even the number of windows in a residence. Additionally, the amount someone walks may be greatly influenced by life circumstances—such as owning a car, having a chronic health condition, or having a dog—and therefore the influence of a highly walkable area on walking behavior may be negligible compared with these other factors. Research which accounts for actual amount of exposure to these neighborhood characteristics may be more likely to detect an association if an actual effect exists.

We identified social support and physical activity as potential mediators in the association between canopy cover and depression, as well as walkability and depression. Therefore, another area of research could test these variables as potential mediators.

Our study considered one neighborhood dimension which may influence walking behavior, walkability, which was calculated based on intersection, population and business density. However, other neighborhood dimensions such as physical incivilities,[57] crime,[57] and sidewalk conditions[58] can also influence walking. Therefore, additional research could examine how these additional walkability dimensions impact walking behavior.

In addition to impacting walking behavior, crime can have a strong influence on mental health and wellbeing by increasing psychological distress and reducing social interaction.[57] Therefore, crime may increase the risk of depression, and future research examining these associations should account for crime.

Study limitations and strengths

This study has a number of limitations. The biggest limitation of this study is the potential for reverse causation and residential selectivity bias. These issues are always of concern in cross-sectional studies, but are magnified in this study for two reasons. First, reverse causations is a major concern because temporality of exposure and outcome was reversed: depression screening occurred about eight months *prior* to ascertainment of participant home location. Reverse causation may be plausible, since depressed individuals may seek out areas that provide social services important to those with mental health problems—and these services are often located in more dense (and more walkable) areas. In this scenario, reverse causation could lead to an association between higher walkability and depression. Second, exposure misclassification is a concern because we were not able to ascertain residential relocation during this eight month time period. This is especially a concern in low-income populations which are highly mobile. If someone moved during this time period, depression screening would have occurred at a prior home location, whereas exposure to canopy cover and walkability would have occurred at the current home location. Exposure misclassification would create non-differential error which would attenuate results. Both of these limitations are dependent on if people moved to similar or different neighborhoods; it is possible that people may move to similar neighborhoods or a short distance their previous location.

A number of study limitations are related to measurement of canopy cover. First, defining relevant neighborhood exposure areas is an ongoing area of

investigation in neighborhood health research, and the relevant neighborhood areas likely varies by the neighborhood characteristic of interest. Therefore, a larger or smaller buffer may be more appropriate for investigation of the association between canopy cover and depression. Second, canopy cover data was collected in 1998, almost 12 years before the study was conducted. Many changes to the urban landscape could occur over this period, which may result in under- or over-estimation of percentage of canopy cover near someone's residence. This under- or over-estimation of canopy cover probably resulted in non-differential bias which attenuated results. Third, other green spaces without trees such as open fields were not measured, nor was proximity to water; how this lack of measurement may impact results is unclear.

Because a low percentage of people from our initial target population participated in both studies and were included in analysis (23%), the study population may not be representative of low-income adults in the Portland metropolitan area. Depressed individuals may be less likely to participate,[59] and therefore the actual percentage of depressed individuals may be higher. However, it is unlikely people participated in the study based on amount of exposure to canopy cover or walkability, and therefore this limitation does not influence our primary study objective of examining the relationship between walkability, canopy cover and depression.

Due to the stigma associated with mental health disorders, participants may have underreported depressive symptoms, therefore decreasing the true prevalence. The likelihood of reporting depressive symptoms may be different

according to race/ethnicity, gender and age. For instance, a study validating the PHQ-2 using a structured interview as the gold standard found specificity was highest for men and non-Hispanic blacks, [60] which could be partially due to the likelihood of some groups to underreport their depressive symptoms. However, even with concerns that depressive symptoms may be under-reported, the prevalence of depression in this study population was a staggering 33%. Additionally, although some sociodemographic groups may underreport symptoms, our analysis controlled for these variables, and therefore this reporting bias likely did not affect the association between our neighborhood exposures and depression.

In spite of these limitations, our study has a number of strengths. The large sample size and high precision of measurement of both canopy cover and walkability are major strengths. Neighborhood-level deprivation is one important covariate, but many of the studies on this topic have not controlled for this. Another strength is our ability to examine both walkability and canopy cover concurrently, which allows us the opportunity to tease out which characteristics may influence depressive symptoms. Lack of consideration for multiple neighborhood environmental factors has been identified as an important gap in current knowledge. [8]

Conclusion

Depressive disorders are disabling and are especially prevalent in low-income populations. Canopy cover and walkability are two theorized neighborhood conditions which may protect against depression, yet our study did not find

evidence to support this conclusion. No association was found between canopy cover and depression, and there was no association between walkability and depression in women. Counter to our hypothesis, our study found the odds of depression in men may be increased in the third walkability quartile. This association may be attributed to our study's inability to control for the confounding effect of crime, or may be due to business density, which is one component of walkability. Future research which controls for crime and separately examines the components of walkability (business, intersection, population density) may help untangle this complex association.

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APPENDIX

A1. Factor loading values of variables used in neighborhood deprivation index (NDI)

Variable	Factor loading value
Percent males and females with less than a H.S. education	0.4015
Percent households with more than 1 person per room	0.3557
median household value	-0.3522
Percent households in poverty	0.3460
Percent households earning less than $30,000 per year	0.2741
Percent males in management, professional or related occupations	-0.3718
Percent females in management, professional or related occupations	-0.3560
Percent Hispanic	0.3584

A2. Statistical confounding analysis for men's model

Full model	Canopy Cover coeff. full	Canopy Cover coeff. reduced	Percent change[a]	Walkblty coeff. full (q2 vs q1)	Walkblty coeff. reduced (q2 vs q1)	Percent change[a]	Walkblty coeff. full (q3 vs q1)	Walkblty coeff. reduced (q3 vs q1)	Percent change[a]	Walkblty coeff. full (q4 vs q1)	Walkblty coeff. reduced (q4 vs q1)	Percent change[a]	**Max change**
Age	0.006	0.008	17.5%	-0.025	-0.001	94.2%	0.297	0.289	2.6%	-0.068	-0.041	39.7%	**94.2%**
Race/ethnicity	0.006	0.007	1.8%	-0.025	-0.029	14.6%	0.297	0.276	7.0%	-0.068	-0.079	15.9%	**15.9%**
Education	0.006	0.006	0.6%	-0.025	-0.027	5.3%	0.297	0.296	0.4%	-0.068	-0.070	2.1%	**5.3%**
Employment	0.006	0.005	28.6%	-0.025	-0.012	52.7%	0.297	0.303	2.0%	-0.068	-0.092	35.2%	**52.7%**
Living status	0.006	0.006	12.2%	-0.025	-0.055	118.5%	0.297	0.304	2.3%	-0.068	0.032	146.9%	**146.9%**
FPL	0.006	0.006	4.0%	-0.025	-0.028	9.0%	0.297	0.291	2.1%	-0.068	-0.067	2%	**9.0%**
NDI	0.006	0.009	36.4%	-0.025	-0.043	68%	0.297	0.294	1.1%	-0.068	-0.017	74.4%	**74.4%**
Reduced model (no education variable)													
Age	0.006	0.007	15.5%	-0.027	-0.005	79.9%	0.296	0.286	3.4%	-0.070	-0.046	28.6%	**79.9%**
Race/ethnicity	0.006	0.007	3.6%	-0.027	-0.029	7.7%	0.296	0.276	6.6%	-0.070	-0.078	27.6%	**27.6%**
Education													
Employment	0.006	0.004	31.0%	-0.027	-0.016	39.3%	0.296	0.300	1.2%	-0.070	-0.097	30.0%	**39.3%**
Living status	0.006	0.006	11.2%	-0.027	-0.055	106.5%	0.296	0.304	2.7%	-0.070	0.031	30.4%	**106.5%**
FPL	0.006	0.006	5.8%	-0.027	-0.031	15.0%	0.296	0.288	2.7%	-0.070	-0.070	28.8%	**28.8%**
NDI	0.006	0.009	37.3%	-0.027	-0.043	59.6%	0.296	0.294	0.8%	-0.070	-0.018	29.4%	**59.6%**

[a] Percent change= $(\text{coefficient}_{\text{full}} - \text{coefficient}_{\text{reduced}})/ \text{coefficient}_{\text{full}}$

[b] shaded areas show percent change greater than 10%

A3. Statistical confounding analysis for women's model

Full model	Canopy Cover coeff. full	Canopy Cover coeff. reduced	Percent change[a]	Walkblty coeff.full (q2 vs q1)	Walkblty coeff. reduced (q2 vs q1)	Percent change[a]	Walkblty coeff. full (q3 vs q1)	Walkblty coeff. reduced (q3 vs q1)	Percent change[a]	Walkblty coeff. full (q4 vs q1)	Walkblty coeff. reduced (q4 vs q1)	Percent change[a]	**Max change**
Age	0.004	0.003	35.5%	0.154	0.119	22.5%	0.182	0.173	5.2%	0.064	0.024	62.5%	**62.5%**
Race/ethnicity	0.004	0.004	7.7%	0.154	0.158	2.7%	0.182	0.200	9.8%	0.064	0.076	18.1%	**18.1%**
Education	0.004	0.003	16.4%	0.154	0.149	3.0%	0.182	0.166	9.1%	0.064	0.023	64.7%	**64.7%**
Employment	0.004	0.002	39.7%	0.154	0.132	14.3%	0.182	0.196	7.2%	0.064	0.071	10.0%	**39.7%**
Living status	0.004	0.002	40.2%	0.154	0.150	2.7%	0.182	0.180	1.5%	0.064	0.108	68.0%	**68.0%**
FPL	0.004	0.004	3.3%	0.154	0.159	3.4%	0.182	0.188	2.9%	0.064	0.065	1.5%	**3.4%**
NDI	0.004	0.004	0.2%	0.154	0.154	0.0%	0.182	0.182	0.0%	0.064	0.064	0.2%	**0.2%**
Reduced model (no NDI variable)													
Age	0.004	0.003	32.7%	0.154	0.118	23.0%	0.182	0.172	5.4%	0.064	0.026	59.4%	**59.4%**
Race/ethnicity	0.004	0.005	11.2%	0.154	0.157	2.1%	0.182	0.200	9.5%	0.064	0.078	21.5%	**21.5%**
Education	0.004	0.003	24.6%	0.154	0.151	1.6%	0.182	0.167	8.5%	0.064	0.017	74.2%	**74.2%**
Employment	0.004	0.003	36.4%	0.154	0.131	14.9%	0.182	0.195	7.0%	0.064	0.073	13.4%	**36.4%**
Living status	0.004	0.003	37.4%	0.154	0.149	3.1%	0.182	0.179	1.7%	0.064	0.110	70.9%	**70.9%**
FPL	0.004	0.004	5.6%	0.154	0.160	3.9%	0.182	0.188	3.2%	0.064	0.064	0.8%	**5.6%**
NDI													
Reduced model (no NDI or percent below FPL)													
Age	0.004	0.003	34.4%	0.160	0.123	22.7%	0.188	0.178	5.6%	0.064	0.026	59.7%	**59.7%**
Race/ethnicity	0.004	0.004	8.6%	0.160	0.164	2.6%	0.188	0.208	10.4%	0.064	0.079	23.7%	**23.7%**
Education	0.004	0.003	29.8%	0.160	0.159	0.4%	0.188	0.173	8.3%	0.064	0.012	81.0%	**81.0%**
Employment	0.004	0.002	53.2%	0.160	0.141	11.5%	0.188	0.212	12.5%	0.064	0.072	13.1%	**53.2%**
Living status	0.004	0.002	42.8%	0.160	0.158	0.9%	0.188	0.188	0.0%	0.064	0.110	72.3%	**72.3%**
FPL													
NDI													

[a] Percent change= (coefficient$_{full}$ - coefficient$_{reduced}$)/ coefficient$_{full}$

[b] shaded areas show percent change greater than 10%

A4. Statistical interaction analysis for men and women

	coefficient	p-value
MEN'S MODEL[a]		
NDI x walkability quartile		0.5031
Quartile 1 vs quartile 2	0.0487431	0.584
Quartile 1 vs quartile 3	0.1193776	0.175
Quartile 1 vs quartile 4	0.1092724	0.228
NDI x canopy cover	-0.0044387	0.214
WOMEN'S MODEL[b]		
NDI x walkability quartile		0.4667
Quartile 1 vs quartile 2	0.0738706	0.321
Quartile 1 vs quartile 3	0.1084599	0.129
Quartile 1 vs quartile 4	0.0928707	0.2
NDI x canopy cover	0.003671	0.507

[a] model adjusted for age, race, employment, living status, FPL, and NDI

[b] model adjusted for age, race, employment, living status, and education

A5. Sensitivity analysis excluding people taking depression or anxiety medications from final model

	Men[a] (N=1131)			Women[b] (N=1630)		
	OR	95% CI	p-value	OR	95% CI	p-value
Canopy cover	1.00	0.99, 1.02	0.792	1.00	0.99, 1.01	0.660
Walkability index						
Quartile 1 (ref)	1.00	--	--	1.00	--	--
Quartile 2	1.12	0.76, 1.67	0.560	1.11	0.79, 1.56	0.541
Quartile 3	1.41	0.94, 2.09	0.095	1.05	0.74, 1.50	0.786
Quartile 4	1.03	0.66, 1.63	0.885	1.04	0.72, 1.51	0.834

[a] adjusted for NDI, age, employment, race, living status, and FPL

[b] adjusted for age, employment, race, education, living status

A6. Sensitivity analysis adjusting for history of depression

	Men[a] (N=1199)			Women[b] (N=2076)		
	OR	95% CI	p-value	OR	95% CI	p-value
Canopy cover	1.00	0.99, 1.02	0.681	1.01	0.99, 1.02	0.339
Walkability index						
Quartile 1 (ref)	1.00	--	--	1.00	--	--
Quartile 2	1.11	0.75, 1.63	0.612	1.28	0.95, 1.72	0.101
Quartile 3	1.32	0.89, 1.97	0.168	1.28	0.95, 1.73	0.108
Quartile 4	0.86	0.55, 1.36	0.525	1.10	0.80, 1.51	0.567

[a] adjusted for NDI, age, employment, race, living status, and FPL

[b] adjusted for age, employment, race, education, living status

A7. Sensitivity analysis including physical health

	Men[a] (N=1306)			Women[b] (N=2068)		
	OR	95% CI	p-value	OR	95% CI	p-value
Canopy cover (primary exposure)	1.00	0.99, 1.02	0.648	1.00	0.99, 1.02	0.439
Walkability index (primary exposure)						
Quartile 1 (ref)	1.00	--	--	1.00	--	--
Quartile 2	0.99	0.67, 1.46	0.959	1.26	0.93, 1.70	0.134
Quartile 3	1.23	0.83, 1.82	0.302	1.11	0.82, 1.51	0.496
Quartile 4	0.90	0.58, 1.41	0.652	1.13	0.81, 1.56	0.473

[a] adjusted for NDI, age, employment, race, living status, and FPL

[b] adjusted for age, employment, race, education, living status

A8. Sensitivity analysis including physical activity

	Men[a] (N=1397)			Women[b] (N=2254)		
	OR with P.A. in model	OR without PA in model	Percent change from final model	OR with P.A. in model	OR without PA in model	Percent change from final model
Canopy cover	1.00	1.00	-0.04%		1.01	+0.5%
Walkability index						
Quartile 1 (ref)	1.00	1.00	---	1.00	1.00	---
Quartile 2	0.95	1.00	-16%	1.31	1.20	+9%
Quartile 3	1.19	1.12	-12%	1.22	1.19	+2%
Quartile 4	0.87	1.35	-11%	1.21	1.14	+6%

[a] adjusted for NDI, age, employment, race, living status, and FPL
[b] adjusted for age, employment, race, education, living status

A9. Sensitivity analysis examining the influence of NDI on final model

	Men[a] (N=1420)			Women[b] (N=2297)		
	OR of model with NDI	OR of model without NDI	Percent change	OR of model with NDI	OR of model without NDI	Percent change
Canopy cover	1.00	1.01	-0.2%	1.00	1.00	-0.01%
Walkability index						
Quartile 1 (ref)	1.00	1.00	--	1.00	1.00	--
Quartile 2	1.12	1.11	-0.9%	1.20	1.20	+0.1%
Quartile 3	1.35	1.35	-0.1%	1.19	1.19	+0.1%
Quartile 4	0.99	1.02	+2.9%	1.14	1.14	-0.1%

[a] adjusted for age, employment, race, living status, and FPL

[b] adjusted for age, employment, race, education, living status