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Changes in Green Space Use During a COVID-19 Lockdown Are Associated With Both Individual and Green Space Characteristics

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Mobility restrictions imposed during the COVID-19 pandemic present a useful study system for understanding the temporal and spatial patterns of green space use. Here, we examine green space characteristics and sociodemographic factors associated with change in frequency of green space use before and during a COVID-19 lockdown in Brisbane, Australia drawing on a survey of 372 individuals. Applying regression analysis, we found that individuals who visited a different green space during lockdown than before tended to decrease their frequency of visits. In contrast, individuals who continued visiting their usual green space during lockdown were more inclined to increase their number of visits. Changes in frequency of green space use were also associated with particular characteristics of their usually visited green space. The presence of blue spaces and accessibility (carparks/public transport) were associated with increased frequency of use while foliage height diversity was associated with reduced frequency of use. We found that females were more likely to change their green space visitation frequency during COVID-19 compared to men and they also reported greater importance of green spaces for social and family interactions and spiritual reasons during COVID-19 compared to before. Males showed greater increases than females in the importance of green space for nature interactions and mental health benefits during the COVID-19 lockdown compared to before. Our results provide key insights for future resilient urban planning and policy that can fulfil a wide range of physical and psychological needs during a time of crisis and beyond.

Keywords: parks, wellbeing, human health, self-perceived benefit, ecosystem services, human-nature interaction, urban nature, pandemic

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INTRODUCTION

On March 11 2020, the World Health Organisation declared COVID-19 an international health emergency. Following the announcement, countries across the world took various measures to slow the spread of the virus that causes COVID-19, including stay at home orders, closures of schools and workplaces, and significant limits on travel. These restrictions inevitably disrupted people's daily activity patterns, social interactions, and use of leisure facilities such as gyms, cafes, and places of worship. Such disruptions caused uncertainty and instability, taking a toll on individual health and community wellbeing (Godinić et al., 2020; Wang and Boros, 2021). The effects were exacerbated in urban areas where dense living arrangements, longer and more severe restrictions, higher infection risk, and unequal access to services and nature coalesce (Maher, 1994; Sharifi and Khavarian-Garmsir, 2020; Mouratidis, 2021; Spotswood et al., 2021). Outdoor green spaces were one of few recreational places that remained accessible during periods of lockdown.

The importance of urban green spaces for ecosystem services—the benefits humans derive from nature—is well established in the literature (Bolund and Hunhammar, 1999; Breuste et al., 2013; Haase et al., 2014). Green space use is positively associated with general physical health and mental health and wellbeing (Grilli et al., 2020). For instance, Olszewska-Guizzo et al. (2021) suggests that COVID-19 restriction periods may have contributed to a heightened risk of mental health disorders, such as depression and/or reduced cognitive functioning and that green spaces are a way to offset the neuropsychological effects of such periods. In view of this, multiple studies have highlighted increased frequency of green space use during periods of COVID-19 restrictions (Berdejo-Espinola et al., 2021; da Schio et al., 2021; Lu et al., 2021) and suggested this is due to their multifunctionality and their capacity to mitigate some of the negative effects of the COVID-19 pandemic on human health and wellbeing. Changes in frequency of urban green space use during COVID-19 lockdowns show that urban green spaces were discovered by some during the pandemic (new park users; Berdejo-Espinola et al., 2021) and rediscovered by other individuals (previous users, re-engaged and increased their use; Venter et al., 2020). Yet, there is also evidence that some regular users decreased their use of green spaces during the pandemic (Khalilnezhad et al., 2021). Travel restrictions imposed during the pandemic present a useful study system for understanding the temporal and spatial patterns of green space use. These conditions present an opportunity to gain deeper insights into features of green spaces associated with increased use during times of crisis and the self-perceived benefits of visiting green spaces during these times.

Green spaces serve a variety of functions for individuals in the community and perceptions of green spaces can be diverse. Individuals may visit green spaces to access specific features such as walking paths, playgrounds, or ecosystem services such as shade and clean air, offered by that particular space. Yet, not all urban green spaces offer the same types, qualities, and quantities of ecosystem services and not every individual has the same demands for such services. Studies show that biophysical features of green spaces, such as tree and grass cover, vegetation complexity, blue spaces, biodiversity, size, and shape play a role on people's decision to visit green spaces. After conducting a survey of individuals in Portugal, Madureira et al. (2018) found that richness and diversity of plant species was a highly attractive feature of green spaces. However, Shanahan et al. (2017), found that people surveyed in Brisbane and the United Kingdom did not preferentially visit green spaces with higher plant species richness or greater tree cover despite evidence that these features offer the potential for improved nature-based experiences and greater wellbeing benefits. Further, Zhang X. et al. (2020) found that irregularly shaped green spaces were associated with pronounced increases in people using the space for walking. Rey Gozalo et al. (2019) discovered that the size of green spaces was positively correlated with the frequency of walking, exercising, and relaxing in Spain. Location and the facilities within green spaces also play a role in how attractive the green space will be to potential visitors. Anecdotal evidence suggests that frequent green space use for physical activity was greater when the time taken to reach a green space was shorter (Dallimer et al., 2014). Voigt et al. (2014) found that facilities in green spaces that promote relaxation and leisure activities were preferred by residents in Berlin, Germany.

Although previous quantitative research has explored patterns of green space use and features of green spaces associated with frequency of use (Dallimer et al., 2014; Madureira et al., 2018; Dade et al., 2020), we know relatively little about green space characteristics that encourage people to repeatedly visit the *same* green spaces, and we have limited empirical knowledge of the extent to which patterns of green space use and features associated with use change when routine activities abruptly shift; as was the case during the COVID-19 pandemic. In this study we examine green space characteristics and sociodemographic factors associated with changes in frequency of green space use during a period of COVID-19 restrictions in Brisbane, Australia, and explore changes in self-perceived benefits associated with visiting green spaces. We (i) quantify how the frequency of green space use changed during the COVID-19 lockdown, (ii) determine the extent to which these changes were associated with sociodemographic and green space characteristics, (iii) identify changes in self-perceived benefits of using green spaces during the restrictions period, and (iv) analyse the association between changes in self-perceived benefits of using green spaces and biophysical green space characteristics.

MATERIALS AND METHODS

We conducted a survey (n = 1,002) in the Brisbane Local Government Area, Australia, to capture people's urban green space visitation patterns, including change in frequency of, and self-perceived benefits associated with, using urban green spaces before and during a stay-at-home restriction (hereafter "lockdown"). We only considered survey participants that provided information about the specific green spaces they visited *before and during* the pandemic (n = 372). We developed statistical models to identify which sociodemographic characteristics and urban green space biophysical variables were associated with changes in frequency of green space use and/or self-perceived benefits of green space use during COVID-19 compared to before the pandemic.

Study Area and Data Collection

The Brisbane Local Government Area (hereafter "Brisbane") has an estimated human population of 1.27 million residents, approximately 4.9% of Australia's population with a population density of 947 individuals per km^2 (Brisbane City Council, 2021). Brisbane's green space network comprises more than 2,100 urban parks, picnic grounds, pocket parks, riverside spaces, botanic gardens, nature reserves, and beaches. These green spaces are widespread across the city containing both native and non-remnant vegetation cover that provides habitat and connectivity to over 80 different vegetation communities and over 2,300 species of wildlife and native plants (Shanahan et al., 2017; Brisbane City Council, 2020a,b).

Relative to other jurisdictions, Brisbane experienced few COVID-19 infections and related lockdowns during the first year of the pandemic. In Brisbane, the most significant lockdown restrictions were introduced on 23 March 2020 and continued until 2 May 2020 when measures were partially relaxed. During lockdown residents were instructed to work from home where possible; practice social distancing and good hygiene and leave home only for essential trips. The restrictions involved the closure of schools and universities, indoor fitness and sports facilities, and all food, drink, and cultural venues. One of the few reasons people were expressly permitted to leave home was for recreation or physical activity in a public green space. However, these trips were limited to the immediate residential neighbourhood and could be conducted with no more than two people from different households (Australian Government Department of Health, 2020).

Our survey was administered immediately following this lockdown period (survey distributed in June 2020) using a market research company (Q&A).[1] Participants were invited to complete the survey according to four nested stratification criteria that ensured the sample reflected a range of Brisbane's demographic groups, broad socioeconomic spread, and an even spatial distribution across the city. The stratification rules were as follows: (a) an equal number of males and females, (b) an equal number of participants above and below 45 years of age, (c) income quartiles reflecting those of the whole Brisbane population and (d) an even distribution of participants' location of residence across Brisbane (North/South/East/West side of Brisbane). The survey was delivered online by a market research company in accordance with the University of Queensland Human Research Ethics Approval, approval number 2020001073. All participants were at least 18 years old and provided written consent to participate in the survey. The survey asked participants to report whether they had visited an urban green space (a) before and (b) during the COVID-19 lockdown. If they answered yes, they were asked to list up to seven of the green spaces they visited, specifying the name and the frequency of use during both periods (*never, once every 2 weeks, once a week, 2–3 days a week, 4–5 days a week, and 6–7 days a week*). For this study, we used the first-listed green space in each time period (hereafter "nominated green space") since 60.05% of survey respondents listed only one green space, and to simplify the interpretation of the analysis. We then geolocated each nominated green space with reference to a Brisbane City Council spatial dataset of public green spaces (Brisbane City Council, 2020c). We also asked survey participants to provide either their exact address, the address to the nearest 10 houses or the location of the street corner closest to their home, depending on what they felt most comfortable revealing. We used this information to geolocate residences using either the exact address when provided by participants, or the mid-point of a street in other cases.

[1] https://qandapanel.com.au/

Dependent Variables

Change in Frequency of Green Space Use During COVID-19 Lockdown

This variable was computed as the difference between frequency of green space use during the COVID-19 lockdown [*never (1), once every 2 weeks (2), once a week (3), 2–3 days a week (4), 4–5 days a week (5) and 6–7 days a week (6)*] and frequency of green space use before lockdown. Given that the frequency of use variable is not continuous we coded change in frequency into three categories, where 0 is *no change* in frequency of green space use during lockdown compared to before the pandemic; 1 is *increased* use of green spaces during the pandemic compared to before lockdown; and 2 is *decreased* use of green spaces during lockdown compared to before the pandemic.

Change in Self-Perceived Benefits of Urban Green Spaces

Participants were asked to report on the extent to which ten common benefits associated using green spaces had increased or decreased in importance during the pandemic related lockdown using a 5-point Likert scale (*1 = much more important, 5 = much less important*). For the analysis, we constructed two new variables named "psychological benefits" and "nature interactions." For "psychological benefits" we constructed mean scale scores taking each participant's mean response across three reasons in the survey questionnaire: reduction of stress, reduction of anxiety, and reduction in depression (*Cronbach's alpha* = 0.94). We followed the same process to construct a "nature interactions" variable using three reasons: connection to nature, appreciation of the environment, and provision of clean air (*Cronbach's alpha* = 0.89). We use the individual Likert variables as outcome variables for physical health benefits, spiritual connection, social interactions, and family interactions.

Independent Variables

Biophysical Factors

Vegetation characteristics (tree cover, grass cover, and foliage high diversity -FHD-) were derived from LiDAR data and other high-resolution imagery at a resolution of 30 m (see Caynes et al., 2016 for more details). We calculated the proportion of *grass* and *tree cover* within each green space using the *raster* and *fasterize* R packages package in R (Ross, 2018; Hijmans, 2021). FHD is a measure of vegetation vertical complexity that accounts for how evenly vegetation is distributed among vertical strata (Caynes et al., 2016). Vegetation (or forest) strata can be composed by three classes of vertical layers. The lowest layer is an herbaceous/shrub story with grasses, herbs, and shrubs. The understory has trees above the shrub layer and below the canopy;

and the overstory comprises the highest layer of vegetation in a forest, including canopy trees (Berger and Puettmann, 2000). Caynes et al. (2016) separated the FHD data into five discrete height intervals, including very low (≥ 0.15– < 1 m), low (≥ 1– < 2 m), medium (≥ 2– < 5 m), high (≥ 5– < 10 m) and very high vegetation (≥ 10 m). As such, FHD values are high where vegetation is more evenly distributed across the vertical strata and low where vegetation is less evenly distributed. We calculated mean FHD within each green space using the raster and *fasterize* packages in R (Ross, 2018; Hijmans, 2021). Data on *blue spaces* present within a green space was obtained from the Brisbane City Council (2018). This is an indicator variable where a 1 indicates the presence of blue spaces in a green space and a 0 indicates no blue space. The *shape* of a green space was characterised using the shape index defined by McGarigal et al. (2012), calculated by dividing the perimeter of a green space by the minimum perimeter of that green space if the perimeter was rearranged to a maximally compact shape (circle). The shape index is minimum for maximally compact green spaces and increases as green space increases in complexity. For this study, we calculated each urban green space *size* and *shape* using the *landscapemetrics* R package (Hesselbarth et al., 2019).

Distance

We measure the distance from each participant's residence to the nominated urban green space visited before the COVID-19 lockdown by calculating the Euclidean distance between the two points using the *gDistance* function from the *regos* R package (Bivand and Rundel, 2020). In some cases, this will overestimate or underestimate the distance that needs to be travelled to reach the green space, but a detailed integrated transport network dataset was not available.

Facilities

Data on facilities present within each urban green space were obtained from Brisbane City Council (2018). During the COVID-19 lockdown, use of several green space facilities, including playgrounds, dog parks, water fountains, barbeque, and picnic areas were restricted; therefore, we excluded them for our analysis. We included only presence of a carpark and access by public transport. *Presence of a carpark* is a dichotomous variable where 0 indicates no carpark is present at the individual's nominated green space and 1 indicates that the green space does have an attached carpark. *Public transport* is also a dichotomous variable where 0 indicates no public transport access at the individual's nominated green space and 1 indicates public transport is available at the green space.

Change of Urban Green Space Visited During Lockdown

We operationalised this variable by comparing the first nominated green space visited before and during lockdown. We then computed it by creating a dichotomous variable where 0 indicates no change and 1 indicates that the individual changed the green space visited during COVID-19 compared to before the pandemic related lockdown.

Statistical Analysis

We first conducted a series of descriptive analyses to evaluate the differences between urban green spaces visited before and during lockdown. **Tables 1, 2** summarize descriptive statistics for each of the measures included in the regression analyses (**Supplementary Data Sheets 1, 2** respectively).

Second, we estimated a series of regression models to address our research questions. The first of these models is a multinomial logistic regression analysis to determine how the frequency of green space use changed during the COVID-19 lockdown, and the extent to which this was associated with sociodemographic and green space characteristics. The dependent variable in this model is change in frequency of use of green space during the COVID-19 lockdown compared to before, coded into three categories, where 0 = *no change*, 1 = *increased* use of green space during lockdown, and 2 = *decreased* use of green space during lockdown. The category "*no change* in frequency of green space use" is used as the reference category in the multinomial regression. Our selection of *independent* variables is informed by the results of previous research on people's perceptions and use of green spaces (Ode Sang et al., 2016; Braçe et al., 2021), and also scholarship on the frequency of green space use during COVID-19 (Uchiyama and Kohsaka, 2020; da Schio et al., 2021; Lu et al., 2021). Studies consistently identify *gender, age,* and *income* as associated with their perception of greens spaces and frequency of use of green spaces not only in "non-pandemic" times, but also during periods of COVID-19 restrictions (Braçe et al., 2021). The influence of green space characteristics on changes in the frequency of green space use during the COVID-19 pandemic is yet to be examined in depth. However, a study by Lu et al. (2021) examining use of urban green space in Asian cities during the pandemic found that during COVID-19 restrictions, urban residents preferred large nature parks to smaller urban parks and also visited green spaces closer to the city centre. Drawing on this limited research and previous research examining green space characteristics that

TABLE 1 | Characteristics of the 372 study participants that responded to items regarding green space visited and reasons for visiting green spaces during the COVID-19 lockdown.

Variables	*n*	Median or % (SD)	Min-Max
Gender			
Males	194	51.6	
Females	178	48.3	
Age	372	43 (17.7)	19–84
Income (AUD $/year)	372	102,000 (14,000)	0–104,000
Change of green space visited during lockdown			
Yes	124	33.3	
No	248	66.6	
Change in frequency of green space use			
No change	143	38.4	
Increased	150	40.3	
Decreased	79	21	

TABLE 2 | Characteristics of urban green spaces visited before and during the COVID-19 lockdown (n = 300).

Variable	Before			During	
	n	Median/n (*SD*)	Min-max	Median/n (*SD*)	Min-max
Distance to green space (metres)	300	1362.05 (4605.78)	81.86–25368.94	1269.91 (4651.94)	81.82–27190.37
Size of green space (hectares)	300	9.79 (222)	0.11–1413.93	9.55 (251.2)	0.05–1413.93
Shape of green space	300	1.72 (1.29)	1.06–11.79	1.65 (1.02)	1.08–11.79
Grass cover	300	22.29 (20.5)	0–100	24.88 (20.5)	0–100
FHD	300	0.80 (0.11)	0.53–1.13	0.80 (0.11)	0.58–1.13
Blue spaces	300	154		144	

influence use during "non-pandemic" times (for example see Abkar et al., 2010; Dade et al., 2020) we selected the following green space characteristics as independent variables: shape of green space, size of green space, presence of blue spaces, tree and grass cover, FHD, presence of car park, and presence of public transport node. We conducted Spearman's correlations and VIF statistics. All VIFs were below 3.6 suggesting multicollinearity would not be problematic, and Spearman's correlations were below 0.43 except in the case of tree and grass cover which returned a value of −0.66 (**Supplementary Table 1**). Tree cover was therefore excluded from the model, while *grass cover* of the green space visited before lockdown, *FHD* of the green space visited before lockdown, the presence of *blue spaces*, *size* of the green space visited before lockdown, and *shape* of the green space visited before lockdown were retained to represent biophysical features of the green space. To ensure model parsimony [lowest Akaike Information Criterion (AIC) (Burnham and Anderson, 2002)] and the selection of the best fitting model we added variables in a stepwise (hierarchical) fashion. Refer to **Supplementary Table 2** for details on the stepwise models not presented in the main text. Model 1 contains only the sociodemographic characteristics; Model 2 is our final model including independent variables that are both informed by the literature and ensure model parsimony. We used the *nnet* R package (Venables and Ripley, 2002) to run multinomial logit regressions. The analytic sample included survey participants with responses for items regarding urban green space engagement both before and during COVID-19 lockdowns (n = 300, **Supplementary Data Sheet 2**).

The second stage of our empirical analyses comprises a suite of six regression models (Models 3–8) that examine the association between changes in the importance of self-perceived benefits of green spaces during the pandemic and particular biophysical green space characteristics. Models 3–8 investigate changes in the importance of specific benefits associated with visiting green spaces including: *nature interactions; psychological health benefits; physical activity; spiritual connection; and social and family interactions*. Each model includes independent variables representing *gender, age, income, size* of green space visited during lockdown, *shape* of green space visited during lockdown, *grass cover* of green space visited during lockdown, presence of *blue spaces* in the green space visited during lockdown, and *FHD* of green space visited during lockdown. Variables were selected based on previous research showing that size, shape, FHD, and grass cover can influence reasons for visiting green spaces (Dade et al., 2020). Although Dade et al. (2020) also found that facilities influenced reasons for attending green spaces, we did not include facilities in these models given that all facilities at public green spaces were closed during the COVID-19 lockdown. Models 3 and 4 are generalised linear regression models (GLM) assuming a gamma distribution because both the "nature interactions" (Model 3) and "psychological health benefits" (Model 4) dependent variables include positive-only values, and the error distributions are right skewed. The dependent variables "physical activity" (Model 5), "spiritual connection" (Model 6), "social interactions" (Model 7), and "family interactions" (Model 8) are ordinal variables containing five categories; thus, we estimate ordered logistic regression models for these data. We used the *MASS* R package to run the ordered logistic regressions (Venables and Ripley, 2002). The analytic sample for Models 3–8 include all survey participants who responded to items regarding green space visited and reasons for visiting green spaces *during* COVID-19 lockdown (n = 372, **Supplementary Data Sheet 1**).

All statistical models were evaluated using goodness of fit tests. For multinomial logistic regression models, we used a Hosmer–Lemeshow Test from the *generalhoslem* R package (Jay, 2019), for generalised linear models we used a Likelihood Ratio Test from the *lmtest* R package (Zeileis and Hothorn, 2002), and for the ordered logistic regression we used a Lipsitz Test from the *generalhoslem* R package. We calculated models' R squared using the *rsq* R package (Zhang, 2021). All models were assessed for and met normality of residuals. All data analyses were carried out with R Studio V1.2 (RStudio Team, 2020).

RESULTS

Descriptive Analysis

The sample comprised 372 individuals of which 48.3% were females, and the average age was 43 (**Table 1**). Of the 372 individuals, 78.8% either increased or did not change their frequency of green space use, while 21.2% decreased their visits to green spaces. There was a great deal of flux in which green spaces were visited, with 33.3% of individuals visiting a different green space during the lockdown than before.

Although in aggregate there appears to be little change between the characteristics of green spaces used before and during the pandemic (**Table 2**), examining individual cases suggests several important differences in the characteristics of green spaces used during COVID-19 compared to before at the individual level. For example, before COVID-19 lockdown, a large section of the population visited green spaces two to 11 times farther away from their residences than the green space visited during lockdown. Conversely, during the COVID-19 lockdown, fewer individuals visited green spaces two to five times farther away from their residences than the green space visited before lockdown. Although a large section of the sample population (66%) visited green spaces of approximately the same size before and during the COVID-19 lockdown. During lockdown, a fraction of the sample population (9 and 9.6%) visited green spaces 10 or more times smaller and larger, (respectively), than the green space visited before lockdown. Urban green space shape patterns did not appreciably change during the lockdown (**Table 2**). There is a slight upward shift in grass cover from before [Interquartile Range (IQR) = 22.29–50.6] to during (IQR = 24.8–52.0) the lockdown. Although some individuals (13.6%) visited green spaces with less grass cover during lockdown (from 25 to 50% cover to 0%) many individuals (20.3%) visited green spaces with larger amounts of grass cover when compared to the green space visited before lockdown. Foliage height diversity followed a similar trend, with 16 and 18% of the sample population visiting green spaces with lower and higher FHD indexes (**Table 2**).

Change in Frequency of Green Space Use During COVID-19 Lockdown

A summary of the associations between dependent and independent variables of Models 1 and 2 are shown in **Table 3**. Detailed results of the multinomial logistic regressions are displayed in **Table 4** and are presented as relative risk ratios (RRR). RRR are the exponentiated regression coefficients and can be interpreted as the relative likelihood of an event occurring between two groups (e.g., change in frequency of use of green spaces during lockdown) given exposure to the variable of interest (e.g., shape of a green space) (Simon, 2001). The category "*no change* in frequency of green space use" is used as the reference category in the multinomial regression. Hosmer-Lemeshow goodness of fit tests indicates a significant improvement in model fit between the base demographic model (Model 1 $p < 0.0361$) and our final model (Model 2 $p < 0.6949$). The test score for Model 2 is well above the 0.05 threshold indicating the model is correct. It is also approaching one; therefore, demonstrating a better fit.

Results of Model 2 demonstrate that individuals were more likely to *increase* their use of green space during lockdown compared to before if they were female compared to male (RRR = 2.413, $p < 0.01$) and younger compared to older (RRR = 0.970, $p < 0.01$). Individuals who visited the same green space during lockdown compared to the green space visited before the lockdown tended to *increase* their frequency of use (RRR = 0.570, $p < 0.01$). Urban green space characteristics also played a role. Individuals were more likely to *increase* their frequency of green space use during the lockdown compared to before the lockdown if the green space they visited had a carpark (RRR = 1.217, $p < 0.01$), was accessible by public transport (RRR = 1.289, $p < 0.01$), contained a blue space (RRR = 1.307, $p < 0.01$), and/or had lower FHD –vegetation is less evenly distributed across vertical layers– compared to green spaces with higher FHD (RRR = 0.211, $p < 0.01$). Individuals were more likely to *decrease* their frequency of green space use during the lockdown compared to before if they were female (RRR = 1.179, $p < 0.01$), or changed their nominated green space during the lockdown compared to before (RRR = 1.437, $p < 0.01$), individuals were also more likely to reduce their frequency of green space use during the lockdown, compared to before, if the green space they visited did not have a carpark (RRR = 0.913, $p < 0.01$), was not accessible by public transport (RRR = 0.760, $p < 0.01$), and had higher FHD –vegetation is more evenly distributed across the vertical structure– compared to green spaces with lower FHD (RRR = 2.933, $p < 0.01$).

Changes in Self-Perceived Benefits of Urban Green Space Use

In Models 3–8 we examine changes in self-perceived benefits associated with urban green space use during the pandemic compared to before. A summary of the associations between dependent and independent variables of Models 3–8 are shown on **Table 3**. Model 3 shows that being male ($b = -0.01$, $p < 0.05$) and older ($b \leq 0.001$, $p < 0.001$) was significantly associated with reporting an increase in the importance of urban green spaces for nature interactions during the lockdown. Characteristics of the green space visited during the lockdown did not influence change in the importance of nature interactions. Model 3 accounts for 11.2% of variance in the outcome variable and was significant (Likelihood ratio test, $p < 0.001$). Similarly, Model 4 indicates that being male ($b = -0.001$, $p < 0.01$) and older than 43 ($b = 0.001$, $p < 0.001$) were significantly associated with reporting an increase in the importance of urban green spaces for psychological benefits during the lockdown. Model 4 accounts for 16.3% of the variance in the outcome variable, which was significant (Likelihood ratio test $p < 0.001$). Models 5–8 are ordered logistic regression models. Lipsitz goodness of fit tests for all models returned a p-value above the 0.05 threshold indicating that all models satisfy the proportional odds assumption and are correctly specified. Results of Model 5 reveal that younger individuals are more likely than older people to report increases in the importance of green spaces for physical activity during the lockdown than before (RRR = 0.983, $p < 0.01$). Model 6 indicates that the odds of reporting increased importance of green spaces for spiritual connection is higher for females compared to males (RRR = 1.516, $p < 0.1$), younger individuals compared to older individuals (RRR = 0.974, $p < 0.01$), and higher income earners (RRR = 1.071, $p < 0.05$). Using a smaller green space with greater shape complexity is also associated with higher odds of reporting increases in the importance of green spaces for spiritual connection during the lockdown (RRR = 0.999, $p < 0.1$; RRR = 1.211, $p < 0.1$). Results of Model 7 show the odds of reporting an increase in the importance of green spaces for social interactions during the COVID-19 pandemic was significantly higher for female compared to males (RRR = 1.461, $p < 0.1$), younger individuals (RRR = 0.983, $p < 0.01$), and higher income earners (RRR = 1.068, $p < 0.05$). Model 8 reveals that the odds

TABLE 3 | Significant associations between dependent and independent variables of eight regression models including sociodemographic and green space characteristics of green spaces used before (Model 1–2) and during (Model 3–8) a COVID-19 lockdown.

	Dependent variables							
Independent variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**
	Change in frequency of use	Change in frequency of use	Nature interactions	Psychological health benefits	Physical activity	Spiritual connection	Social interaction	Family interactions
Gender—females	+	±	–	–		+	+	+
Age	–	–	+	+	–	–	–	–
Income						+	+	+
Change the green space visited		±						
Distance to green space								
Carpark		±						
Public transport		±						
Size of green space						–		
Shape of green space						+	+	
Grass cover								
FHD		±						
Blue spaces		+						

For Models 1-2: "+" denotes an increase and "–" denotes a decrease; and for Models 3–8: "+" denotes a positive association and "–" denotes a negative association. Gray cells represent variables that were not included in the regression.

TABLE 4 | Change in frequency of use of urban green spaces during the COVID-19 lockdown explained by sociodemographic and green space characteristics variables.

Independent variable	**RRR**		**SE**		**95%CI**			
	Increased use	**Decreased use**	**Increased use**	**Decreased use**	**Increased use**		**Decreased use**	
Model 1								
Intercept	2.243	0.527	0.568	0.694	–0.305	1.921	–2.000	0.717
Gender—females	2.430**	1.238	0.275	0.315	0.349	1.426	–0.403	0.830
Age	0.971**	0.990	0.008	0.009	–0.045	–0.013	–0.027	0.007
Income	1.003	1.035	0.037	0.045	–0.070	0.076	–0.053	0.122
Hosmer-Lemeshow Test[¥]		*p-value = 0.0361*						
AIC		*623.295*						
Model 2								
Intercept	7.345**	0.224**	0.006	0.010	1.982	2.005	–1.516	–1.478
Gender—females	2.413**	1.179**	0.007	0.008	–0.086	0.089	0.149	0.017
Age	0.970**	0.990	0.006	0.007	–0.004	–0.001	–0.024	<0.001
Income	1.000	1.039	0.033	0.038	–0.064	0.006	–0.034	0.011
Change the green space visited	0.570**	1.437**	0.003	0.011	–0.056	– <0.001	0.340	0.038
Distance to green space[§]	1.000	1.000	<0.001	<0.001	– <0.001	< 0.001	– <0.001	<0.001
Carpark[§]	1.217**	0.913**	0.003	0.007	0.019	0.020	–0.105	–0.007
Public transport [§]	1.289**	0.760**	0.002	0.001	0.025	0.025	–0.275	–0.027
Shape of green space[§]	1.047	0.928	0.102	0.134	–0.015	0.024	–0.337	–0.018
Size of green space	1.000	0.999	0.001	0.001	– <0.001	<0.001	–0.003	<0.001
FHD[§]	0.211**	2.993**	0.006	0.011	–1.568	–1.543	1.075	1.117
Grass cover[§]	1.004	1.005	0.006	0.007	– <0.001	0.001	–0.008	0.001
Blue spaces[§]	1.307**	0.988	0.012	0.021	0.024	0.029	0.052	0.002
Hosmer-Lemeshow Test[¥]		*p-value = 0.6949*						
AIC		*640.16*						

[§]*Urban green space characteristics are from before the COVID-19 lockdown (n = 300).* [¥]*Hosmer-Lemeshow Test with higher p-values indicate better model fit (Fagerland and Hosmer, 2012). ^p < 0.10, *p < 0.05, **p < 0.01. RRR = relative risk ratios. SE = standard error.*

of reporting increases in the importance of green spaces for family interactions were higher for females compared to males (RRR = 1.411, $p < 0.1$), younger people compared to older individuals (RRR = 0.982, $p < 0.01$), higher income earners

(RRR = 1.062, $p < 0.05$), and those who used green spaces with more complex shapes during the lockdown compared to those who visited more compact green spaces (RRR = 1.265, $p < 0.05$).

DISCUSSION

In this study we discovered that changes in the frequency of green space use and the importance of green spaces for self-perceived benefits use during a COVID-19 lockdown were associated with a number of individual characteristics and green space characteristics. In sum, our findings suggest four key takeaway points.

Our first key finding is that frequency of green space use increased during COVID-19 for some individuals but decreased for others. This pattern of change in frequency of green space use was particularly evident among females in the sample and suggests that the impact of COVID-19 restrictions on changes in frequency of green space use among females may have been moderated by green space characteristics. Our results provide support for those reported by Braçe et al. (2021) who found gender differences in perceptions of green space characteristics, with females attributing greater importance to characteristics, such as pleasant views, playgrounds, lightning, and safety than their male counterparts.

Secondly, individuals who did not change the park visited during the lockdown period were more likely to increase their frequency of visits. Increasing frequency of use may be associated with individuals having more free time and using green spaces for a greater variety of activities during COVID-19 when other facilities such as gyms and cafes were unavailable. Also, being familiar with the available features and other people who use the green space has the potential to increase opportunities for social, physical, and psychological benefits. Increased frequency of use was also associated with specific features of green spaces visited pre-lockdown; in particular the presence of a blue space. Recent research suggests that more frequent visits to blue spaces are associated with positive wellbeing and lower rates of mental distress Abkar et al. (2010) and White et al. (2021) suggests that water in green spaces is one of the most important biophysical factors that contribute to individuals' positive mood change. Thus, the presence of blue spaces might enhance the odds of individuals increasing their frequency of green space use especially during times of stress.

Individuals who went to a different green space during lockdown were more likely to report a decrease in visitation compared to before the lockdown. This could be explained by the routine activity theory (Cohen and Felson, 1979), which posits that changes in the structure of the patterns of daily activity could explain other events. During COVID-19 lockdowns, people's daily life was forced to drastically change because important urban nodes or places where daily activities are usually carried out were closed. Therefore, routine daily life during lockdown was characterised by reduced mobility, prolonged stays at home, telework or job losses, disruptions in social relationships, and declines in physical activity levels; all with implications for mental wellbeing (Ogden, 2020; Salari et al., 2020; Biroli et al., 2021; Mckeown et al., 2021; Mouratidis, 2021). One potential explanation for why individuals visited a different green space during the lockdown is that green spaces took on some of the functions of other nodes during the lockdown (for example gyms, cafes). That is, individuals visited green spaces with different characteristics, to satisfy unmet demands resulting from the restrictions. However, it is also plausible that the new green space visited during lockdown did not fulfil individuals' needs and may have caused them to decrease their frequency of use. For example, we found that green spaces with a higher proportion of canopy cover among forest strata (FHD), which tend to be located in the outskirts of the city, were associated with a remarkable decrease in visits during lockdown. In contrast, green spaces with fewer vegetation vertical layers (which are more characteristic of neighbourhood parks) were associated with increases in use. Our results may suggest that local green spaces and in closer proximity to people's homes can act as nature-based solution by fulfiling needs that are not necessarily related to nature interactions during times of crisis.

Our third finding is that people travelled to green spaces two to 11 times closer to their home during the lockdown compared to before, suggesting that the mobility restrictions imposed to stop the spread of COVID-19 may have changed individuals' daily activity patterns and further supporting a role for the routine activity theory in explaining the changes. Therefore, visiting urban green spaces with different characteristics may have served as a pathway to accommodate people's new daily activity patterns and needs resulting from the COVID-19 restrictions. However, the opportunity to access the services provided by either the same or a different green space may also depend on the configuration of the urban landscape and individuals' access to green spaces. Proximity was not the only indicator of accessibility that was associated with increased frequency of green space use during the lockdown. Individuals who visited green spaces with *carparks* and/or *public transport* nodes were also more likely to increase their frequency of green space use during lockdown. Although Brisbane residents have excellent accessibility to green spaces, relative to many other capital city residents (Berdejo-Espinola et al., 2021) this finding illustrates that ensuring equitable access across all sociodemographic groups and neighbourhood settings is pivotal for facilitating green space use to satisfy unmet needs during times of crisis.

Finally, our results show that the importance of self-perceived benefits associated with using green spaces changed markedly during the COVID-19 lockdown, and that these changes were associated with sociodemographic variables and to a lesser extent with green space characteristics. Despite the closure of facilities within green spaces, such a playgrounds, benches, and sporting features, on average, individuals reported increased importance of green spaces for their cultural ecosystem services. This reinforces the importance of biophysical features of green spaces in everyday urban life. We found that males and older individuals were more likely to express greater increases than females and younger people in the importance of green space for nature interactions and mental health benefits during the COVID-19 lockdown compared to before the pandemic. This might be related to changes in routine activity patterns for males, including teleworking, looking after children, and reallocation of household responsibilities that posed new stressors in their daily life (Douglas et al., 2020; Biroli et al., 2021). While the importance of urban green spaces for mental wellbeing is well established in the literature (Keniger et al., 2013; Zhang J. et al., 2020), these benefits have been articulated more strongly by females in times of crisis (Burnett et al., 2021; Gastelum-Strozzi et al., 2021; Lopez et al., 2021). In fact, Gastelum-Strozzi et al. (2021) have shown that males in Mexico City indicated feeling remarkably fewer effects of the pandemic on mental health than females. It may be that for males living in Brisbane, utilising green spaces for mental wellbeing has emerged as a condition of the COVID-19 pandemic after making other places for social interactions and physical health unavailable. In contrast, we found that females were more likely than males to report increased importance of green spaces for spiritual, social, and family interactions. This reflects research conducted by Burnett et al. (2021) in the United Kingdom, who found that females who reduced their use of green spaces during the pandemic were more likely to agree that they missed interacting with others in green spaces than males. Future research could explore the idiosyncrasies across sexes.

The shape of green spaces also emerged as an important feature associated with changes in benefits associated with green space use. Individuals using irregularly shaped green spaces were more likely to report increased importance of the green space for social interactions during the lockdown. Scholarship on social cognition suggests that social gazing—visual behavior between two or more individuals (Kleinke, 1986)—is one form to communicate and an important component of social interaction (Emery, 2000). Thus, spending time in less compact green spaces might help increase the number of everyday visual encounters where people can at least see others while socially distancing and stimulating a sense of social connection even when physical distancing is enforced. Further, individuals using irregularly shaped green spaces were more likely to report increased importance in green spaces for spiritual connection during the COVID-19 pandemic. Across Brisbane, the shape of urban green spaces tend to be relatively compact, with a mean shape index of 1.45 [compact shape = 1 according to McGarigal et al. (2012)], meaning that irregularly shaped green spaces are less common. Thus, the uniqueness of compact green spaces may facilitate the development of a sense of place attachment—the emotional bond between person and place (Scannell and Gifford, 2010). Stedman (2003) suggests that individuals do not become directly attached to the physical features of a green space, but rather to the meaning that those features represent. Thus, attachment to a green space could be related to the attachment to the experiences individuals can have in a green space, perhaps nature experiences (for example, birdwatching), or to the attachment to the social interactions that the green space affords them. Unique identifiers of the green space territory, such as a unique shape are important to facilitate opportunities for social connection, particularly during stressful times. In this context, future pandemic-resilient urban planning and policy might consider the size and shape of green spaces to ensure safe access to green spaces with appropriate social distancing.

While this study extended current knowledge on urban green spaces and their use during the COVID-19 pandemic it is not without limitations. We note that the sample is relatively small, and caution should be used when generalising the findings to other settings. Further, the study is conducted in Brisbane, Australia which had been relatively protected from COVID-19 compared to other regions during the early phase of the pandemic. Another limitation is that we asked individuals to report about the green spaces visited before and during a COVID-19 lockdown and did not account for the influence of household dynamics and how other members of the household may affect green space visitation. We encourage new research to explore this avenue. Lastly, our data are retrospective, given that participants reported their frequency of use and perceptions of the benefits of green spaces before and during the restrictions period 30–90 days after their use. This means that there may be some inaccuracy in people's reports due to the memory recall errors, however, we expect recall bias to be limited due to the relatively short reference period (Ayhan and Isiksal, 2004).

Our findings suggest a number of areas for future research and considerations for policy and practice. First, they highlight the need to ensure accessibility to urban green spaces with appropriate ecosystem services for all sociodemographic groups and all geographic areas, before, during, and after disasters/collective crises as they are important multifunctional sites that can serve as a nature-based coping mechanism for communities and individuals (Berdejo-Espinola et al., 2021). Accessibility to green spaces must consider not only proximity to, and availability of green spaces, but also modes of access, such as car parking, and public, and active transport (the latter not considered in this study). Yet, making green spaces available is only the first step; ensuring that they are matched to the needs of the population is also vital. Our findings also suggest that features found to be associated with mental health and wellbeing benefits such as blue spaces may facilitate higher usage during periods of crises. Thus, the presence of blue spaces may have the potential to benefit communities. Further, the complexity of green space shape may be important for facilitating place attachment and supporting the social function of green spaces. Planning and co-designing crisis-resilient urban areas while considering the key individual and community factors might lead to more accessible, functional urban green spaces.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The University of Queensland Human Research

Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

VB-E and RZ: conceptualisation, formal analysis, and writing original draft. VB-E, RZ, RF, and AS-C: methodology. VB-E, RZ, AS-C, JR, and RF: writing-review and editing. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fevo.2022.804443/full#supplementary-material

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