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Title: The Relationship between Self-Reported Exposure to Greenspace and Human Stress in Baltimore, MD

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Abstract

Purpose: A cross-sectional study was used to investigate if greenspace (GS) exposure predicts stress, a known factor affecting health outcomes.

Methods: The study employed an anonymous survey of residents in Baltimore, Maryland, which collected demographic data, measures of GS exposure, recent stressful life events, and incorporated the Perceived Stress Scale (PSS), a validated measure of perceived stress. The sample was constructed using a combination of random and snowball techniques. Multivariable linear regression was used to assess the effect of GS on the magnitude of perceived stress, independent of the base effect of stressful life events and the effects of other covariates.

Results: Three hundred twenty-three complete surveys were received. Respondents spent a mean of 25.5 hours accessing (visual and physical) GS per week. Mean PSS scores were 15.75 for females and 13.45 for males. Controlling for all covariates, we found that one additional hour of GS exposure per week predicted a reduction of .049 in PSS (p=.007). Combined hours of visual and physical access to GS, hours spent only visually accessing GS, and total hours spent outdoors in GS were all statistically significant predictors of PSS scores.

Conclusion: Total hours spent accessing GS both visually and physically was a statistically significant predictor of perceived stress, after controlling for other factors that influence stress. These findings support the plausibility that the stress reducing effects of GS exposure may be part of complex set of factors behind the relationship between GS and health outcomes observed at the community level.

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Highlights

- Each additional hour of greenspace (GS) exposure per week reduces PSS score by 0.05
- Visual exposure to GS alone reduces perceived stress
- Physical exposure to GS alone reduces perceived stress
- Stress reduction may be mechanism in relationship between GS and health outcomes

Introduction

The World Health Organization has identified the social determinants of health, as "mostly responsible for health inequities - the unfair and avoidable differences in health status seen within and between countries" [1]. Factors shaping where we live, work, and play have become increasingly important considerations in health- and design-related fields.

Many studies have revealed a protective relationship between the percentage of greenspace (GS) where a person lives and their actual [2-4] and perceived health [5,6]. Several mechanisms have been postulated to explain the relationship between percentage of neighborhood GS and positive health outcomes including relationships between GS and crime, air quality, and stress. However, studies assessing relationships between GS and both crime and air quality report variability due to qualitative factors that could not be assessed using an area-based metric. For example, while greenspace that does not obstruct visibility has been linked to lower crime rates[7,8] as has greening vacant lots [9], vegetation that obstructs visibility may invite criminal activity[8]. Similarly, while air quality is a factor affecting health outcomes, and trees can reduce air pollutants [10], the siting of trees relative to the pollution source and other factors may interact to determine the degree of benefit if any [11-13].

One possible factor that may explain the GS health relationship observed at the neighborhood level is stress. Stress is a known factor in both the etiology of disease and disease prognosis. Stress can affect health through increasing propensity for behavioral risk factors for disease [14] or through physiologic adaptations caused by the release of stress hormones [15]. Prolonged activation of the stress response increases the risk for permanent effects, contributing to the development of chronic diseases and weakening the body's ability to cope with existing disease [15-17]. Increased levels of stress have been reliably linked to incidence of depression, incidence and mortality from cardiovascular disease, and progression of HIV/AIDs [15].

Potential stress mediating effects of exposure to GS have been noted in both experimental and observational studies. In an experimental study, students exposed to a video stressor were divided into groups that either subsequently viewed natural scenes (including vegetation or vegetation and water) or urban scenes (without vegetation or water). Stress recovery, measured through a variety of physiologic measures and a state affect questionnaire, was more rapid and complete in the group that viewed natural scenes [18]. Similarly, students exposed to a stressor who sat in a room with a view of trees had a more rapid decline in diastolic blood pressure than those who sat in a windowless room [19]. In addition, various physiologic indicators of stress decreased to a greater extent for students when exposed to forested environments than when exposed to urban environments without vegetation [20]. Residents of neighborhoods with a greater percentage of GS had lower chronic stress assessed using salivary cortisol levels, and lower self-reported stress, as measured using the Perceived Stress Scale [21]. Socioeconomic disparities in all-cause mortality rates and mortality due to circulatory diseases, for which stress is a known factor, were also lower in greener neighborhoods [2].

However area-based studies cannot capture variability in exposure due to human behavior, and experimental studies cannot assess if GS is inversely related to chronic stress during day to day life. In addition, even in experimental studies, the variability in quality, density, and type of GS and any difference in stress response are generally not addressed.

The purpose of this cross-sectional study is to investigate if GS exposure is statistically significant in predicting stress, a known factor affecting health outcomes, in a non-hospitalized population going about day to day activities without experimental interference in Baltimore, MD.

Methods

This study employed an anonymous survey of residents in Baltimore, Maryland, which collected demographic data, measures of exposure to GS, an inventory of recent stressful life events, and incorporated the Perceived Stress Scale (PSS), a 10 question validated survey instrument developed to measure individual variability in stress response due to differences in coping strategies and available resources [22]. The institutional review board of SUNY Upstate Medical University (FWA #00005967, IRB #00000391) approved the study following expedited review.

Location Selection

Baltimore was chosen as a study location because it is an urban area with a temperate climate and a wide range of GS availability, as well as documented geographic health disparities [23,24]. In addition, socio-economic, environmental, and health data is made publicly available from multiple sources using the same geographic units called Community Statistical Areas (CSA's). CSA's are aggregates of demographically similar census blocks grouped by neighborhood, compiled by the Baltimore Neighborhood Indicators Alliance (BNIA) at the University of Baltimore's Jacob France Institute (JFI) [25].

Survey Instrument Development

Data were gathered using a survey instrument designed specifically for this study, and distributed both on paper and online. The primary outcome of interest was the respondent score on the PSS. Higher scores on the PSS have been shown to be statistically significant predictors of negative health behaviors using linear regression, including increased fat intake [26], increase in smoking, reduced quitting effectiveness, and reduced exercise [22,26,27], although some studies have noted conflicting results in any observed relationship between PSS scores and exercise habits [26].

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There is also precedent for its use in another study dealing with stress and green space [21]. It has been validated as useful for measuring perceived stress over the past month, and is noted as especially useful for predicting health-related behaviors and outcomes [15,22].

Individuals were asked to report on areas where they either visually or physically access GS around their home, at work and/or school, and during recreation in three separate matrices during the past month, to be consistent with the time period most accurately assessed by the PSS. Instructions defined GS as any outdoor place with plants. "Spending time in" was described as physically being within an outdoor space with vegetation. "Just looking at" was described as viewing a vegetated space without being in it, such as through a window. Respondents were asked to consider their habits in a typical week over the past month, to be consistent with the timeframe of the accuracy for the PSS. Total hours per week in each area were summed to compute hours of exposure per week for each individual, overall and separately for visual and physical exposure.

The newly developed GS exposure questions were pilot-tested in a beta version of the survey instrument among passersby in downtown Syracuse. Initially, indoor plant exposure was included. However, individuals had difficulty accounting for being "in" indoor GS, pointing out the difference between one houseplant and an indoor garden environment. In response to this, the GS exposure questions were revised to focus on outdoor environments, and the language describing "being in" versus "looking at" was revised to include "like through a window" for clarification.

Covariates were selected based on both theory and previous research. Information about basic demographic characteristics, behaviors, and stressful life events was collected to control for their potential confounding effects. Demographic characteristics included gender, age, race, income, employment status and educational attainment and marital status, which have been shown to be associated with differences in mean PSS scores [27,28], and so were measured. Participants were also asked to report on exercise habits (hours of vigorous and moderate exercise per day and number of days per week), and hours spent working and/or in school per week, along with any existing medically diagnosed disease.

Stressful life events were measured using the Recent Life Changes Questionnaire (RLCQ). The RLCQ is an updated (1995) version of the Social Readjustment Rating Scale, which was originally developed in 1965 to measure the impact of various stressful life events on stress and disease [29]. The updated version includes 87 possible events that are weighted and summed to compute a Life Change Units (LCU) Score [29]. The RLCQ contains some events of various magnitudes, including some which may contribute to chronic stress more than a month past the event (death of a spouse, pregnancy, etc.). Therefore respondents were asked to consider events occurring within the past three months.

Data Collection

A power calculation was performed using the G*power 3 calculator [30] using the default small, medium, and large effect sizes for the linear regression, fixed model R^2 increase protocol. Results indicated that for a medium effect size (.15), 230 samples would be needed, and for a large effect size (.35), 109 samples would be needed. There was no precedent for what effect size to expect given these methods, so the goal was to collect as many survey responses as possible.

The survey sample was constructed using a combination of random and snowball techniques. To construct the initial invitee list for the survey, an anonymous list of addresses was obtained from the Baltimore city demographer. Thirty of these addresses were identified from each of the 55 CSA's located within Baltimore, using a random selection process. A total of 1,650 survey packets were mailed to these selected addresses in the spring of 2013. To supplement the initial mailing, a list of community organizations, religious institutions, and schools was also obtained from the city demographer. One of each per CSA was randomly selected, contacted, and asked to distribute the survey. While these organizations were offered paper copies of the survey for their constituents, all who agreed requested a link to the online version instead. In addition, 600-700 flyers were distributed at public places such as bus stops, telephone poles, laundromats, and nearby businesses near randomly-selected locations. Some subjects were provided a hard copy of the survey during distribution of the flyers. Information given verbally was limited to the contents of the consent document and the recruitment letter distributed in the survey. The Baltimore City Office of Planning was also contacted, along with all of the Baltimore City Council members, some of whom agreed to send the web link to their constituents and community organizations. If people asked, they were instructed that it was permissible to forward the link to other potential participants via email, Facebook, or other means. The online survey link was also advertised through Facebook and Twitter pages, including a dedicated Facebook page for the study. To encourage participation, all respondents were offered the opportunity to enter an incentive drawing with one $200 prize, one $100 prize, and four $25 prizes. Identifiable information for the incentive drawing was submitted separately from the de-identified survey response.

Analysis

The effect of GS on the magnitude of perceived stress, independent of the base effect of stressful life events and the effects of other covariates, was assessed principally via multivariable linear regression analysis. Total hours of GS exposure were computed for each respondent.

Following data cleaning, validation of responses for PSS measures was performed by comparing PSS scores from the survey with PSS scores reported in an analysis of three separate

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PSS studies reported by Cohen and Janicki-Deverts (2012). In addition, a linear regression was performed with LCU as a predictor of PSS, controlling for demographic factors known to predict differences in PSS, including race, gender, marital status, and educational attainment, age and hours worked per week. To examine the reliability of subjects' responses to the GS exposure questions, Chi Square analyses were performed to check for agreement between responding "yes" or "no" to "I spend time in greenspace" and reporting any versus no hours of time spent in Greenspace.

Statistical analyses were performed for all models using the statistical software program, SPSS© version 20. Covariates were selected for inclusion in regression analyses if ANOVA analyses showed that they predicted mean differences in GS exposure, PSS (or both), or if other research or theory suggested that they may be important.

The primary analysis involved a series of linear regression models. Model series 1 was exploratory and assessed the association between PSS and total weekly hours spent accessing GS visually and physically. Covariates included gender, race, age, hours spent working/in school per week, household income, number of people in household, marital status, educational attainment, housing type, hours of vigorous exercise per week, CSA homicide rate, hours spent accessing GS in vacant lots, and hours spent socializing in GS. Due to a small number of respondents reporting race other than White or African American, race was classified in regression analysis as White or not white.

Model 1A controlled for hours spent accessing GS in vacant lots as a variable in the model, while Model 1B excluded the number of hours accessing GS in vacant lots from total hours of exposure instead. Model 1A was chosen as a base model since some respondents noted when accounting for hours spent accessing GS on vacant lots, that the space was a community garden. In Baltimore there are resources to help residents utilize vacant lots as community space,

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including various grants and the Adopt a Lot program. For this reason subtracting or otherwise discounting GS exposure resulting from a vacant lot was deemed not appropriate, and results support this assertion.

Using model 1A as a base, three backwards multivariable regression models were constructed to assess whether the hours of GS exposure predicted PSS. After controlling for covariates, model 2 - 4 assessed whether hours of combined visual and physical exposure to GS, hours of only visual exposure to GS, and hours of only physical exposure to GS was statistically significant in predicting PSS, respectively. For Model 2, backwards linear regression was performed on model 1A. For Models 3 & 4, backwards regressions were repeated on Model 1A; substituting total hours of strictly visual exposure to GS for total combined hours (Model 3), and total hours of strictly physical exposure was substituted for total combined hours (Model 4). Additionally, models 2-4 were repeated controlling for recruitment strategy, eliminating outliers that may have overestimated exposure to GS, and isolating respondents that were recruited via random mailing only.

Results

Respondent characteristics

Of 1,650 envelopes mailed out, 126 were returned as undeliverable by the close of the study, leaving 1524 study invitations that may have reached a viable address. From that possible total, 132 complete responses were received via mail, for a mailed response rate of roughly 8.7%. An additional 191 responses were received via electronic means, for a total of 323 responses. Of 323 respondents (including both online and mailed responses) who started the survey, 257 completed it, for a completion rate of 79.5%. Most responses came from the random mailing (40.9%), followed by social media (26.3%) and listserve/meeting (14.2%), while 8.7%

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indicated that they received the survey from a friend, 6.8% indicated they received the survey link via a flyer, and 3.1% indicated "other" (Table 1). The number of potential respondents reached is unknown since packets were mailed to anonymous addresses rather than individuals, and it was not possible to track who saw the online links. Therefore, a true overall response rate could not be calculated. No statistically significant mean differences in either GS exposure or PSS were detected in ANOVA analyses between respondents recruited through different means (Table 2).

Respondents spent a mean of 25.5 hours accessing GS (total of visual and physical access) per week, and exercised vigorously a mean of 4.7 hours per week consumed 5 alcoholic drinks per week, and slept 7 hours per night. The mean PSS score for female respondents was 15.75 and for men was 13.45. This is consistent with PSS scores collected in two large telephone surveys (Harris Poll Survey and eNation Survey) of the non-institutionalized U.S. population 1986, 2006, and 2009, where the mean PSS score ranged from 13.68-16.14 for women and from 12.07-15.52 for men [28] , The mean 3 month LCU score for the sample was 147.3. High recent life stress is generally indicated by a 6 month LCU score of 300, or a 1 year LCU score of 500 [29]

The sample (See Table 3) was skewed in terms of demographics with more individuals reporting white race, higher educational attainment, and higher median income relative to the general population of Baltimore. ANOVA analyses showed no statistically significant differences in GS exposure by these variables, except in the case of race. However, the only statistically significant differences between racial groups in terms of GS exposure was between African American and Asian American/Pacific Islander; the latter a category with a very small numbers.

Responses were received from all but 5 of the 55 CSA's. CSA's with 0 respondents tended to have a greater percentage of African-American residents and a median income more similar to the city as a whole when compared to the CSA's with at least one response. However, responses were returned from individuals living in CSA's that were demographically similar to the city as a whole. The percentage of canopy among CSA's with respondents varied widely, from much less than, similar to, and higher than the city as a whole (Table 4).

Validation and Reliability Results

Validation of the reliability of responses was possible due to the inclusion of the PSS and the Recent Life Changes Questionnaire (RLCQ). Pearson's bivariate correlation analysis revealed that the correlation between the two variables was statistically significant (p = .000, r = .366), and a linear regression model showed an increase in stressful life events (LCU score) were statistically significant in predicting an increase in perceived stress (p= .000; R^2= 0.253). Responses to this survey showed that the directional differences in PSS for demographic categories of age, gender, income, race, and educational attainment were in fact consistent with the results reported in previous studies [27,28].

Chi square analyses (see Table 5) indicated that the proportion of individuals who reported hours of visual exposure after indicating that they could not see GS was low for each area (26.1%, p<.001 around the home, 9.8%, p<.001 around school/work, and 8.3% p<.001 during recreation). Similarly, few people reported hours of physical exposure to GS after indicating that they did not spend time in GS for each area (33.3%, p<.001 around the home, 8.0% , p<.001 at school/work, and 13.8%, p<.001 during recreation) The proportion of individuals indicating they had no visual or physical access to GS and reported hours for either, was lower (9.1%, p<.001 around the home, 2.1%, p<.001 at school/work, and 12.0%, p<.001

during recreation). There was statistically significant and high level of agreement between answering "yes" to ability to see GS and reporting hours of visual exposure (70.0%, p<.001 around the home, 66.0% , p<.001 at school/work, and 53.5%, p<.001 during recreation). Complete agreement is not expected, since having visual access and visually accessing GS is not exactly the same. Higher levels of agreement were noted between those who affirmed spending time in GS and then reported hours of physical exposure (83.5%, p<.001 around the home, 71.8%, p<.001 at school/work, and 74.1%, p<.001 during recreation). There was also a high level of statistically significant agreement for those reporting yes to having either visual or physical access, and reporting hours for any location (86.8%, p<.001 around the home, 83.5% , p<.001 at school/work, and 83.8%, p<.001 during recreation). Results support a good level of confidence that most people understood the question and reported accordingly.

Multivariable Analysis – Model 1

Model 1A (See Table 6) included all covariates to evaluate the relationship between hours of GS exposure and PSS. Only LCU score, household income, hours of weekly exercise, and hours spent accessing GS remained statistically significant. All relationships for covariates reflected directional trends supported by literature and theory. Model 1A explained 31.7% of the variance in PSS. Controlling for all covariates, Model 1A found that one additional hour of GS exposure per week (inclusive of both physical and visual exposure) predicted a reduction of.049 in PSS (p=.007). Model 1A was used as the base for all subsequent models.

Multivariable Analysis - Models 2-4

Combined hours of visual and physical access to GS, hours spent only visually accessing GS, and total hours spent outdoors in GS were all statistically significant predictors of PSS scores, controlling for the effects of race, gender, income, marital status, age, stressful life events, exercise habits, CSA level homicide rate, educational attainment, and housing type (Table 7). Model 2 found that combined hours of visual and physical exposure to GS was statistically significant in predicting reductions in PSS (-.042, p=.002). Model 3 found that total hours of visual exposure to GS was statistically significant in predicting reductions in PSS (-.052, p=.008), and Model 4 found that total hours of physical exposure to GS also predicted reductions in PSS (-.065, p=.017). After backwards regression, many of the same covariates remained statistically significant with similar beta coefficients for each of the three models.

Additional Follow-up Analyses

Models 2-4 were repeated controlling for recruitment strategy and excluding potential over estimators to test for robustness and the impact of potential biases. Potential over estimators were classified as individuals who reported over 112 average weekly hours of GS exposure per week (assuming GS exposure wasn't possible during 8 hours of each day required for sleep). This resulted in the exclusion of 7 individuals for combined exposure and one individual for visual exposure, and 0 individuals for physical exposure. One hour of combined weekly GS exposure (-.074, p=.001), one hour of weekly visual GS exposure (-.076, p=.001), and one hour of weekly physical GS exposure (-.065, p=.017) all remained statistically significant in predicting reductions in PSS. These additional controls and exclusions resulted in an increase in effect size for hours of combined GS exposure and visual GS exposure, overall and relative to both exercise and income. Recruitment strategy was not a statistically significant in predicting PSS for any of the models and was excluded in backwards regression in all models. Therefore results for physical exposure to GS were not affected by these additional controls and exclusions

As an alternate method of controlling for recruitment, Models 2-4 were performed isolating respondents recruited by mail and excluding potential over-estimators, since the mailing represented a random distribution method and the largest group of respondents by distribution strategy. This resulted in a much smaller sample size of 100 individuals. Only hours of physical GS exposure were statistically significant at less than a 5% level (-.086, p=.033). However total combined hours (-.56, p=.067) and visual hours (-.056, p=.080) continued to predict reductions in PSS similar in direction and magnitude to Models 2-4, and were statistically significant at a less than 10% level.

Discussion

The results of these analyses show that an increase in hours of GS exposure reliably predicts a statistically significant reduction in perceived stress in a non-hospitalized population without experimental interference in Baltimore, MD. The inverse relationship between all investigated types of GS exposure and PSS score was both statistically significant and robust. An increase in hours of visual and physical exposure to GS was consistently statistically significant in predicting reductions in PSS in a similar magnitude and direction across models. Stressful life events, income, educational attainment, and hours of vigorous weekly exercise were also consistently statistically significant across models and varied in the direction expected, supporting the validity of the model.

Controlling for all covariates initially considered, Model 1A found that one additional hour of GS exposure per week (inclusive of both physical and visual exposure) predicted a reduction of.049 in PSS (p=.007). This is a reduction equivalent to making about $2,882 more per year, or vigorously exercising about 37 additional minutes per week. In Models 2-4, including further refined covariates, similar equivalencies were noted. One hour of combined visual and physical exposure to GS per week was equivalent in to an additional $2,210 in annual household income or 35 minutes of vigorous exercise per week in terms of reducing perceived stress (Model 2); one additional hour of visual exposure to GS per week was equivalent in terms of reduction of perceived stress to an additional $2737 of annual income or 45 minutes of vigorous exercise per week (Model 3); and one weekly hour spent outdoors in GS had the greatest effect size with a reduction in perceived stress equivalent to an additional $3,611 of annual income, or 47 minutes of vigorous exercise per week (Model 4).

In sum, these results show that an increase in hours of physical and/or visual exposure to GS is statistically significant in predicting reductions in perceived stress, controlling for other covariates known to predict stress. This adds to the body of literature supporting that GS exposure is part of a complex set of factors that predict how an individual responds to stress, and that GS exposure is a plausible mechanism behind the observed relationship between GS and health. As such, the results of this study have many implications for planners/designers, researchers, and health practitioners.

For planners and designers, the conclusions of this research are relevant because consideration of interactions between the physical environment and human social and behavioral factors is crucial in order to create environments that support ecological and human health. This research further supports the conclusion that access to areas with GS may be important to human health and wellbeing. Since both visual and physical access to GS were found to be important factors for reducing stress based on our sample, it is important for designers to consider the many ways in which access to GS can be achieved in a way that is safe and appropriate for site users. Efforts to increase availability and accessibility of GS in an urban environment can have multiple benefits, and readily align with already existing municipal goals such as mitigating stormwater, creating complete transportation and recreation networks, mitigating brownfields, and creating health supporting environments for residents of very urbanized areas. Opportunities to improve access to GS through both programming and site design should be considered.

For researchers, there are several specific areas for further research called for following this study. For instance, the population that responded to this survey was not representative of the city of Baltimore in terms of demographics. The complexity and length of the survey may have contributed to this issue. Repeating this study with a simplified survey, focused mainly on covariates consistently found to be statistically significant in all models, along with additional efforts to include participants from underrepresented groups is warranted. Additionally, this and other similar studies have been cited in temperate regions [2,3,21,31,32]; repeating measures in non-temperate regions (such as in desert or extreme northern environments) may provide additional insight into the relationship between GS and stress, in areas where what constitutes "green" space may be defined differently. Furthermore, Baltimore is one of two cities participating in the National Science Foundation's Long Term Ecological Research Network (LTER). The other urban location is Phoenix, AZ, where GS typically present in temperate climates is sometimes created and supported through irrigation. It would be interesting to assess whether a similar inverse relationship between stress and GS could be observed through exposure to other types of naturalistic environments, or only in areas with verdant "green" masses of vegetation typically present in temperate climates. There may be important implications regarding sustainability and the use of native vegetation in arid environments.

For health practitioners, this research offers evidence to suggest that including GS through programming and environmental design may be an important factor that could support existing health efforts. Increasing access to GS can occur through either the design of new facilities, or by incorporating appropriate visual or physical access to GS as appropriate based on the particular needs of the general or patient population. Increased exposure to GS can be incorporated into existing programs, facility design, and through patient education. Furthermore, GS exposure as a variable may be an important factor to assess during development of facility and program evaluation protocols.

Perhaps the greatest implication is for multidisciplinary collaboration in urban environments like Baltimore where there is a potential to assess the distribution of available and accessible GS across a city as part of a larger plan to create health supporting urban environments. In urban environments especially, differences in physical ability, access to transportation, and even available leisure time due to economic constraints and other obligations can limit an individual's ability to access GS on a day-to-day basis and should be considered. Especially where there are stark geographic disparities in health, multidisciplinary collaboration to ensure that the physical environment in all neighborhoods includes opportunities to reduce stress and promote health is crucial to support, rather than act as a barrier, to other important programmatic efforts.

Limitations

It is important to state that the results of this study are not sufficient to support a conclusive finding that a causal relationship exists, since this was a cross sectional study utilizing a non-representative convenience sample in one city. However, experimental studies showing a reduction in stress when exposed to greener or more natural [18,19] areas support the likelihood that GS exposure is affecting stress outcome rather than the other way around. Additionally, studies dealing with university populations, similar to this sample in terms of educational status, generally indicate people tend to seek out GS when dealing with stress [33]. These statements together make it unlikely that the results of this study can be simply explained by an inverse hypothesis, i.e. that people with more stress avoid or otherwise do not have access to GS, especially when controlling for the wide array of covariates in this analysis. The relationship observed in this study is consistent in terms of directionality with other studies comparing GS and other health outcomes [2,4]. The relationship between GS and PSS scores noted in this body of research is substantial and within reason.

This study used multiple recruiting strategies to attain a sample. Differences between groups recruited via various means could have an impact on the relationship studied. However, the inverse relationship observed in the original Models 2-4 remained consistent when controlling for recruitment strategy in regression, even when removing over-estimators. While hours of exposure to GS when isolating the mailed recruit only sample was only statistically significant for physical exposure, this is likely a result of the reduction in sample size to less than half the full sample. Effect sizes remained similar to the original model, and p-values indicated significance at the 10% level. Given this, and the lack of significance for any of the recruitment variables when controlled for in regression, the reduction in statistical significance is likely the result of an insufficient sample size rather than any real difference in the mail based respondents, supporting the acceptability of combining the multiple strategies.

It is possible that people who valued GS were more likely to respond to this survey. However, the included incentives, and the variety of sampling strategies which emphasized random selection partially reduced sampling bias. Furthermore, this sample included individuals with a wide range of GS exposures, so if it did occur to some extent, it is unlikely to have had a large effect on the results. It is equally likely, given the skew in terms of educational attainment and the lack of statistically significant differences in GS exposure between demographic groups, that those who had completed a thesis or other research were more likely to assist in a research study.

The results of this study cannot definitively conclude that this relationship applies to the larger population of Baltimore due to a skew in terms of income, race, and educational attainment relative to the city as a whole. However, it is important to recognize that this relationship is likely applicable even to under-sampled demographic groups for several reasons. First, while stress is known to differ based on a variety of demographic variables, variation in mean GS exposure in this sample was not statistically significant based on income, race as categorized in analysis, or educational attainment. Second, research has supported the conclusion that protective relationships observed between available GS in one's neighborhood on health outcomes [2,3] and stress [21] were stronger for those in lower income groups, which were under-sampled in this study. Third, while variations in landscape preference between ethnic and socioeconomically distinct groups have been noted [34,35], having access to spaces including nature is highly valued even across distinct groups [34]. Future research on this relationship is warranted for underrepresented groups.

While the results of models 2-4 suggest that that spending time in GS may predict a greater reduction in perceived stress than strictly visual access, caution should be used when interpreting these results. Despite a high degree of agreement in the actual reporting of hours for each matrix based on check questions, it may be easier to account for time that one spends outdoors in GS than it is to account for time spent visually accessing it. This self-reported data collection method is not sufficient to say that one is more valuable than the other, and future studies are recommended. Importantly, both visual and physical hours are independently statistically significant and reasonably similar in predicting reductions in PSS, indicating a robust relationship.

This study found that hours of GS exposure was statistically significant in predicting PSS. However, it was not able to produce conclusive evidence about the effect of the magnitude, density, or variability of vegetation present. Experimental studies monitoring stress response

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related to various or configurations of GS may be useful for future research.

Importantly, the results of this study and subsequent research addressing this relationship cannot replace the need to assess stakeholder attitudes towards GS in any design or planning project. While the results of this study in the context of other research suggest that including areas with accessible GS is likely very important for coping with stress, the role of perceptions of lack of control in decision-making with regards to one's environment should never be ignored.

Conclusion

Based on the sample, the number of hours spent accessing GS both visually and physically was statistically significant in predicting perceived stress, after controlling for stressful life events, demographics, housing type, exercise, and hours of GS time due to socializing and vacant lots. In the context of other research, this supports that it is plausible that the stress reducing effects of GS exposure may be part of complex set of factors behind the relationship between GS and health outcomes observed at the community level. Further research to assess whether this relationship can be applied to other populations is recommended, as results can have far reaching implications for planners, researchers, and health practitioners as interest in multidisciplinary design advances, especially in urban areas.

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Table 1.
Frequencies and percentages of survey responses by mode of contact.

Mode of Contact	Number of Responses	Percent of Total Responses
Mail	132	40.9 %
Meeting / Listserve	46	14.2 %
Social Media	85	26.3 %
Friend	28	8.7 %
Flyer	22	6.8 %
Other	10	3.1 %
Total	323	100.0 %

Table 2.
ANOVA results for total hours in Greenspace (GS) and Perceived Stress Scale (PSS) scores by sample characteristics.

Variable	ANOVA p-value for GS Total Hours	ANOVA p-value for PSS Score
Mode of Contact	0.099	0.503
Age	0.874	<0.001
Gender	0.585	0.006
Race/Ethnicity	0.040	0.021
Educational Attainment	0.937	0.004
Income Quintiles	0.703	0.021
Marital Status	0.006	0.047
Housing Type	0.008	0.024
Owner/Renter	0.270	<0.001
Life Change Units (LCU) Quintiles	NA	<0.001
GS Total Hours Quintiles	NA	0.034

Note. NA = not applicable.

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Table 3.
Demographic characteristics of the study sample and the city of Baltimore.

Characteristic	Number in Sample (N = 323)	Percent of Sample	Percent of City of Baltimore
Gender[a]			
Male	97	33.5	47.1
Female	192	66.4	52.9
Age in Years[b]			
18-24	23	7.8	16.0
25-44	151	51.0	37.0
45-64	92	31.1	32.1
65+	30	10.1	14.9
Race[c]			
White	241	80.3	29.6
African American	41	13.7	63.7
Asian/Pacific Islander	4	1.3	2.3
Native American	1	0.3	0.4
Other	13	4.3	1.8
Ethnicity[d]			
Hispanic	9	3.2	4.2
Educational Attainment[e]			
High School Graduate or Less	53	17.8	48.8
Trade or Associates Degree or Some College	15	5.1	23.5
Bachelors Degree	99	33.3	14.6
Graduate School	130	43.8	13.1
Median Household Income		$70,000	$41,819

Note: Baltimore city data obtained from: U.S. Census Bureau; using *American FactFinder*; http://factfinder2.census.gov; (20 July 2016). NA = not available.
[a]Gender is missing for 33 sample subjects and 1 subject reported 'Other'. [b]Age is missing for 27 sample subjects. [c]Race is missing for 23 subjects. [d]Ethnicity is missing for 41 subjects. [e]Educational attainment is missing for 26 subjects.

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Table 4.
Comparison of characteristics of the city of Baltimore overall, and by census supervisory areas (CSAs) with 0, approximately 10, and approximately 30 sample respondents.

Area	Median Income ($)	Vacant Building Density[a]	Homicide Rate[a]	% ≤High School	% African-American	% Canopy	% GS
City of Baltimore	37,395	567.2	20.9	52.6	63.6	27.4	NA
CSAs with 0 Respondents							
Claremont/Armistead	30,606	0.0	14.6	67.5	53.7	28.0	53.7
Gr.Mondawmin	34,438	844.9	31.1	61.6	96.7	22.4	46.4
Howard Park/West Arlington	36,662	128.2	15.6	51.9	94.9	39.2	67.3
Sandtown-Winchester/Harlem Park	22,277	2411.5	45.3	75.5	96.9	15.4	30.3
Westport/Mt. Winans/Lakeland	37,678	572.0	26.7	72.5	66.1	22.1	44.4
CSAs with Approximately 10 Respondents							
Belair Edison	43,769	152.1	24.1	63.2	87.3	28.0	53.7
Canton	77,222	94.5	2.5	25.8	4.1	9.6	31.4
Fells Point	62,185	92.9	8.9	28.3	8.0	7.2	9.9
Hamilton	51,668	26.7	3.1	45.8	56.7	34.0	59.8
Lauraville	55,122	55.5	15.5	41.4	58.3	40.0	66.7
Midtown	33,303	178.0	11.5	32.2	34.3	13.0	19.2
Patterson Park N&E	44,252	688.4	20.6	59.9	38.7	5.2	12.4
South Baltimore	69,625	103.7	0.0	35.5	2.7	5.1	24.2
Waverlies	33,239	239.6	21.9	55.3	79.5	19.4	4.7
CSAs with Approximately 30 Respondents							
Greater Charles Village/Barclay	32,258	434.6	20.7	35.2	35.0	23.1	34.9
Greater Roland Park/Poplar	90,492	8.2	4.1	8.2	7.6	58.6	79.3
Medfield/Hampden/Woodberry/Remington	47,759	89.9	10.9	40.5	11.9	31.7	47.9

Note. Summarized from *Baltimore Neighborhood Health Profiles 2011* (Ames et al., 2011) and canopy/GS data provided by U.S. Forest Service data--2007. GS = Greenspace. NA = not available.
[a]Per 10,000.

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Table 5.
Reliability of percent of respondents who report hours of visual exposure to Greenspace (GS) with reported ability to see GS and time spent in GS.

Report of Any Hours of Visual Exposure to GS	**Can See GS**			**Spends time in GS**			**Can See or Spends Time in GS**		
	Yes	No	P-value	Yes	No	P-value	Yes	No	P-value
Around the Home									
Total (N)	267	23	<0.001	254	33	<0.001	281	11	<0.001
Yes (%)	70.0	26.1		83.5	33.3		86.8	9.1	
No (%)	30.0	73.9		16.5	66.7		13.2	90.9	
At School / Work									
Total (N)	151	61	<0.001	103	100	<0.001	170	48	<0.001
Yes (%)	66.0	9.8		71.8	8.0		83.5	2.1	
No (%)	34.0	90.2		28.2	92.0		16.5	97.9	
During Recreation									
Total (N)	127	84	<0.001	197	58	<0.001	216	50	<0.001
Yes (%)	53.5	8.3		74.1	13.8		83.8	12.0	
No (%)	46.5	91.7		25.9	86.2		16.2	88.0	

Note. All p-values are from chi-square statistics.

Table 6.
Multivariable linear regression results for Model 1A predicting Perceived Stress Scale (PSS) score.

Predictor	Beta Coefficient	Standard Error	P-value
Life Change Unit (LCU) Score	0.017	0.003	<0.001
Male	-0.681	0.925	0.462
White	-0.337	1.310	0.797
Age	-0.061	0.036	0.092
Hours of Work and School per Week	-0.001	0.024	0.969
Household income per $1000	-0.017	0.007	0.024
Number of Persons in Household	0.703	0.389	0.072
Single	1.635	1.143	0.154
Divorced/Separated	0.712	1.472	0.629
Widowed	1.892	3.594	0.599
≤ High School Education	2.484	1.421	0.082
Associates Degree/Trade/Some College	0.666	2.214	0.764
Graduate School	-0.063	0.934	0.946
Multi-Story Apartment	-1.200	1.495	0.423
Single Story Apartment	-0.302	3.031	0.921
Rowhouse/Townhouse	-0.481	1.055	0.649
Multi-Family Detached House	-0.668	2.201	0.762
Hours/Week of Vigorous Exercise	-0.079	0.038	0.040
CSA Homicide Rate per 10,000	-0.018	0.037	0.627
Total Hours Exposed to GS/Week	-0.049	0.018	0.007
Total Hours Exposed to GS/Week Minus Socializing	-0.005	0.100	0.962
Total Hours Exposed to GS/Seek Minus Time Spent in Vacant Lots	0.098	0.009	0.324

Note. R^2=0.317. CSA = Census Service Area.

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Table 7.
Multivariable linear regression results for Models 2- 4 predicting Perceived Stress Scale (PSS) score.

Predictor	Beta Coefficient	Standard Error	P-value
Model 2[a]			
• Life Change Unit (LCU) Score	0.018	0.003	<0.001
• Age	-0.060	0.028	0.036
• Household income per $1000	-0.019	0.007	0.004
• Number of Persons in Household	0.553	0.333	0.099
• ≤ High School Education	2.630	1.135	0.021
• Hours/Week of Vigorous Exercise	-0.072	0.035	0.041
• Total Hours Exposed to GS/Week	-0.042	0.013	0.002
Model 3[b]			
• LCU Score	0.017	0.003	<0.001
• Age	-0.067	0.028	0.019
• Household income per $1000	-0.019	0.007	0.004
• Number of Persons in Household	0.573	0.336	0.089
• ≤ High School Education	2.502	1.143	0.030
• Hours/Week of Vigorous Exercise	-0.070	0.035	0.049
• Total Hours Visual Exposure to GS per Week	-0.052	0.019	0.008
Model 4[c]			
• LCU Score	0.017	0.003	<0.001
• Household income per $1000	-0.018	0.007	0.008
• Number of Persons in Household	0.842	0.358	0.019
• Single	2.084	0.973	0.033
• ≤ High School Education	2.583	1.142	0.025
• Hours/Week of Vigorous Exercise	-0.083	0.036	0.022
• Total Hours Spent in GS/Week	-0.065	0.027	0.017

Note. [a]R^2=0.288. [b]R^2=0.286. [c]R^2=0.286.

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