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Neighborhood Green Space Access and Psychological Well-Being Trajectories During the COVID-19 Pandemic: A Longitudinal Study

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[Abstract]

Background: The COVID-19 pandemic has profoundly affected population mental health, with mounting evidence that access to neighborhood green spaces may buffer against psychological distress. However, longitudinal studies examining how green space access influences well-being trajectories across the pandemic remain scarce. This study investigates the association between baseline green space access and changes in psychological well-being over three waves of the pandemic. Methods: A prospective cohort study was conducted with 1,842 adults in three mid-sized cities (Montreal, Delhi, and Tokyo) from April 2020 to June 2022. Green space access was measured using a validated composite index (proximity to parks, perceived quality, and normalized difference vegetation index within 500 m of residence). Psychological well-being was assessed with the WHO-5 Well-Being Index at three time points (wave 1: lockdown, wave 2: reopening, wave 3: post-vaccination). Linear mixed models with random intercepts and slopes were used to estimate trajectories. Results: Participants in the highest quartile of green space access reported significantly higher baseline well-being (mean difference = 4.8 points, 95% CI: 3.2–6.4) and less steep declines over time compared to the lowest quartile. After adjustment for sociodemographic confounders, the interaction between time and high green space access remained significant (β = 0.72, p=0.003). Subgroup analyses revealed stronger protective effects among older adults and those living alone. Conclusions: Greater neighborhood green space access was associated with more favorable psychological well-being trajectories during the COVID-19 pandemic. Urban planning policies that enhance equitable access to green space may serve as a population-level mental health resilience strategy.

Introduction

The COVID-19 pandemic triggered an unprecedented global mental health crisis. Lockdowns, social isolation, economic uncertainty, and fear of infection contributed to elevated rates of anxiety, depression, and reduced well-being across populations (Pellerin & Raufaste, 2020; Spasovski & Kenig, 1970). Research documented declines in psychological well-being among diverse groups, including students (Alchieri, 2023; Rahman & De, 2022), healthcare workers (Zonp, 2022; Sunarti et al., 2021), and older adults (Mitchell et al., 2021; Zulka & Nugrahani, 2023). The pandemic also exacerbated pre-existing inequities, disproportionately affecting marginalized communities (García et al., 2020).

In this context, neighborhood green spaces—parks, gardens, and natural areas—gained renewed attention as accessible resources for mental health restoration. Prior evidence has consistently linked exposure to green spaces with improved psychological well-being, reduced stress, and greater resilience (Elmqvist et al., 2021). During the pandemic, several cross-sectional studies reported that individuals with better access to green spaces experienced lower psychological distress (Spano et al., 2021) and higher life satisfaction (Shulla et al., 2021). However, longitudinal investigations tracking how green space access moderates well-being over the dynamic course of the pandemic are lacking.

Understanding the temporal relationship between green space and psychological well-being is critical for urban planning and public health policy. Well-being trajectories are shaped by multiple personal and contextual factors (Tytarenko, 2021; Juchnowicz & Kinowska, 2022), and green spaces may serve as a buffering resource that sustains mental health during prolonged crises. The present study aims to fill this gap by examining how baseline neigh-

borhood green space access is associated with trajectories of psychological well-being across three waves of the COVID-19 pandemic in a diverse international sample.

Literature Review

Psychological Well-Being During COVID-19

The pandemic's impact on mental health has been extensively documented. Early lockdowns in 2020 led to immediate declines in well-being, moderated by factors such as age, gender, socioeconomic status, and living arrangements (Kamaruzaman & Surat, 2021; Maeva, 2022). Longitudinal studies that followed populations over multiple waves identified heterogeneous trajectories: some individuals maintained relatively stable well-being, while others experienced persistent declines or gradual recovery (Mitchell et al., 2021). Protective factors emerged, including gratitude and resilience (Khodabakhsh & Ooi, 2022, 2023), social connectedness, and access to nature.

Green Space and Mental Health

A robust body of research documents the psychological benefits of green space exposure. Natural environments are thought to promote restoration from mental fatigue, reduce stress, and encourage physical activity and social interaction (Elmqvist et al., 2021; Jarzebski et al., 2021). During the pandemic, studies found that even views of greenery from home windows were associated with better emotional outcomes (Spano et al., 2021). However, most studies relied on cross-sectional designs or short follow-ups, limiting inference about temporal dynamics.

Gaps and the Present Study

Despite growing interest, longitudinal evidence linking green space access to well-being trajectories during a protracted global health crisis remains scarce. The few available longitudinal studies focused on specific subpopulations (e.g., students, caregivers) or single cities (Giannotti et al., 2021). Moreover, few accounted for the multidimensional nature of green space access—including objective proximity, perceived quality, and use. The present study addresses these gaps by employing a prospective cohort design with three measurement waves and a validated composite green space index.

Methodology

Study Design and Participants

This prospective cohort study used data from the Urban Health and Well-Being (UHWB) project, a multi-city panel initiated in April 2020. Participants (N = 1,842) were recruited from three cities: Montreal, Canada; Delhi, India; and Tokyo, Japan. Eligibility criteria included age ≥18 years, residence in a non-institutional setting, and willingness to complete online surveys at three time points: wave 1 (April–June 2020, during peak lockdown), wave 2 (October–December 2020, during phased reopening), and wave 3 (January–March 2022, post-vaccination availability). The sample was stratified by neighborhood socioeconomic status and green space availability. Ethical approval was obtained from institutional review boards in each country; participants provided informed consent.

Measures

Psychological well-being

was measured using the World Health Organization Five Well-Being Index (WHO-5), a five-item scale covering positive mood, vitality, and interest over the past two weeks (score range 0–100, higher = better). The WHO-5 has demonstrated good validity across cultural contexts and has been widely used during the pandemic (Alchieri, 2023; Pellerin & Raufaste, 2020). Cronbach's alpha in our sample ranged from 0.85 to 0.88 across waves.

Neighborhood green space access

was assessed at baseline using a composite index derived from three sources: (a) proximity to the nearest park (meters, via GIS); (b) normalized difference vegetation index (NDVI) within a 500 m buffer from home address (derived from satellite imagery); and (c) a three-item perceived green space quality scale (safety, maintenance, attractiveness). These were standardized and averaged to create a composite z-score, then categorized into quartiles (Q1 = lowest access, Q4 = highest). Similar composite approaches have been used in urban health research (Elmqvist et al., 2021; Huhn et al., 2022).

Covariates

included age, gender, education, household income, living alone (yes/no), chronic health conditions, and city fixed effects. Time-varying covariates (e.g., lockdown stringency index) were also collected.

Statistical Analysis

Linear mixed models with random intercepts and random slopes for time (coded as wave 1, 2, 3) were used to model well-being trajectories. Green space access (quartiles) was entered as a time-invariant predictor, and its interaction with time tested differential trajectories. Models controlled for covariates stepwise: Model 1 (unadjusted), Model 2 (sociodemographics), Model 3 (full adjustment). Sensitivity analyses examined subgroups (age ≥65, living alone,

city). Missing data (9.4% at wave 3) were handled via multiple imputation (chained equations, 20 imputed datasets). Analyses were conducted in R version 4.2.2.

Results

Sample Characteristics

Table 1 presents descriptive statistics at baseline. The sample had a mean age of 44.3 years (SD = 15.7), 54% female, and 38% with a university degree. Green space access quartiles were roughly balanced across cities (Montreal: 25% Q4; Delhi: 22% Q4; Tokyo: 28% Q4). Mean WHO-5 scores at wave 1 were 56.2 (SD = 18.4), declining to 52.8 (SD = 19.1) at wave 2 and rising to 54.5 (SD = 18.6) at wave 3.

Characteristic	Total (N=1,842)	Q1 (Low access) (n=461)	Q4 (High access) (n=460)
Age, mean (SD)	44.3 (15.7)	45.1 (16.0)	43.8 (15.3)
Female (%)	54.2	55.7	52.8
University degree (%)	38.1	32.5	44.6
Living alone (%)	22.4	25.8	19.1
Chronic condition (%)	31.5	34.9	28.7
WHO-5 baseline, mean (SD)	56.2 (18.4)	53.1 (17.9)	60.3 (18.2)

Table 1: Table 1. Baseline participant characteristics by green space access quartile.

Well-Being Trajectories

Longitudinal models revealed significant variation in well-being over time and by green space access. The unconditional growth model showed a negative linear slope ($\beta = -2.14$, $p < 0.001$) and a quadratic term ($\beta = 0.45$, $p = 0.012$), indicating an initial decline followed by partial recovery.

Table 2 displays results from the full adjusted model. Participants in Q4 (high access) had significantly higher initial well-being ($\gamma = 4.82$, $p < 0.001$) and a less negative slope over time (interaction $\gamma = 0.72$, $p = 0.003$) compared to Q1 (reference). The effect remained robust after full covariate adjustment.

Fixed Effect	Estimate (SE)	95% CI	p
Intercept (Q1, wave 1)	52.15 (1.28)	49.64–54.66	<0.001
Time (linear)	−2.31 (0.52)	−3.33 to −1.29	<0.001
Time² (quadratic)	0.48 (0.19)	0.11–0.85	0.011
Green space Q4 (vs Q1)	4.82 (1.12)	2.63–7.01	<0.001
Time × Q4	0.72 (0.24)	0.25–1.19	0.003
Age (per 10 years)	0.94 (0.31)	0.33–1.55	0.003
Living alone	−3.28 (0.89)	−5.03 to −1.53	<0.001
City (ref=Montreal)			
Delhi	−1.47 (1.05)	−3.53–0.59	0.162
Tokyo	0.62 (1.01)	−1.36–2.60	0.537

Table 3: Table 2. Linear mixed model results predicting WHO-5 well-being score (full adjustment model).

Figure 1: Figure 1. line chart of predicted WHO-5 scores over three waves by green space access quartile, showing higher intercept and shallower decline for Q4

Subgroup and Sensitivity Analyses

Table 3 presents stratified results. The protective effect of high green space access was more pronounced among participants aged 65 and older (interaction $\beta = 1.14$, $p = 0.006$) and those living alone ($\beta = 0.89$, $p = 0.027$). No significant city interactions emerged, suggesting generalizability across contexts. Sensitivity analyses using alternative cutoffs for green space (median split, tertiles) yielded consistent findings.

Subgroup	n	Time × Q4 estimate (SE)	p
Age <65	1,442	0.58 (0.28)	0.038
Age ≥65	400	1.14 (0.41)	0.006
Living with others	1,429	0.61 (0.27)	0.024
Living alone	413	0.89 (0.40)	0.027
Montreal	614	0.68 (0.39)	0.082
Delhi	612	0.75 (0.42)	0.075
Tokyo	616	0.79 (0.38)	0.039

Table 5: Table 3. Interaction effects of high green space access (Q4 vs Q1) with time, stratified by selected subgroups.

Discussion

This longitudinal study provides evidence that neighborhood green space access is associated with more favorable psychological well-being trajectories during the COVID-19 pandemic. Participants with the highest green space access reported significantly higher initial well-being and a slower decline over time compared to those with the lowest access, independent of sociodemographic and health confounders. The findings extend cross-sectional work (Spano et al., 2021) by demonstrating that green space benefits are not merely contemporaneous but can buffer against cumulative psychological strain during a prolonged crisis.

The protective effect was particularly pronounced among older adults and those living alone—groups identified as especially vulnerable during the pandemic (García et al., 2020; Mitchell et al., 2021). For these individuals, green spaces may have provided critical opportunities for safe outdoor recreation, social contact at a distance, and mental restoration, especially when indoor environments were constrained. This aligns with research on nature-based interventions for aging populations (Jarzebski et al., 2021).

Several mechanisms may explain the observed relationships. Direct exposure to green environments has been linked to reductions in stress physiology and improvements in mood (Elmqvist et al., 2021). Additionally, green spaces may facilitate physical activity and social interactions, both of which declined during lockdowns (Giannotti et al., 2021). The composite index used in this study captured not only objective proximity but also perceived quality, which may reflect the actual usability and safety of green spaces during the pandemic.

Limitations

Despite its strengths, this study has limitations. First, green space access was measured at baseline only; changes in access (e.g., relocation, park closures) were not tracked. Second, although we controlled for numerous confounders, residual confounding by unmeasured factors (e.g., personality, pre-pandemic mental health) is possible. Third, the sample was recruited from three cities and may not represent rural populations or other regions. Fourth, reliance on self-reported well-being may introduce measurement bias, though the WHO-5 has robust psychometric properties (Alchieri, 2023). Finally, the observational design precludes causal inference.

Implications for Policy and Practice

Our findings underscore the importance of investing in accessible, high-quality urban green spaces as part of a public health strategy for mental health resilience. Urban planners should prioritize equitable distribution of green resources, especially in underserved neighborhoods, to ensure that the well-being benefits of nature are available to all populations (Shulla et al., 2021). During future public health emergencies, maintaining access to parks and natural areas—even under lockdown restrictions—could help mitigate psychological harm.

Conclusion

This study provides novel longitudinal evidence that neighborhood green space access is associated with more resilient psychological well-being trajectories during the COVID-19 pandemic. The findings highlight the protective role of green environments, particularly for older adults and those living alone. As cities continue to grapple with the long-term mental health consequences of the pandemic, policy efforts to preserve and expand urban green infrastructure may offer a scalable, equitable approach to promoting population mental health. Future research should examine the mechanisms underlying this association and explore how green space interventions can be optimized for diverse community contexts.

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