The importance of urban planning: Views of greenness and open space is reversely associated with self-reported views and depressive symptoms

Jack A. Pfeiffer[1,2], Joy L. Hart[1,2], Lindsey A. Wood[1,2], Aruni Bhatnagar[2,3], Rachel J. Keith[2,3], Ray A. Yeager[2,4], Ted Smith[2,5], Madeline Tomlinson[1,2], Delana Gilkey[1,2], Savanna Kerstiens[1,2], Hong Gao[2,5], Sanjay Srivastava[2,3], Kandi L. Walker[1,2]

AFFILIATION
1 Department of Communication, University of Louisville, Louisville, United States
2 Christina Lee Brown Envirome Institute, University of Louisville, Louisville, United States
3 Division of Environmental Medicine, Department of Medicine, University of Louisville, United States
4 School of Public Health and Information Sciences, University of Louisville, Louisville, United States
5 School of Medicine, University of Louisville, Louisville, United States

CORRESPONDENCE TO
Joy L. Hart. Department of Communication, University of Louisville, Louisville, KY 40292, United States. E-mail: joy.hart@louisville.edu
ORCID ID: https://orcid.org/0000-0003-3220-2638

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ABSTRACT

INTRODUCTION Exposure to green spaces is beneficial to mental health in a variety of ways, ranging from stress reduction to increased attentiveness and elevated self-esteem. The impact of views of greenness, as opposed to direct exposure, has been examined, but the association between self-reported views and depressive symptoms is not known. The purpose of this study is to examine the relationship between views of greenness and Patient Health Questionnaire–9 (PHQ-9) score.

METHODS Questionnaire responses from 191 participants in the Health, Environment, and Action in Louisville (HEAL) study were examined. Univariate statistical analyses included Mann-Whitney U, Kruskal-Wallis, and Spearman rank tests. Inferential statistical analysis was linear regression.

RESULTS Participant satisfaction with residential greenness was significantly associated with reduced PHQ-9 score (partially adjusted: linear coefficient = -0.42; 95% CI: -0.70 – -0.14; fully adjusted: linear coefficient = -0.21; 95% CI: -0.44 – 0.02). Additionally, being satisfied with local greenness was significantly associated with having views of greenness from home (linear coefficient = 1.97; 95% CI: 1.23–2.68).

CONCLUSIONS Though views of greenness were not directly associated with depression, satisfaction with local greenness was associated with reduced PHQ-9 score, and having views of greenness from home was crudely associated with increased greenness satisfaction. The findings suggest urban greening interventions that focus on greenness satisfaction may be a strategy to reduce depression. Further research is necessary to better understand these relationships.

INTRODUCTION

Despite rigorous evidence, exposure to green spaces has long been thought to provide myriad mental health benefits. Practices such as 'forest bathing', or mindfully experiencing a forested environment, have been promoted for their positive impact on the human psyche, with benefits including reduced stress and anxiety, decreases in attentional fatigue, and improved developmental cognition[1-4]. In communities with elevated morbidities, increased availability of green space has been associated with lower cortisol levels, and therefore less stress[5], perhaps reducing the health effects of illness. Further, exposure to the natural environment, such as through walks, can lessen the symptoms of depression, though the effects are often small and not consistently reported between studies[6-8].

But for all of these benefits, what is it about green spaces and nature that can heal ailing minds? Is it because forests and other green spaces physically make our environments healthier[9,10]? Is it that green spaces encourage more exercise[11]? Is it the reduction of demanding stimuli otherwise omnipresent in our daily lives, thus allowing our minds to freely wander and heal[12,13]? The answer is likely to be found in a combination of factors. A question remains, however: Is the presence of green spaces in one's surroundings sufficient to provide the observed benefits, or is physical interaction with these green spaces necessary? Is greenness more an

abstract concept experienced at the personal level, with derived benefits depending on one's perceptions, even at a distance[14]? Is it enough to merely witness greenness in daily life? Can serious and commonplace mental illnesses such as depression be treated or prevented by people coexisting alongside green spaces, even without direct contact?

Major depression is among the most common mental health disorders in the United States. The 2013–2016 National Health and Nutrition Examination Survey (NHANES) found that 8.1% of US adults experienced depression in any given two-week period, paralleling results from previous NHANES surveys and suggesting that depression has maintained a steady presence in the general population over time[15]. A 2018 study found that lifetime prevalence of a major depressive disorder, as defined in the Diagnostic and Statistical Manual of Mental Disorders, Version 5 (DSM-5), in US adults was 20.6%, with the majority of cases being classified as moderate or severe[16]. The hallmark of major depressive disorder, as outlined by the DSM-5, is the presence of at least five symptoms, such as depressed mood, loss of interest in and satisfaction with activities, disrupted sleep patterns, reduced capacity to concentrate, and irritability[17]. In the worst cases, depression can prove fatal, as a serious symptom of severe, untreated depression is thoughts of self-harm. The Centers for Disease Control and Prevention (CDC) estimate that, in the US, 47173 deaths occurred in 2017 as the result of suicide[18]. The customary approach to treat depression typically involves medication, therapy, or both. Less often is the social and physical environment considered in prevention or management. Given the prevalence and the impact of depression, it is essential to understand the ways in which depressive symptoms can be mitigated through environmental factors.

Whether at home, school or in the workplace, views of greenness have been found to benefit mental health in a variety of ways. A study, examining university students living in campus dormitories, found that those who had natural views from their room windows had significantly increased attention capacity compared with those who had views of built spaces[19]. In a controlled laboratory setting, adults who viewed slides depicting natural scenes prior to being exposed to a mental stressor had increased parasympathetic activity and improved recovery of autonomic nervous system function post-exposure compared to those who viewed slides of built environments[20]. Additionally, improvements in self-esteem were noted in adults exposed to scenes of nature[21]. Another set of studies found that workers in largely sedentary office settings who had views of greenness from windows had significantly increased workplace satisfaction and general wellbeing compared with those who did not[22]. A similar study found that residents who had windowed views of greenness from their low-rise apartments reported elevated satisfaction with their neighborhood and overall wellbeing, whereas those who had views of built environments had lower satisfaction[23]. Further, a study of young Japanese men determined that 'forest bathing' produced physiological and psychological responses indicative of improved physical and mental health when compared to the same measures taken in an urban environment[4].

Though some benefits of natural views from indoor built settings have been documented, the impact of such views on depressive symptoms remains unclear. For example, one study found that those who moved to greener urban environments, compared to their previous residence, had significantly improved mental health; those who moved to urban areas that were less green experienced a pre-move decline in mental health that eventually shifted back to baseline[24]. In contrast, Tennessen and Cimprich[19] found no significant differences on a depression-dejection scale between those who did and did not have views of greenness from their dormitory windows. Further, in terms of housing density, one study found that individuals living in areas with higher housing density had lower depressive symptoms and a borderline significant association between lower depressive symptoms and living in an area with moderate access to green space versus no access[25].

Many past studies examining the impact of the natural environment on depressive mood have relatively small sample sizes, and predominately focus on the presence of greenness but less on how it is experienced at the personal level[8,26]. The current literature lacks thorough examination of the impact of greenness satisfaction on the overall benefit of greenness on depression. Additionally, the relationship between views of nature from home and depression does not appear to be known. Is abundance or presence of greenness in one's residential environment sufficient to incur previously observed mental health benefits, or are factors of greenness preference, and ultimately satisfaction, equally as important?

The primary purpose of this study is to determine whether views of greenness from one's home are associated with PHQ-9 score. Secondary objectives are to examine the relationship of abundance of greenness and satisfaction with greenness with PHQ-9 score.

METHODS

During the summers of 2018 and 2019, South Louisville residents were recruited for the Health, Environment, and Action in Louisville (HEAL) study, part of Green Heart Louisville (GHL), a controlled longitudinal study assessing the impact of urban greening interventions on various health and environmental outcomes. Though several methods were employed, recruitment largely occurred via mailing, door-to-door distribution of flyers, and participation in community events. Interested individuals were screened for eligibility by phone; eligibility criteria included being aged 25–70 years, living within the study area in South Louisville, KY, and meeting certain health requirements (e.g. not pregnant, not diagnosed with cancer). Those found eligible were invited to

attend clinical events.

After participant consent was obtained at clinical events, demographic and socioeconomic information was gathered, then participants visited several stations for clinical measurements (e.g. blood pressure, vascular functions, body fat composition), and finally they completed questionnaires at their desired pace, with some questionnaires completed as they waited at clinical stations. One questionnaire was the Patient Health Questionnaire–9 (PHQ-9), administered to determine the burden of depression in the study sample[27]. Shortly after the clinical visit, a subset of participants answered additional questionnaires pertaining to perceptions of greenness.

All study methods and materials were approved by the University of Louisville Institutional Review Board (IRB), and participant health information protection guidelines were followed as outlined in the Health Insurance Portability and Accountability Act (HIPAA). Participation in the study was voluntary. As participant identifiers were gathered during data collection, data were deidentified prior to analysis.

In total, HEAL recruited 735 participants and 203 completed the additional perceptions of greenness questionnaire. After the removal of missing values and declined-to-answer responses, a final sample of 191 participants remained.

Measures

Depression status

Depression status was determined based on responses to PHQ-9 items and not clinically diagnosed[27]. Specifically, responses to nine statements (Supplementary file Table 1) were used to calculate an aggregate depression score: 0–4 minimal or no depression, 5–9 mild depression, 10–14 moderate depression, 15–19 moderately severe depression, and 20–27 severe depression. Continuous PHQ-9 score served as the outcome variable.

Greenness variables

Three variables pertaining to greenness in participants' communities were examined. The primary exposure variable, view of nature from home, was defined as 'yes/no'. Participants were asked to indicate level of agreement that there is 'lots of greenery around my local area (trees, bushes, gardens)', with response options: 'strongly disagree', 'disagree', 'agree', and 'strongly agree'. Participants were also asked to indicate a number from 1–10 that represented 'satisfaction with the level of greenness in your neighborhood', with 1 meaning 'not at all satisfied' and 5 meaning 'neither dissatisfied nor satisfied', and 10 meaning '100% satisfied'.

Demographic and socioeconomic variables

Several demographic and socioeconomic variables were considered to determine their relevance as confounders and predictors of the study outcome. These variables included: age, sex, race, ethnicity, number of people living in household, and annual household income. Age was defined in years. Sex was defined as male or female. Race was redefined as White/Caucasian, Black/African-American, or Other (i.e. American Indian/Alaskan Native, Asian, Hawaiian/Pacific Islander, and other). Ethnicity was defined as Hispanic/Latino or Non-Hispanic. Household size was defined as one, two, three, four, or five or more. Annual household income before taxes was defined in US$ as: <20000, 20000–44999, 45000–64999, 65000–89999, 90000–124999, or ≥125000.

Other variables

We included other variables as potential predictors or confounders. These variables included body mass index (BMI), general health, self-esteem, regular exercise, frequency of alcohol consumption, and perception of area safety. BMI was defined continuously in terms of kg/m^2. General health was categorized based on responses: 'excellent', 'very good', 'good', 'fair', or 'poor' to the question: 'In general, would you say your health is …'. Perception of self-esteem was based on responses to the question 'How would you respond to the following statement: 'I have high self-esteem', where a scale from one to five, with one meaning 'not very true of me', three meaning 'somewhat true of me', and five meaning 'very true of me', was used. Regular exercise status was based on the question: 'Do you exercise regularly (more than 10 minutes each time)?' and defined as 'yes/no'. Frequency of alcohol consumption was defined based on the responses: 'never', 'monthly or less', '2–4 times per month', '2–3 times per week', and '≥4 times per week'. Perception of area safety was based on responses to the statement 'My neighborhood is safe from crime', where a scale of one to five was provided, with one meaning 'strongly agree', three meaning 'neither agree nor disagree', and five meaning 'strongly disagree'.

Statistical analysis

The outcome variable, continuous PHQ-9 score, was tested for normality using the Anderson-Darling test for normality and was found not to have a normal distribution. Subsequent univariate analysis examined the relationship between all included variables and the outcome variable using non-parametric tests of independence (e.g. Mann-Whitney U test, Kruskal-Wallis test, Spearman rank test) (Table 1). Also, all non-outcome variables, categorized by dichotomous views of nature from home, were compared using chi-squared, Fisher's exact, and t-tests of independence to examine their relationship with the primary exposure variable (Table 2). Variables included in the analysis were examined for confounder and predictor status. Confounders were those variables found to be significantly associated with both outcome and exposure in univariate analysis (Tables 1 and 2) and to noticeably impact the magnitude of the outcome coefficient upon inclusion (i.e. 10% rule). Detected confounders were income and satisfaction with level of greenness in the local area. Age was also included

Table 1. Descriptive statistics of study population by outcome – PHQ-9 score (N=191)

Variables	n (%) or mean ± SD	PHQ-9 score mean ± SD	p[a]
Views of greenness from within home			0.1673
Yes	81 (42.4)	4.0 ± 4.2	
No	110 (57.6)	5.3 ± 5.4	
Age (years)	50.7 ± 12.0		0.7579
BMI (body mass index, kg/m^2)	29.7 ± 6.1		0.0694
Sex			**0.0171**
Female	116 (60.7)	5.3 ± 5.0	
Male	75 (39.3)	3.9 ± 4.7	
Race			0.1638
White/Caucasian	157 (82.2)	4.7 ± 5.0	
Black/African-American	26 (13.6)	4.5 ± 4.3	
Other	8 (4.2)	7.4 ± 4.3	
Ethnicity			0.0972
Non-Hispanic	186 (97.4)	4.7 ± 4.9	
Hispanic	5 (2.6)	8.6 ± 5.3	
Annual household income before taxes (US$)			**0.0069**
<20000	34 (17.8)	6.2 ± 5.6	
20000–44999	55 (28.8)	5.6 ± 5.3	
45000–64999	42 (22.0)	3.8 ± 3.8	
65000–89999	31 (16.2)	4.1 ± 5.3	
90000–124999	26 (13.6)	3.6 ± 4.1	
>125000	3 (1.6)	1.3 ± 0.6	
Number of people in household			0.7630
1	53 (27.7)	5.8 ± 5.8	
2	79 (41.4)	3.8 ± 4.2	
3	27 (14.1)	5.6 ± 5.1	
4	15 (7.8)	5.5 ± 5.4	
≥5	17 (9.0)	4.2 ± 4.0	
General health status			**<0.0001**
Poor	1 (0.5)	6.0	
Fair	28 (14.7)	10.2 ± 5.2	
Good	83 (43.4)	5.4 ± 4.8	
Very good	68 (35.6)	2.0 ± 2.5	
Excellent	11 (5.8)	3.3 ± 3.7	
Self-esteem			**<0.0001**
1 (lowest)	16 (8.4)	10.6 ± 6.2	
2	15 (7.8)	9.1 ± 4.5	
3	58 (30.4)	6.4 ± 5.1	
4	46 (24.1)	2.5 ± 2.3	
5 (highest)	56 (29.3)	2.1 ± 2.9	
Exercises regularly			**0.0006**
Yes	118 (61.8)	3.5 ± 3.4	
No	73 (38.2)	6.8 ± 6.2	

Continued

Table 1. Continued

Variables	n (%) or mean ± SD	PHQ-9 score mean ± SD	p[a]
Frequency of alcohol consumption			**0.0012**
Never	59 (30.9)	6.0 ± 5.2	
Monthly or less	50 (26.2)	5.7 ± 5.4	
2–4 times per month	30 (15.7)	2.5 ± 2.5	
2–3 times per week	27 (14.1)	4.3 ± 5.2	
≥4 times per week	25 (13.1)	3.2 ± 3.9	
Perception that neighborhood is safe			**0.0096**
Strongly agree	4 (2.1)	2.7 ± 1.5	
Agree	18 (9.4)	2.2 ± 3.6	
Neither agree nor disagree	24 (12.6)	3.5 ± 3.6	
Disagree	72 (37.7)	5.4 ± 5.3	
Strongly disagree	73 (38.2)	5.3 ± 5.1	
Satisfaction with level of greenness in local area			**0.0062**
1 (not at all satisfied)	21 (11.0)	6.9 ± 6.4	
2	13 (6.8)	5.7 ± 7.2	
3	18 (9.4)	7.6 ± 6.4	
4	30 (15.7)	3.9 ± 4.0	
5 (neither dissatisfied nor satisfied)	24 (12.6)	5.9 ± 4.3	
6	27 (14.1)	3.4 ± 3.5	
7	15 (7.9)	4.5 ± 3.7	
8	19 (10.0)	3.3 ± 3.6	
9	10 (5.2)	3.5 ± 3.9	
10 (100% satisfied)	14 (7.3)	2.9 ± 4.1	
Perception of abundance of greenery in local area			0.1084
Strongly disagree	20 (10.5)	4.9 ± 4.5	
Disagree	51 (26.7)	5.6 ± 5.7	
Agree	94 (49.2)	4.6 ± 4.7	
Strongly agree	26 (13.6)	3.4 ± 4.1	

a Non-parametric (Mann-Whitney U/Kruskal-Wallis/Spearman rank) p for comparison of PHQ-9 scores between variable categories.

as a confounder as a matter of best practice, despite not meeting all criteria, given its common implication in almost all biological interactions. Predictors were those variables found to be significantly associated with the outcome variable in univariate analysis (Table 1) and that were not confounders. Detected predictors were sex, general health status, self-esteem, regular exercise, frequency of alcohol consumption, and perception of neighborhood safety. Multicollinearity among the included variables was examined based upon tolerance and variance inflation factors. Linear regression was used to examine the association between views of greenness from home and PHQ-9 score. Partially adjusted and fully adjusted models are reported, with the partially adjusted model containing the primary exposure variable and confounders only, and the fully adjusted model containing the primary exposure variable, confounders, and predictors. Results are reported significant at alpha <0.05, and 95% confidence intervals (95% CI) are also provided. Statistical analyses were carried out using SAS statistical software (version 9.4 with SAS/STAT 14.1, SAS Institute Inc., Cary, NC).

RESULTS

The participant mean age was 50.69 years (Table 1; median 53.12; range 28.71–70.36). The majority of the sample was female (60.73%), Caucasian (82.20%), and Non-Hispanic (97.38%). Regarding greenness exposures, 81 (42.41%) stated that they had views of greenness from within their home, 120 (62.83%) agreed that there was an abundance of

Table 2. Descriptive statistics of study population by exposure – views of nature from home (N=191)

Variables	Total n (%)	Views of nature from home		p[a]
		Yes (N=81) n (%)	No (N=110) n (%)	
Age (years), mean ± SD	50.7 ± 12.0	53.6 ± 11.8	48.5 ± 11.8	**0.0032**
BMI (body mass index, kg/m^2), mean ± SD	29.7 ± 6.1	30.0 ± 5.9	29.5 ± 6.4	0.5714
Sex				0.5107
Female	116 (60.7)	47 (58.0)	69 (62.7)	
Male	75 (39.3)	34 (42.0)	41 (37.3)	
Race				0.8251
White/Caucasian	157 (82.2)	67 (82.7)	90 (81.8)	
Black/African-American	26 (13.6)	10 (12.4)	16 (14.5)	
Other	8 (4.2)	4 (4.9)	4 (3.7)	
Ethnicity				0.6520
Non-Hispanic	186 (97.4)	78 (96.3)	108 (98.2)	
Hispanic	5 (2.6)	3 (3.7)	2 (1.8)	
Annual household income before taxes (US$)				**0.0450**
<20000	34 (17.8)	22 (27.2)	12 (10.9)	
20000–44999	55 (28.8)	19 (23.5)	36 (32.7)	
45000–64999	42 (22.0)	17 (21.0)	25 (22.7)	
65000–89999	31 (16.2)	11 (13.5)	20 (18.2)	
90000–124999	26 (13.6)	12 (14.8)	14 (12.8)	
>125000	3 (1.6)	0 (0.0)	3 (2.7)	
Number of people in household				0.5909
1	53 (27.8)	25 (30.9)	28 (25.4)	
2	79 (41.4)	35 (43.2)	44 (40.0)	
3	27 (14.1)	9 (11.1)	18 (16.4)	
4	15 (7.8)	7 (8.6)	8 (7.3)	
≥5	17 (8.9)	5 (6.2)	12 (10.9)	
General health status				0.3840
Poor	1 (0.5)	1 (1.2)	0 (0.0)	
Fair	28 (14.7)	12 (14.8)	16 (14.6)	
Good	83 (43.4)	37 (45.7)	46 (41.8)	
Very good	68 (35.6)	29 (35.8)	39 (35.4)	
Excellent	11 (5.8)	2 (2.5)	9 (8.2)	
Self-esteem				0.3025
1 (lowest)	16 (8.4)	4 (4.9)	12 (10.9)	
2	15 (7.8)	6 (7.4)	9 (8.2)	
3	58 (30.4)	29 (35.8)	29 (26.3)	
4	46 (24.1)	16 (19.8)	30 (27.3)	
5 (highest)	56 (29.3)	26 (32.1)	30 (27.3)	
Exercises regularly				0.1352
Yes	118 (61.8)	55 (67.9)	63 (57.3)	
No	73 (38.2)	26 (32.1)	47 (42.7)	

Continued

Table 2. Continued

Variables	Total n (%)	Views of nature from home		p[a]
		Yes (N=81) n (%)	No (N=110) n (%)	
Frequency of alcohol consumption				0.1748
Never	59 (30.9)	28 (34.6)	31 (28.2)	
Monthly or less	50 (26.2)	21 (25.9)	29 (26.4)	
2–4 times per month	30 (15.7)	14 (17.3)	16 (14.5)	
2–3 times per week	27 (14.1)	13 (16.0)	14 (12.7)	
≥4 times per week	25 (13.1)	5 (6.2)	20 (18.2)	
Perception that neighborhood is safe				0.1779
Strongly agree	4 (2.1)	3 (3.7)	1 (0.9)	
Agree	18 (9.4)	10 (12.4)	8 (7.3)	
Neither agree nor disagree	24 (12.6)	7 (8.6)	17 (15.4)	
Disagree	72 (37.7)	34 (42.0)	38 (34.6)	
Strongly disagree	73 (38.2)	27 (33.3)	46 (41.8)	
Satisfaction with level of greenness in local area				**0.0002**
1 (not at all satisfied)	21 (11.0)	3 (3.7)	18 (16.4)	
2	13 (6.8)	3 (3.7)	10 (9.1)	
3	18 (9.4)	2 (2.5)	16 (14.6)	
4	30 (15.7)	13 (16.0)	17 (15.4)	
5 (neither dissatisfied nor satisfied)	24 (12.6)	10 (12.4)	14 (12.7)	
6	27 (14.1)	12 (14.8)	15 (13.6)	
7	15 (7.9)	7 (8.6)	8 (7.3)	
8	19 (10.0)	14 (17.3)	5 (4.5)	
9	10 (5.2)	8 (9.9)	2 (1.8)	
10 (100% satisfied)	14 (7.3)	9 (11.1)	5 (4.6)	
Perception of abundance of greenery in local area				**<0.0001**
Strongly disagree	20 (10.5)	6 (7.4)	14 (12.7)	
Disagree	51 (26.7)	12 (14.8)	39 (35.5)	
Agree	94 (49.2)	41 (50.6)	53 (48.2)	
Strongly agree	26 (13.6)	22 (27.2)	4 (3.6)	

a Chi-squared/Fisher's exact/t-test p for comparison between views of nature from home categories.

greenery in their neighborhood, and 85 (44.50%) indicated satisfaction with the level of neighborhood greenness. In terms of perceptions of health and health behaviors, 162 (84.82%) were of good or higher general health, 160 (83.8%) were of average or greater self-esteem, and 118 (61.78%) exercised regularly. In PHQ-9 responses, low energy and sleep issues were the most commonly reported concerns (Supplementary file Table 1). Few experienced thoughts of self-harm. Based on overall PHQ-9 scores, 77 (40.31%) participants were found to have depression of some form (Supplementary file Table 2). Of these individuals, 44 (57.14%) had mild depression, 22 (28.57%) had moderate depression, 7 (9.09%) had moderately severe depression, and 4 (5.19%) had severe depression. Multicollinearity was absent from the analysis, as tolerance values were all in excess of 0.57 and variance inflation factors were all 1.76 or below.

Results of the partially and fully adjusted linear regression models are presented in Tables 3 and 4. The primary exposure, views of greenness from within the home, was not found to be significantly associated with depression during univariate analysis; the protective effect of this exposure was also not significant in either the partially adjusted (linear coefficient = -0.80; 95% CI: -2.29 – 0.68) or fully adjusted (linear coefficient = -0.86; 95% CI: -2.07 – 0.35) models.

Interestingly, it was not the abundance or views of greenness that was found to be significantly associated

Table 3. Linear regression examining association between PHQ-9 score and exposure to views of greenness from home – partially adjusted model

Variables	Coefficient	95% CI	p
Views of greenness from within home	-0.80	-2.29 – 0.68	0.2874
Age (years)	0.03	-0.03 – 0.87	0.3417
Annual household income before taxes	-0.71	-1.22 – -0.20	**0.0063**
Satisfaction with level of greenness in local area	-0.42	-0.70 – -0.14	**0.0032**

R^2=0.1082. Adjusted R^2=0.089.

Table 4. Linear regression examining association between PHQ-9 score and exposure to views of greenness from home – fully adjusted model

Variables	Coefficient	95% CI	p
Views of greenness from within home	-0.86	-2.07 – 0.35	0.1611
Age (years)	0.01	-0.03 – 0.06	0.5913
Annual household income before taxes	-0.26	-0.69 – 0.17	0.2271
Satisfaction with level of greenness in local area	-0.21	-0.44 – 0.02	0.0758
Sex	-0.44	-1.59 – 0.71	0.4502
General health status	-1.67	-2.47 – -0.87	**<0.0001**
Self-esteem	-1.50	-2.01 – -0.98	**<0.0001**
Exercises regularly	-0.78	-1.99 – 0.43	0.2057
Frequency of alcohol consumption	-0.04	-0.47 – 0.39	0.8609
Perception that neighborhood is safe	0.31	-0.23 – 0.86	0.2595

R^2=0.4471. Adjusted R^2=0.4164.

with depression, but rather participant satisfaction with the level of greenness in their neighborhood (partially adjusted: linear coefficient = -0.42; 95% CI: -0.70 – 0.14; fully adjusted: linear coefficient = -0.21; 95% CI: -0.44 – 0.02). Perhaps views of greenness are related to satisfaction with the level of greenness, and therefore indirectly associated with depression. For example, univariate (chi-squared, p=0.0002) and crude linear (linear coefficient = 1.97; 95% CI: 1.23–2.68: R^2=0.1383) results suggest such an association between views of greenness and satisfaction with neighborhood greenness level. In the partially adjusted model, the confounder income was found to be significantly associated with the outcome (linear coefficient = -0.71; 95% CI: -1.22 – -0.20), but such a relationship was not observed in the fully adjusted model. In the fully adjusted model, the predictors general health status (linear coefficient = -1.67; 95% CI: -2.47 – -0.87) and self-esteem (linear coefficient = -1.50; 95% CI: -2.01 – -0.98) were significantly associated with the outcome as well.

DISCUSSION

We found that satisfaction with neighborhood greenness was associated with lower rates of depression in an urban population. Although the relationship between views of greenness and depression was not significant, a possible protective association was observed. Perhaps the significance of the association was diminished by the small sample size, reducing power and making type II error more likely; thus, potential associations should be investigated in future research. Additionally, the association between satisfaction with neighborhood greenness and depression highlights the importance of individual perceptions and thus the need to involve community members in urban greening and similar interventions.

In addition to the variable annual household income, which indicated significantly lower PHQ-9 scores in higher income brackets in the partially adjusted model, the predictors general health status and self-esteem scale were found to be significantly associated with the outcome. For each one-level increase in health quality above 'poor', PHQ-9 score was significantly reduced. It is possible that when asked 'In general, would you say your health is …', participants would factor mental health into their responses, but multicollinearity was not found, suggesting that responses to the general health status item were independent of the outcome variable. The significant association between greater health and lower PHQ-9 score suggests that interventions that improve general health could

help in reducing the burden of depression.

For each one-level increase in self-esteem above '1' on the 1–5 scale, PHQ-9 score was significantly reduced. The association between self-esteem and depression is complex; some researchers adhere to the vulnerability model, suggesting that low self-esteem leads to depressive symptoms; others adhere to the scar model, suggesting that depressive symptoms leave 'scars' that ultimately result in lower self-esteem; and others suggest that both models have merit[28-31]. Future longitudinal studies will be better equipped to address these complexities. Self-esteem was independent of the outcome, suggesting the possibility that interventions that build self-esteem could simultaneously reduce the burden of depression.

Although neither the primary exposure nor the perception of abundance of greenness was found to be significantly associated with the outcome, satisfaction with local greenness was significantly associated with reduced PHQ-9 score. Perhaps, rather than being determined by the quantity of greenness present in one's local area or the simple act of viewing natural scenery, one's personal satisfaction with local greenness is more instrumental in alleviating depressive symptoms. Additionally, univariate and crude linear analyses found that views of greenness from home were significantly associated with satisfaction with area greenness, suggesting the possibility that views of greenness may be indirectly associated with depression. Perhaps the primary exposure was not found to be significantly associated with depression due to undetected collinearity. This relationship will need to be further examined in future research focusing on the impact of satisfaction.

Urban greening interventions and exposure to natural settings have been shown to improve many facets of mental health, suggesting they could significantly reduce depression in affected populations[6,26,32]. Given that satisfaction with area greenness was significantly associated with lower PHQ-9 score and that views of greenness from home were significantly associated with increased satisfaction with area greenness, community participation in and feedback on planned interventions seem to be of significant importance. Inclusion of as many voices as possible in intervention planning and implementation may increase the likelihood of satisfaction. As public health officials, policy makers, and urban planners consider modifications to the built and natural environments, satisfaction with greenness should be considered.

Research examining views of greenness and depressive symptoms is sparse and inconclusive[19,24]. Although not significant, study findings point to the possibility of a protective effect between the primary exposure and depression; thus, re-examination of potential associations with larger samples is warranted. Our finding that higher self-esteem is associated with a reduction in PHQ-9 score, and therefore depressive symptoms, is supported by extant literature[33,34]. Though little research has examined the relationship between general health and depression, depression has been found to be higher in those with chronic comorbidities, supporting the finding that greater general health is associated with reduced depressive symptoms[35,36]. Thus, the findings of this study generally align with existing literature and point to areas for future inquiry.

Limitations

Some limitations were present. First, the study is cross-sectional, removing the possibility of assessing causality. Second, recruitment predominately occurred by convenience sampling, which does not ensure a representative sample. Third, questionnaire responses relied on self-reports, making recall bias or misreporting possible. In a related vein, factors, such as overall contentment, optimism, and depression, might have influenced evaluations of greenness. For example, previous work suggests that depressed individuals have lower satisfaction with life, which may, in turn, influence evaluations of greenness[37]. Fourth, weaknesses in the scale employed may have resulted in some cases of depression being undetected[38]. Fifth, aesthetic preferences may influence satisfaction with greenness and ultimately our findings; thus, such preferences may be considerations in future inquiry. Finally, research would benefit from the addition of an objective greening measure, such as the normalized difference vegetation index (NDVI). Despite these limitations, the study findings contribute to the literature on relationships between perceptions of greenness, health characteristics, and depression.

CONCLUSIONS

Although no significant association was found between the primary exposure and outcome, study findings suggest that satisfaction with local greenness is significantly associated with a reduction in PHQ-9 score. Further, greater self-esteem and general health were significantly associated with reduced PHQ-9 score. Though only indicated in the partially adjusted model, elevated income may also be associated with reduced depressive symptoms. Given the pervasiveness of depression in the US population, any interventions capable of lowering disease burden are essential, particularly those that can affect a large number of people. Though increasing overall urban greenness has benefits, the findings suggest that satisfaction with local greenness, rather than the level of greenness, may assist with alleviating depressive symptoms. Therefore, it is especially important that urban greening interventions consider the opinions of community members.

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CONFLICTS OF INTEREST
The authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none was reported.

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Ethical approval was obtained from the University of Louisville Institutional Review Board (IRB), and participant health information protection guidelines were followed as outlined in the Health Insurance Portability and Accountability Act (HIPAA). Participation in the study was voluntary and those who participated gave informed consent.

DATA AVAILABILITY
The data supporting this research are available from the authors on reasonable request.

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