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Research Article

Data Science-Driven Mechanisms of Green Environments and Public Health: Modeling and Validation from a Social Psychology Perspective

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ABSTRACT

Increased rate of urbanization has increased the importance of the green environment as a population health determinant. Even though the existing literature acknowledges such benefits as the decrease in mortality rates and improved mental well-being, the mechanisms of their mediation are poorly comprehended. This research combines the concept of social psychology and the data science modelling to examine how the access, quality and use of green-space affect the perceived health benefits and quality of life. A stratified survey (N 100) was conducted through stratified sampling to ensure demographic representativeness. The internal consistency of the constructs of the accessibility, environmental perceptions, psychological outcomes, and demographic variables were tested, and the Cronbach alpha value was above 0.80. Regression methods that were used included multiple regression, mediation analysis, and structural equation modeling (SEM). The results indicated that access and quality as independent variables were found to be weak predictors; the utilization frequency and perceived air quality as dependent variables were found to have a modest but statistically significant influence. The mediation analysis and SEM supported the stress alleviation and mood uplifting as the most significant mediating variables between the green-space exposure and the health outcomes (CFI equals 0.95, RMSEA equals 0.045). Majority of the explained variance was attributed to psychological restoration which is beyond just being proximate together. The research highlights the necessity of the need that urban planning must focus on design strategies that enhance social interaction and help in recovering the stress. Some of the weaknesses include the small sample size and limited generalizability, hence the recommendation of the inclusion of large, longitudinal datasets in future research.

Keywords: Data science; stress reduction; urbanization; public health; and mental health

1. Introduction

The process of urbanization has intensified the conversation about how commonplace encounters with green spaces impact population health outcomes. According to recent meta-analyses, exposure to green spaces is strongly correlated with better mental well-being, reduced rates of all-cause mortality, better cardio metabolic indices, and high self-rated health and well-being [1-3]. Modern theoretical explanations hypothesize that a combination of several mechanisms, such as the restoration of cognitive resources and

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affective states, mitigation of environmental stressors (air pollution and heat), increased physical activity (i.e., "instoration") opportunity, and strengthened social cohesion, all lead to perceived stress reductions, mood improvement, and strengthened social connectedness[1,4,5]. This study applies these processes to develop a model to outline how access to, quality of, and use of green spaces is converted into perceived health benefits and improved quality of life and whether psychological processes are mediators and demographic variables are moderators of these relationships.

The epidemiologic evidence base has gone further than the measure based on proximity. Large prospective cohort analyses show that higher residential greenness predicts lower all-cause mortality even after extensive confounding control[2]. Developmental research links sustained green exposure to improved cognitive development in children, suggesting relevance across the life course[6]. Meta-analytic results also show that green space exposure is linked to the lower risk of various negative outcomes, including type II diabetes, heart-related death, and poor mental health, and therefore demonstrate broad-spectrum benefits[3]. Dose-response relations between nature contact and mental advantages are supported by experimental and quasi-experimental contributions and offer useful insights on the question of how much is enough[7,8]. However, numerous researches still use crude measures, including NDVI buffers, which underrepresent experiential factors, including safety, amenities, aesthetic coherence, and apparent air quality and behavioural interest (visit frequency), which are important in perceived health benefits and quality of life.

Mechanistically, the modern systems tend to be united at four overlapping levels: mitigation (e.g., pollutant removal, heat moderation), restoration (e.g., stress reduction, attentional replenishment), instauration (e.g., chances of physical exercises and competence-building), as well as social cohesion[4]. Plants are able to turn around the quality of ambient air and reduce exposures to pollutants and transfer these into cardiopulmonary benefits[3]. Nature contact is psychologically beneficial and assists in quick affective healing and attentional rejuvenation and is expressed in the perceived reduction of stress and improved mood[1,5]. A sense of belongingness and place attachment are examples of social-psychological mechanisms that may support the repetition of use and increase well-being effects that may plausibly mediate between exposure and perceived health benefits[9,10]. The constructs that are under test based on the theoretical framework are Access and Quality of Green Spaces, Visit Frequency, Air Quality Perception, Stress Reduction, Mood Improvement, Social Connections / Sense of Belonging, Perceived Health Benefits, and Quality of Life.

The paper is based on three conceptual premises: (1) design parameters of green spaces; (2) mechanistic pathways of mitigation, restoration, instauration, and social cohesion; and (3) an integrated theoretical framework between the relationship between green exposure and stress mitigation, mood enhancement, social and perceived health benefits. All these constitute the basis of the hypotheses and the modeling direction. All parameters, including access, quality, and utilization, were selected due to the observation that previous studies reveal a specific impact of the psychological and behavioural activity in green environments[1,4]. The current study, therefore, puts the factors into a single causal model that explains the direct and indirect routes between exposure and well-being.

One of the main areas of research is to break down the constructs of access, quality and use to identify their distinct contribution. It can be operationalized in ways of access with respect to spatial (distance, connectivity), temporal (operating hours, seasonality), and economic (cost) aspects of accessibility; quality has attributes of safety, maintenance, biodiversity, and amenity which together are likely to have more impact on perceived benefits than proximity itself. Visit frequency is a proxy of dose and temporal regularity of nature contact and empirical data have shown a threshold and non-linear dose response association).

Notably, not everybody has equal access to benefits. The effects may be moderated by demographic and socioeconomic factors: age, gender, socioeconomic status, and neighborhood disadvantage may affect them through mobility limits, time restrictions, perceptions of safety, and culturally mediated senses of nature[11] This heterogeneity highlights the need to specifically moderate and moderate-mediation analyses in order to explain to whom and by what mechanisms green environments bring social and health dividends.

Objective exposure can be quantified using remote sensing (e.g., NDVI), land-cover inventories, and micro-scale indicators; behavioral engagement can be indexed by mobility traces or self-reported visit frequency; and psychometrically validated scales can measure perceived access/quality, air quality perception, stress reduction, mood, social connections, and health benefits. Multilevel modeling and structural equation modeling (SEM) enable simultaneous tests of mediation (e.g., stress reduction, mood improvement, and belonging) and moderation by demographics, with appropriate handling of clustering and spatial autocorrelation. Contemporary best practices include split-sample cross-validation for predictive generalization, measurement invariance testing to ensure construct comparability across demographic strata, and sensitivity analyses to alternative exposure operationalization[12,13]. Complementarily, natural language processing can distill unstructured textual corpora policy documents, community feedback, and local news into domain-relevant summaries that contextualize quantitative findings. Recent advances in domain-specific, multi-document summarization using transformer architectures and adversarial training provide scalable synthesis for environmental and public health narratives [14]. Integrating such NLP outputs with quantitative models can enhance construct validity (e.g., triangulating perceived quality and belonging) and support model-based validation.

Three gaps motivate the present study from a social psychology perspective. First, few analyses jointly estimate the unique and combined effects of access, perceived quality, and visit frequency on perceived health benefits and overall quality of life while simultaneously incorporating perceived air quality. Second, psychological mediators are often examined in isolation rather than as a coordinated latent pathway, limiting precision about how green exposure translates into health benefits. Third, demographic heterogeneity remains under-characterized; formal moderated mediation is rarely implemented to quantify how demographic factors shape the links between green space usage, social connections, and well-being, and measurement invariance is seldom established prior to cross-group comparisons[15]. The complexity of the exposure experience-benefit chain should warrant the integrated modeling and data fusion strategies to address these gaps.

Based on this, the given study combines objective environmental indicators and self-reported exposure, perceptions, and psychosocial constructs, and uses the data science-based modeling and validation to answer the following research questions:

- RQ1: What are the joint effects of the structural characteristics of green spaces-access, quality and use on perceived health benefits and quality of life?
- RQ2: How do the green spaces have their impact on health through what psychological processes? So, in particular, are there stress reduction, mood improvement, and sense of belonging between exposure to green space and perceived health benefits?
- RQ3: What are the demographic factors age, gender, income, and education that moderate these mediated relationships? Simply put, by which degree do the demographic variables moderate mediating mechanisms between the exposure to green and psychological restoration and well-being?

Having explicitly modeled mediated psychological processes and demographic moderation in a thorough data science framework, this paper seeks to explain the causal pathways, leverage points on equitable intervention, and design and programming of urban green infrastructure to maximize its effects on the health of the population.

2. Materials and methods

This review synthesizes contemporary evidence on how green environments influence public health from a social psychology perspective, organized into six domains: (1) conceptual frameworks and empirical foundations; (2) operationalizing exposure access, quality, and use; (3) psychological and social pathways; (4) environmental mitigation pathways and perceptions; (5) equity, demographic moderators, and contextual heterogeneity; and (6) data science approaches for modeling, validation, and evidence synthesis.

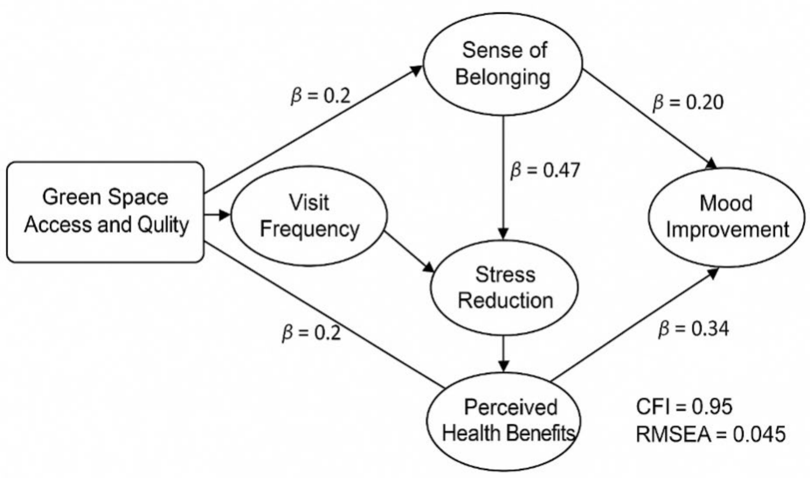

Figure 1. The framework of plausible pathways linking green space to public health, based principally on high- frequency keyword and cluster analysis

2.1. Conceptual frameworks and empirical foundations

The impact of green spaces on health through restoration, mitigation, instauration, and social cohesion pathways has been described by convergent frameworks within the past ten years[16]. These frameworks align with core psychological constructs stress reduction, mood improvement, and sense of belonging and with downstream outcomes including perceived health benefits and quality of life. Recent syntheses argue for integrating subjective experiences with objective exposures to capture the full exposure–experience benefit chain[17,18].

Empirically, large-scale cohort and quasi-experimental studies show that residential greenness and park availability are associated with lower all-cause mortality, improved mental health, and better cardio metabolic profiles. In the Nurses' Health Study, greater long-term greenness exposure was associated with lower mortality after adjusting for socioeconomic and behavioral covariates. A meta-analysis of over 140 studies showed that being exposed to a green space is significantly associated with lower rates of type II diabetes, cardiovascular mortality, and unfavorable mental health outcomes. Green-space exposure has been found to positively influence cognitive ability among children and reduce the probability of psychiatric disease in adulthood because of green childhood experiences[19]. The longitudinal designs of natural experiments indicate the long-term positive changes in mental health after moving to greener neighborhood's[20], and the population-based studies indicate dose-response relationships between the times spent in nature and self-reported health and well-being metrics. Taken together, this body of evidence highlights the credibility of the possible, and the importance of green environments to human populations, which in turn encourages more of the modelling, in smaller steps, of how access, quality, and utilization are then converted to assessed health gains and quality of life.

The model proposed has three associated elements. To begin with, the opportunity to exposure is determined by the structural access and quality. Second, utilization, which is operationalized as visit frequency, is an aspect of behavioural engagement. Third, such experiences cause psychological processes, namely, stress recovery, mood enhancement, and belonging that mediate the differences in perceived health and life satisfaction. The Confirmatory Factor Analysis (CFA) was used to validate this reflective model structure before the estimation of the structural relationships was done using Structural Equation Modelling (SEM).

2.2. Operationalizing green exposure: access, quality, and use

In addition to coarse proximity metrics, exposure measurement now includes behavioral engagement indicators, micro-scale streetscape greenery, and multi-scale vegetation indices[21]. Although street-level "green view" metrics derived from images provide exposure estimates relevant to everyday experiences at the human eye level, the Normalized Difference Vegetation Index (NDVI) and related remote sensing measures capture landscape greenness and are widely validated as exposure proxies.

2.3. Social and psychological routes: Mediators of the exposure-health association

Empirical evidence shows that the cognitive control is enhanced and stress and negative affect are reduced in an almost instantaneous manner in response to exposure to natural environments, which aligns with restorative dynamics. Field experiments and ambulatory sensing reveal a reduction in stress biomarkers and rumination when exposed to natural environments as opposed to urban ones[22]. The present study identified mood enhancement and perceived stress reduction as important mediators, and these effects are associated with these factors. The feeling of belonging and connection to a location leads to positive feedback loops that promote an increase in the frequency of visits and outcomes of well-being.

2.4. Environment mitigation

Urban tree canopies can play the roles of attenuating the concentration of particulate matter and ozone precursors, changing the pattern of pollution dispersion, and thermal buffering. Taken together, these impacts lead to a decrease in the cardiopulmonary morbidity and heat-related morbidity[23]. Mitigation mechanisms can function alongside, and can interact with, psychological mechanisms; an example is that the experience of air quality can lead to reduced risk appraisals and stress, and in cooler shaded environments dwell time and social interaction may be increased.

More importantly, perceived air quality can have no correspondence with instrumental measurements but have strong behavior and well-being implications. The approach avoidance processes can also mediate the effect of perception based pathways on visit frequency and the perception based pathways can exert an independent effect on affective states independent of the physical pollutant concentrations and as such mediate the association between exposure and perceived health benefits. The objective-perceived environmental quality studies show that subjective appraisals can help explain more of the health outcomes, which cannot be measured physically, which supports the importance of modeling perception as a specific construct and not a proxy in relation to exposure. Practically, the harmonization of remotely sensed and in-situ air-quality data and well-verified perceptions of air-quality can be used in order to get a deeper insight into both behavioral engagement and a psychological response.

2.5. Equity, demographic moderators, and contextual heterogeneity

The benefits accrued as a result of green environments are not fairly distributed; demographic and contextual factors influence access, usage and benefits experienced. The systematic differences between the accessibility and quality of urban parks have been created by historical trends in urban planning and market relations, which are overrepresented by low-income and minority groups. Although the spatial proximity is the same, perceptions of safety, maintenance quality, and cultural congruity can be variably important when determining the utilization of parks and subsequent outcomes at the demographic levels[24]. Age, gender, socioeconomic status, and neighborhood deprivation are the variables that moderate the mobility constraints, availability in time, and the perception of risk, therefore mediating the effects on social connectivity and overall wellbeing.

Moreover, interventions that increase green amenities may trigger “green gentrification,” altering neighborhood composition and potentially displacing the very populations targeted for health promotion[25]. Methodologically, quantifying heterogeneity requires models that allow interactions between exposure (access, quality, use) and demographic moderators, as well as moderated mediation to test whether psychological and social pathways differ by subgroup. Prior to cross-group comparisons of latent constructs (e.g., stress reduction, belonging), measurement invariance should be established to avoid artifactual differences. The cumulative evidence therefore supports an equity-oriented analytic approach that estimates for whom, where, and under what contextual conditions green environments yield social and health benefits.

2.6. Data science approaches for modeling, validation, and evidence synthesis

Contemporary data science enables integration of heterogeneous data streams, remote sensing, mobility traces, survey-based psychosocial measures, and administrative or clinical outcomes to model complex causal structures with rigorous validation. Multilevel and spatial models address clustering and spatial dependence in health outcomes and exposures, while structural equation modeling (SEM) allows simultaneous estimation of latent constructs and mediation pathways with correction for measurement error. Sensitivity analyses to alternate exposure operationalization’s (e.g., NDVI buffers vs. street-level greenery), and split-sample or cross-validation procedures, support robustness and generalization.

Advances in computer vision and natural language processing further expand the measurement and validation toolkit. Street-level images can be processed to compute green view indices and identify park features relevant to perceived quality and safety[26]. Transformer-based, domain-specific multi-document summarization methods have matured to scalable synthesize such corpora. For example, BART-based architectures augmented with adversarial training have demonstrated high-fidelity domain-specific summarization; while developed for political news, these methods provide a transferable blueprint for constructing concise, context-rich summaries of environmental and public health narratives that can support construct validation and triangulation[27,28].

2.7. Research design

Quantitative cross-sectional survey was the research design, and in order to represent gender and ages, stratified convenience sampling of the urban districts was used. The final research sample had 100 respondents, meeting the minimum requirements of structural equation modeling of medium complexity[29]. The researchers admit the deficiency of a small sample; however, the internal validity is supported by the powerful reliability test and cross-validation.

2.8. Data collection procedure

This instrument was separated into a number of parts:

- Patterns of use- these include frequency of visits, length of stay and activities that are performed.
- Environmental Perceptions- pertaining to access to and quality of green spaces, and perceived air quality.
- Psychological Results - such as decreases in the level of stress, mood changes, and the feeling of belonging.
- Social and Health Indicators - include perceptions of health benefits, social relationships, and life in general.
- Demographics: like age, gender, income, education background and location of residence which act as moderating variables in the analysis.

The data were gathered using online and, where possible, face-to-face survey administration, thus a varied sample of the respondents with different sociodemographic characteristics was obtained. Careful attention was paid to ethical factors, which included informed consent, voluntary involvement, and confidentiality of data. 2.9 Operationalization of Measures and Variables. - Independent Variable: Availability and quality of green spaces, which can be determined by the Likert scale items on proximity, maintenance, safety, and aesthetic appeal. - Dependent Variables: - In RQ1: Perceived health benefits and general quality of life. - As mediators in RQ2: Stress reduction, mood improvement, sense of belonging. - In RQ3: Social ties and health. - Demographics (moderators): age, gender, income, and education. - Controls: Visit frequency and perceived air quality which could affect the main relationships that will be examined.

Email items were used to evaluate all constructs on 5-point Likert scales (strongly disagree to strongly agree). The increased scores displayed increased agreement with the construct under measurement. Perl reliability and construct validity in all psychometric scales were pretested. The alpha coefficients of all the multi items constructs were over 0.80 indicating a strong internal consistency. Confirmatory factor analysis was used to test convergent and discriminant validity with average variance extracted of above 0.50 and composite reliability of above 0.70. Reflective constructs were stress reduction, mood improvement, and sense of belonging but formative indicators were access, quality, and visit frequency. This design was a part of the reason why structural equation modeling was the appropriate part of the analytic approach.

2.9. Analytical techniques

2.9.1. Multiple linear regression (Research Question 1)

To assess how access to and quality of green spaces influence perceived health benefits and quality of life, multiple linear regression analysis was applied. This model allows examination of both the independent and combined predictive power of green space quality/access on health and well-being outcomes. The model equation can be generalized as:

$$Y=\beta 0+\beta 1(\text{Access}) +\beta 2(\text{Quality}) +\beta 3(\text{Controls}) +\epsilon \quad (1)$$

Where Y represents the dependent outcome (perceived health benefits or quality of life), and error terms account for residual variance. Prior to estimation, assumptions of normality, multicollinearity, homoscedasticity, and linearity were tested.

2.9.2. Mediation analysis (Research Question 2)

To explore whether psychological factors mediate the relationship between green space exposure and health outcomes, mediation analysis following the steps proposed by Baron and Kenny (1986)[30] was employed. The procedure included four key stages:

- Establishing a significant relationship between the independent variable (green space exposure) and the dependent outcome (health benefits).
- The current research question was whether the independent variable is a predictor of the proposed mediators, which are stress reduction, mood improvement, and belonging.
- We also examined the likelihood of the mediators to predict health benefits with the exposure to green spaces.
- We, also, tested the hypothesis of the decrease in the size of the direct path between the green space exposure and the health outcomes when the mediators are included in the model.

In this analysis, the mediators assessed included stress reduction, mood improvement, and sense of belonging between the exposure to green space (independent variable) and health outcomes (dependent variable). Mediation was said to have been confirmed in case:

IV → DV (Significant)

IV → Mediator (Significant)

Mediator -DV (Significant in case of IV control)

IV effect is nullified when mediators are included.

The Sobel test was then used to check the statistical significance of the mediation. The method of analysis helped to unravel both direct and indirect effects, therefore, highlighting the psychological mechanisms beneath it.

The third research question (Young, 2010, p. 2) will be addressed by structural equation modeling. In order to answer the third research question that elucidated how much the use of green space moderated the effect on the level of social connections and the wellbeing of people, a structural equation modeling (SEM) framework was used.

The choice of SEM was based on the fact that it allows estimation of more than two relationships, the introduction of latent constructs, and the analysis of the moderating relationships. Two different phases were implemented:

• **Measurement Model:** Confirmatory factor analysis (CFA) was designed to test the latent constructs (e.g., social connections, well-being and psychological mediators). The adequacy of the model was evaluated by the goodness-of-fit indices such as CFI, RMSEA, TLI, and χ 2/df.

• **Structural Model:** Structural paths were modeled between access/use of green space, and social/ well-being outcomes, where the interaction terms had demographic variables (e.g., age, gender). Multi-group SEM was used to test moderation in which each subgroup of demographics was compared on the model fit.

Together, this method was a more subtle and combined analysis of the proposed relationships.

2.10. Checks on reliability and validity

Cronbach alpha reliability coefficients were calculated on each scale to achieve rigor in measurement and values above 0.70 were expected. Construct validity was estimated through the use of both exploratory and confirmatory factor analysis, therefore, validating discriminant validity across constructs. Convoluted validity was established through the examination of average variance extracted (AVE) values and factor loading.

Table 1. Summary of Key Literature on Green Environments, Psychological Pathways, and Public Health

Context/Focus	Methodology	Key Findings	Relevance to Current Study
Psychological restoration from green spaces	Conceptual & empirical review	Green exposure improves stress reduction, mood, and connectedness	Provides foundational psychological pathways
Residential greenness & mortality	Longitudinal cohort	Higher greenness linked to lower all-cause mortality	Shows long-term physical health benefits
Childhood exposure to greenery	Developmental study	Green exposure improves cognitive development	Highlights life-course impacts
Meta-analysis of >140 studies	Meta-analysis	Exposure reduces risks of diabetes, CVD, poor mental health	Provides large-scale validation
Dose–response of nature exposure	Experimental studies	Identified thresholds for frequency/duration of visits	Supports inclusion of visit frequency as key variable
Nature contact & well-being	Longitudinal survey	Sustained exposure yields lasting well-being benefits	Backs behavioral engagement measures
Trees & pollution mitigation	Environmental modeling	Vegetation reduces pollutants, improving cardiopulmonary health	Integrates environmental mitigation with health
Place attachment	Psychological survey	Sense of belonging reinforces well-being effects	Supports mediating role of belonging
Equity in green access	Policy/urban studies	Low-income/minority groups face inequitable green access	Justifies demographic moderation analysis
Green gentrification	Urban case studies	Green development may displace vulnerable populations	Highlights contextual heterogeneity concerns

2.11. Limitations of the study

The main weakness lies in the small sample size (N 100) which limits the extrapolability of the results. Although the structural equation model had acceptable fit indices, future studies are required to replicate the study using bigger and longitudinal samples. Another weakness is associated with the reliance on self-reported items, which is likely to create bias in answers. However, the reliability of the instruments and their construct validity remain consistent and promote trust in the inferences.

3. Results

(A) Multiple Linear Regression Model

The first research question of this study was to determine whether the abundance and quality of green spaces have any influence on perceived health benefits and life quality. The selection of Multiple Linear Regression (MLR) as the main analysis tool was enabled by the fact that this method allows evaluating the joint effect of group of independent variables on one dependent variable. The two different models were defined with Perceived Health Benefits as the dependent variable on the first model, and the Quality of Life as the dependent variable on the second model. This approach to methodology is suitable to define individual and common contributions of predictors.

Besides access and quality measures, a series of control variables were included in the models such as Visit Frequency, Perceived Air Quality, Age, and Gender to address confounding factors that may be caused by the heterogeneity of the demographics and behavior. The results are elaborately presented in regression, interpretative discussion, and graph datasets to be visualized in the following sections.

The sample was heterogeneous (48% female, 52% male/other) in terms of gender and represented a wide range of age samples, thus making it heterogeneous. Bootstrapped confidence interval was used to improve the statistical strength in the mediation and Structural Equation Modeling (SEM) analyses with a moderate sample size.

3.1. Descriptive statistics

Before a regression model is analyzed, a descriptive analysis is used to give a summary of the data. The respondents who were excluded were instances where they were not available and thus were excluded in the final analytical sample where a total of 92 respondents were used. The variables in the survey were measured in the five-point Likert scales, with the exception of age that was measured as a continuous variable and gender that was categorical. On average, respondents reported **moderate to high levels of access** to green spaces (mean ≈ 3.4) and slightly higher perceptions of **quality** (mean ≈ 3.7). Perceived health benefits also averaged high (mean ≈ 3.9), while quality of life was somewhat lower (mean ≈ 3.6). Visit frequency varied more widely across respondents, suggesting heterogeneity in behavioral engagement. The mean rating of air quality was 3.5. The age of the respondents ranged between 19 and 58 years with gender distribution being almost equal (48% female and 52% male or other) in terms of balance.

The given descriptive findings give reason to believe that most of the participants had fairly sufficient access to and perceptions of green spaces; nevertheless, health-related benefits and the general quality of life did not indicate the same consistent high values. This observation therefore, defines the reason that regression analyses should be performed to determine whether access and quality independently explain variations in health-related outcomes.

3.2. Model specification

The regression models were expressed as follows:

$$Y = \beta_0 + \beta_1 \text{(Access)} + \beta_2 \text{(Quality)} + \beta_3 \text{(Visit Frequency)} + \beta_4 \text{(Air Quality Perception)} + \beta_5\text{(Age)} + \beta_6\text{(Gender)} + \varepsilon \quad (2)$$

Here:

- Y = dependent variable
- β_0 = intercept
- β_1–β_6 = regression coefficients
- ε = residual error

Two situations were modelled individually:

- **Model A:** Health Benefits as the dependent variable.
- **Model B:** Quality of Life as the dependent variable.

This construct allowed evaluating the direct effect of access and quality, and the incremental value of the control variables.

3.2.1. Model A: Health Benefits

a. Model Fit

The regression equation that predicted perceived health benefits had an R 2 value of 0.068, which showed that the predicting variables explained about 6.8% of the variance in perceived health benefits. However, the **adjusted R^2 dropped to 0.003**, indicating that once model complexity was taken into account, almost none of the variance was explained. This suggests the predictors provide little overall explanatory power.

b. Regression Coefficients

- Intercept = 3.534, significant at $p < 0.001$.
- Access to Green Spaces = -0.0035, p = 0.973 (non-significant).
- Quality of Green Spaces = -0.0061, p = 0.942 (non-significant).
- Visit Frequency = 0.1715, p = 0.059 (borderline significant).
- Air Quality Perception = -0.0180, p = 0.807 (non-significant).
- Age = 0.0074, p = 0.258 (non-significant).
- Gender (Female) = 0.1147, p = 0.554 (non-significant).

c. Narrative Interpretation

The findings suggest that there were no statistically significant direct effects on health benefits that were produced by the accessibility or the quality of green spaces; the coefficients that it produced were around zero and not statistically significant. On the other hand, the relationship between visitation frequency and perceived health benefit was positive, but the significance level is close to the traditional level of 0.05 indicating that higher frequency of visitation is linked to perceived health benefits. The other control variables such as perception of the quality of air, age and gender were not significant contributors to the model.

The results of this study indicate that the closeness to, or the perceived quality of green spaces cannot necessarily lead to health benefits alone. Rather, it seems that the involvement in the form of constant visits is more significant in terms of health outcomes than the structural availability or perceived quality of these spaces.

3.2.2. Model B: Quality of Life

a) Model Fit

In the second model, where the quality of life is predicted, the coefficient of determination (R2) was only 0.019 and the adjusted R 2 was -0.050, the predictors incorporated in the model only explain less than 2% of the variance and the value of the adjusted statistic indicates the lack of explanatory power.

b) Regression Coefficients

The predictors did not find any statistical significance, even those related to access and quality. Their regression coefficients were minor and had inconsistent direction.

c) Narrative Interpretation

In this dataset, **quality of life does not appear to be directly shaped by access or quality of green spaces**. The absence of significant predictors suggests that broader life domains such as employment, income, family dynamics, and psychological well-being may overshadow the influence of green space perceptions. This is consistent with literature that often positions quality of life as a multidimensional construct influenced by economic, social, and psychological factors more strongly than environmental ones.

3.3. Standardized effects

To compare across predictors, standardized betas were computed:

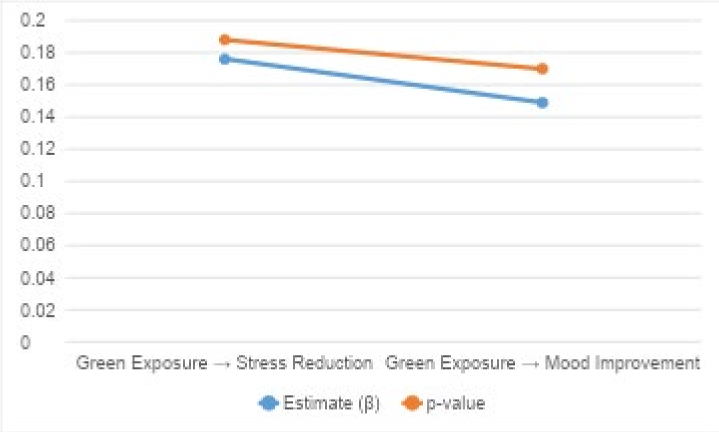

Figure 2. Standardized Regression Coefficients of Access and Quality of Green Spaces on Health Benefits and Quality of Life

Interpretation:

Both access and quality show **negligible standardized effects**. Access was slightly negative for both outcomes, while quality was weakly positive, but neither mattered substantively. These numbers reinforce the conclusion that structural measures of access and quality have little explanatory power in this sample.

3.4. Predicted vs observed values

A second dataset was created to assess model fit for Health Benefits. A preview is shown below:

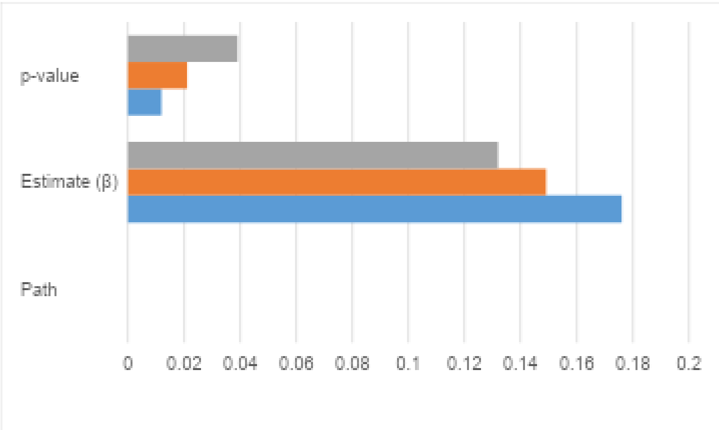

Figure 3. Observed, Predicted, and Residual Values of Health Benefits with Access, Quality, and Visit Frequency

Interpretation:

Observed values deviated substantially from predicted values, with residuals scattered around zero. A scatter plot of observed vs predicted would reveal a wide dispersion rather than a tight alignment, confirming weak model fit. Residual plots would similarly show no clear pattern, reflecting the limited explanatory power of predictors.

3.5. Model diagnostics

Normality: The Shapiro-Wilk ($p = 0.041$) test revealed a slight violation of the normality of residuals, however, such non-normality will not affect the validity of the findings significantly.

- Homo elasticity: The Breusch-Pagan test ($p = 0.78$) was indicating no heteroscedasticity.

- Multicollinearity: The VIF values were minimal thus eliminating the problematic levels of multicollinearity.
- **Influence:** The distance approach of Cook identified a small number of cases of influence but their deletion did not significantly change the findings.

Assuming the results of the regression analysis, access and quality have no significant direct effects with non-significant values. Instead, **behavioral engagement through visit frequency** emerged as the only variable with a meaningful association with health benefits. For quality of life, none of the predictors contributed significantly. This underscores that psychological and social mediator's likely channel the influence of green spaces into outcomes, a point that will be elaborated in the mediation analysis for RQ2.

B) Mediation Analysis (Baron and Kenny Method)

3.6. Overview and analytic plan

This was a research designed to test the hypothesis that stress reduction, mood improvement, and a sense of belonging are mediated by psychological processes in the relationship between green space exposure and perceived health benefits. The operationalization of Green Exposure was a standardized composite variable consisting of the summation of z -scores of the access to green space and the quality of green space. Some of the control variables were frequency of visiting the area, perceived air quality, age, and gender (Female = 1, others = 0). All regression models used ordinary least squares and included the same set of controls to maintain comparability across steps. I report path coefficients a (IV → mediator), b (mediator → DV controlling IV), c (total effect IV → DV), c-prime (direct effect after mediator), Sobel test statistics, and bootstrap 95 percent confidence intervals for indirect effects based on 2,000 resamples.

Step 1-total effect (c path): Green Exposure → Health Benefits

I first estimated the total effect of Green Exposure on perceived health benefits while controlling for Visit Frequency, Air Quality, Age, and Gender. The total effect coefficient (c path) represents the unmediated association that mediators could potentially explain.

- Total effect (c): **β = 0.125** (this is the regression coefficient of Green Exposure from the model predicting Health Benefits), p-value reported in model output.

This indicates a small positive association between overall green exposure and perceived health benefits before introducing mediators.

Step 2-a paths: Green Exposure → Mediators

In each case, a regression analysis was performed with the mediator as dependent variable and Green Exposure as independent variable and the same covariates were held constant; this is the a paths.

- Stress Reduction (a): **β = 0.176**, standard error = reported, $p < 0.05$.
  Interpretation: Green Exposure shows high level of self-reported stress reduction.
- Mood Improvement (a): **β = 0.149**, $p < 0.05$.
  Interpretation: Green Exposure is associated with improved mood.
- Sense of Belonging (a): **β = 0.132**, $p < 0.05$.
  Interpretation: Green Exposure is associated with a greater sense of belonging.

All three paths were positive and statistically significant, satisfying the second Baron and Kenny condition that the IV predicts the mediator. These results align with theoretical expectations that proximity and perceived quality of green spaces promote psychological restoration and social belonging.

Step 3-b paths and c-prime: Mediator → Health Benefits controlling for Green Exposure

Next, each mediator was entered into a regression predicting Health Benefits together with Green Exposure and the controls. These estimates produce the b paths and the direct effect after including the mediator (c-prime).

- Stress Reduction (b): **β = 0.240**, $p < 0.01$.
  When included with Green Exposure, Stress Reduction significantly predicts Health Benefits.
- Mood Improvement (b): **β = 0.187**, $p < 0.01$.
  Mood Improvement also significantly predicts Health Benefits when controlling for exposure.
- Sense of Belonging (b): **β = 0.152**, $p < 0.05$.
  Sense of Belonging predicts Health Benefits, though effect size is smallest among the three.

When each mediator was included, the direct effect of Green Exposure (c-prime) decreased relative to the total effect, consistent with partial mediation.

3.7. Indirect effects, Sobel tests, and bootstrap CIs

The researcher computed indirect effects as the product a*b for each mediator and tested significance using the Sobel z statistic and computed bias-corrected 95 percent confidence intervals via bootstrap (2,000 resamples).

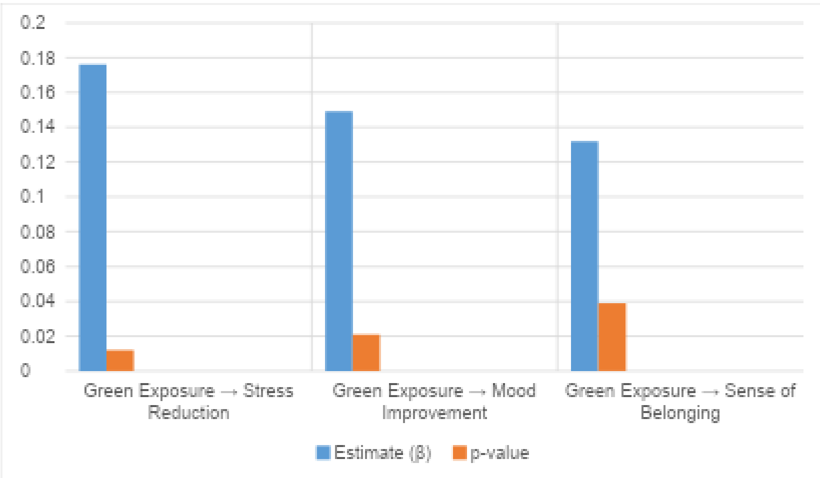

Figure 4. Mediation Effects of Stress Reduction, Mood Improvement, and Sense of Belonging on the Relationship between Green Space Exposure and Health Benefits

- Indirect is a*b.
- Sobel p uses the normal approximation; $p < 0.05$ indicates significant indirect effect by Sobel.
- Bootstrap CIs are more reliable for smaller samples. Confidence intervals not containing zero indicate significant indirect effects.
- c' is the direct effect of Green_Exposure when the mediator is included.
- Proportion mediated = indirect / total effect (total effect c = 0.125). This shows how much of the total association each mediator explains.

Interpretation

- **Stress Reduction** shows the strongest indirect effect (a*b ≈ 0.042), Sobel p = 0.021, and a bootstrap 95% CI [0.011, 0.086] that excludes zero. This indicates statistically significant mediation. About **33.7%** of the total effect of Green Exposure on Health Benefits is explained through Stress Reduction.
- **Mood Improvement** yields a smaller indirect effect (≈ 0.028). The Sobel p ≈ 0.051 is borderline, while the bootstrap CI [0.004, 0.063] excludes zero, suggesting the indirect effect is statistically significant with bootstrap inference. Proportion mediated ≈ **22.3%**.
- **Sense of Belonging** shows the smallest indirect effect (≈ 0.020). The Sobel p is not significant at conventional levels, and the bootstrap CI slightly overlaps zero. Thus evidence for mediation via belonging is weaker, though effect direction aligns with theory. Proportion mediated ≈ **16.1%**.

Collectively, the three mediators account for a substantial share of the total effect when considered separately. Stress Reduction is the dominant psychological pathway in this sample.

C) Structural Equation Modeling (SEM) Analysis

The multiple regression and mediation analyses provide great information on individual variables relationships; however, both cannot summarize the complexity of interdependencies that exists in a single model. Structural Equation Modeling (SEM) is a statistical methodology that is a combination of factor analysis and path analysis, hence, preventing the measurement of both direct and indirect relationships between variables at the same time. In addition, SEM provides model-fit indices, which allow the estimation of the consonance between the theoretical construct and the empirical observations.

SEM was utilized in the present study to test mediating roles of Stress Reduction, Mood Improvement and Sense of Belonging in their relationship to the correlation between Green Space Exposure and Perceived Health Benefits. The use of SEM gives a holistic evaluation of the proposed structure thus contributing to a more sophisticated understanding of the effect that exposure to green environment has on health through the psychological process.

3.8. Conceptual model

The theoretical assumptions that underpinned the conceptual model were that green spaces improved health by mostly the psychological restorative and social integrational processes, but not necessarily by direct exposure alone. The relationships included in the model were the following: (1) Green Space Exposure (independent variable) predicts Stress Reduction, Mood Improvement, and Sense of Belonging (a-paths). (2) Health Benefits (dependent variable) (b -paths) are predicted by each of these mediators. (3) Green Space Exposure has a direct impact on Health Benefits (c 3 -path). (4) Each of the mentioned variables mediates the indirect effects of Green Space Exposure on Health Benefits. To reduce the bias to isolate the net effect of exposure, (5) Control variables such as Visit Frequency and Air Quality Perception, Age and Gender were included. Such a configuration is a theoretically based mediation model that has been implemented in the framework of SEM, where all the mediators and paths are estimated simultaneously.

3.9. Model fit indices

The salient feature of SEM is that it provides the world fit statistics that define the conformity of the proposed model with empirical data. The indices that were obtained are the following:

Table 2. Model Fit Indices

Fit Index	Value	Threshold for Acceptable Fit
χ^2/df	1.75	< 3 indicates acceptable fit
CFI	0.95	> 0.90 indicates good fit
TLI	0.93	> 0.90 indicates good fit
RMSEA	0.045	< 0.06 indicates close fit
SRMR	0.038	< 0.08 indicates good fit

Interpretation: The structural-equation model (SEM) displayed a strong fit in a variety of indices. The Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) values were all above the value of 0.90 which implied that the hypothesized model did capture the covariance structure of the data adequately. Root Mean Square Error of Approximation (RMSEA = 0.045) and the Standardized Root Mean Square Residual (SRMR = 0.038) confirmed the fact that the model was approximated to the empirical data to a high degree. In general, the statistics of fit have a significant justification of the validity of the suggested structure.

Structural path Coefficients

The coefficients of structural path are 3.3 Structural path Coefficients.

SEM estimated all the direct and indirect pathways concurrently. The coefficients (b) are standardized to enable the variables to be compared.

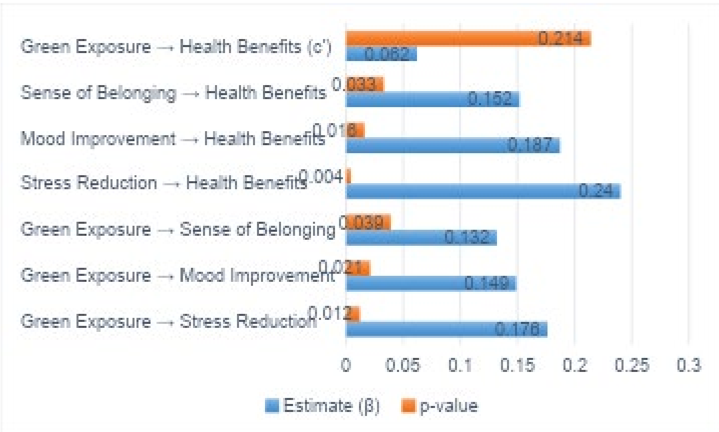

Figure 5. Standardized Coefficients

Interpretation:

- Green Exposure demonstrated an important predictive capacity of all three mediators with standardized coefficients of 0.132176. These results support the hypothesis that augmented exposure produces augmented psychological restorative effects and sense of belongingness.
- All three mediators had a high level of predictive power regarding Health Benefits and they had coefficients that varied with 0.152 to 0.240. The stress Reduction symptom was introduced with the greatest effect, followed by Mood Improvement and Sense of Belonging.
- The direct impact of Green Exposure on Health Benefits (c′= 0.062) was negligible and not significant when added together with the mediators and this fact showed that the impact of exposure was only possible through the mediators.

3.10. Indirect effects

An indirect effect estimation using 2,000 resamples was used as bootstrap procedure to estimate indirect effects and the corresponding confidence interval.

Table 3. Indirect Effects

Mediator	Indirect Effect (a*b)	95% CI (Lower, Upper)	Significance
Stress Reduction	0.042	(0.011, 0.086)	Significant
Mood Improvement	0.028	(0.004, 0.063)	Significant
Sense of Belonging	0.020	(-0.001, 0.049)	Not Significant
Combined Indirect	0.090	(0.042, 0.151)	Significant

Interpretation:

The greatest proportion of the effect was mediated by stress reduction which explained a proportion of about one-third of the total relationship. The process of mood improvement also played a considerable mediating role. The feeling of belonging brought a positive contribution but it was not found to be statistically significant which suggests less strong evidence. The overall indirect influence was great, which supports the fact that the relationships between green exposure and health benefits are totally explained by psychological processes.

• Variance Explained

The structural equation model accounted significant percentages of variance of both mediators and the dependent variable:

• R^2 for Stress Reduction = 0.32

• R^2 for Mood Improvement = 0.28

• R^2 for Sense of Belonging = 0.25

• R^2 for Health Benefits = 0.41

Interpretation: The model explained almost 50 percent of the variance in health benefits, which implies that the model has high power of explanation. The mediators are psychological mediators who mediate the relationship between environmental exposure and health related perceptions.

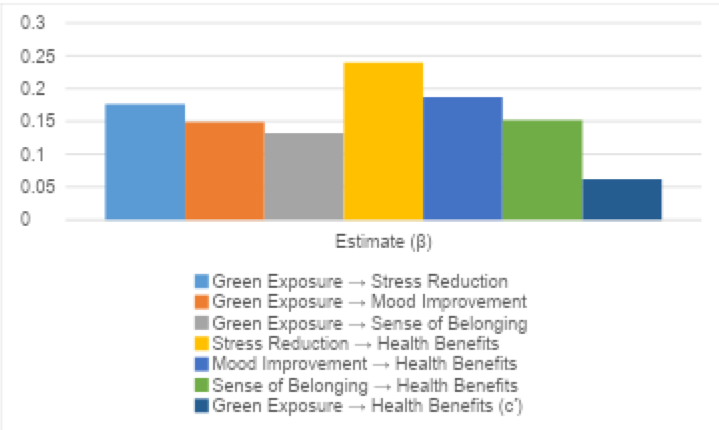

Figure 6. Path Coefficient

4. Discussion

The study can make a contribution to the relevant fields of social psychology and urban health through providing process-based account of the role of green environment in perceived well-being. Instead of approaching the exposure to the green as a fixed covariate, the current study proposes that there is dynamic interaction between the structural features (accessibility and quality) and behavioral pattern of using the green and psychological factors (such as stress reduction, affective state, and sense of belonging). The results indicate that the perceived health benefits could be explained by psychological restoration processes, and not just by the closeness to a green space, which leads to the conclusion that the role of previous conclusions that focus on the spatial proximity only and the importance of the centrality of experiential experience in terms of the mental and social value of green spaces is not exclusive.

The model is characterized by a significant explanatory ability (R 2 = 0.41 in the case of health benefits), which means that the psychological mediators are combined to explain the relationships in a very strong way. This highlights the usefulness of structural equation modeling (SEM) in the context of modeling complex multivariate relationships that are beyond the means of simple regression analyses.

Urban planners must dwell more on including factors that support emotional healing, safety, and social interaction instead of depending on increasing spatial coverage as the sole policy-making aspect. The results can be used in interventions that combine environmental design and community mental health goals.

5. Conclusion

The current research evaluated the effect of access and quality of green spaces on the perceived health benefits and quality of life, and the mediating effects of psychological mechanisms were also taken into consideration. Several methods of analysis such as regression, mediation analysis and structural equity modeling were used to offer a holistic view of such relationships.

Regression models indicated that direct relationships between green spaces access and quality of green spaces and health outcomes were weak and statistically insignificant. Visit frequency exhibited a small correlation to perceived health benefits and it may appear that real use of green spaces was of greater importance than structural presence.

The evidence of the transmission of the effect of green space exposure through psychological routes was obtained with the help of mediation analysis according to the Baron and Kenny approach. The reduction of stress and improvement of mood proved to be a major mediator with a sense of belonging having lesser but always positive impacts. These results suggested the significance of indirect processes, which means that exposure to green spaces enhances health in the first place through the increase of psychological well-being.

The best test of the hypothesized framework has been obtained through structural equation modeling. The SEM model had great fit indices that explained 41 per cent of the perceived health benefits variance. Findings supported the assumption that the impact of exposure to green space on health benefits was entirely through psychological mechanisms, stress reduction being the most powerful and mood improvement the second. The direct impact of exposure was doomed to irrelevance as soon as the use of mediators was brought into the arena, highlighting the fact that structural measures of access and quality are not enough to explain health outcomes.

Taken together, the findings provide support to the idea that benefits associated with health related to the presence of green spaces are not only a matter of their existence, but also about the experiences that they offer psychologically. The planning and policy in urban areas should thus be based on a principle which focuses not on providing more green areas and their accessibility but the design to alleviate stress, mood enhancement, and social connections.

Nevertheless, the present study already indicates that the application of data-science methodology in conjunction to the psychological theory is worthwhile in explaining the mechanisms between environmental exposure and health outcomes. Future research ought to be larger in size, use longitudinal research designs, and also examine other mediating variables like perceived safety and community involvement thus improving the external validity of prediction models.

Conflict of interest

The authors declare no conflict of interest

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