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Understanding Multiple Dimensions of Perceived Greenspace Accessibility and Their Effect on Subjective Well-Being During a Global Pandemic

Megan Maurer[1,2†], Elizabeth M. Cook[3†], Liv Yoon[1], Olivia Visnic[3], Ben Orlove[1], Patricia J. Culligan[4] and Brian J. Mailloux[3†]*

[1] The Earth Institute, Columbia University, New York, NY, United States, [2] Department of Geosciences and Natural Resource Management, University of Copenhagen, Frederiksberg, Denmark, [3] Environmental Science Department, Barnard College, New York, NY, United States, [4] College of Engineering, University of Notre Dame, South Bend, IN, United States

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****Correspondence:***
Megan Maurer
megm@ign.ku.dk

[†] These authors share first authorship

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The COVID-19 pandemic has demonstrated how the accessibility of greenspace can shift in response to social-ecological disturbance, and generated questions as to how changing dimensions of accessibility affect the ecosystem services of greenspace, such as improved subjective well-being. Amidst the growing consensus of the important role of greenspace in improving and maintaining well-being through times of duress, we examine how access to greenspace is affecting subjective well-being during the COVID-19 pandemic. Both the relationship of greenspace to subjective well-being and the barriers to greenspace access are well-established for normal conditions. Much remains to be known, however, about how barriers to access and the effect of greenspace on subjective well-being shift in response to periods of social duress, such as the current COVID-19 pandemic. Using data from surveys and interviews conducted with 1,200 university students in the United States during the spring of 2020, we assess the effect of going outdoors on subjective well-being, commonly experienced barriers to going outside, and how these barriers in turn affected subjective well-being. We find that time spent outside, particularly in greenspace, correlates with higher levels of subjective well-being, and that concern over COVID-19 risk and transmission negatively affects this relationship both in reducing time spent outdoors and the subjective well-being benefits. We also find that type of greenspace (public vs. private) does not have a significant effect on subjective well-being, that while those in areas with lower population density have significantly higher subjective well-being when outdoors, all participants experience a statistically equal benefit to subjective well-being by going outside. Our findings suggest how understanding the ways dimensions of accessibility shift in response to times of social duress can aid public health messaging, the design and management of greenspace, and environmental justice efforts to support the use of greenspace in improving and maintaining subjective well-being during future crisis events.

Keywords: subjective well-being, risk perception, COVID-19, greenspace accessibility, urban-rural differences, environmental justice (EJ), public greenspaces, cultural ecosystem services

INTRODUCTION

In the spring of 2020, life dramatically changed for millions as the COVID-19 pandemic spread across the globe. In order to protect the health and safety of residents, governments introduced a series of mandates to stay at home, wear masks, maintain six feet of distance ("social distancing"), and close schools, parks, and non-essential businesses (Courtemanche et al., 2020; Guy et al., 2021). These response measures, while necessary to stop the spread of COVID-19—the disease caused by severe acute respiratory syndrome coronavirus 2 (SARS COV-2)—also created a severe social disruption by curtailing activities outside the home, including time spent outdoors in parks and other greenspaces (Badr et al., 2020; Moreland et al., 2021). While access to greenspace will likely return to pre-COVID norms once this pandemic is over, it is unlikely that this current disruption will be the last time people around the world experience an event that limits access to, and perceived accessibility of, greenspace. For example, the ongoing climate crisis includes a number of potential social-ecological disturbances, including infectious disease outbreaks and increased heat waves (Smith et al., 2014; Depietri and McPhearson, 2018), which might also limit or prevent outdoor activities. Currently, however, little is known about how changes in greenspace accessibility during times of social disruption and crisis affect the health and well-being of individuals.

The COVID-19 pandemic has, and continues to, take the lives of millions around the world; it has also exacted a toll on the physical and mental health, economic security, and overall well-being of people everywhere. The threat to health and safety posed by the disease itself, in conjunction with the social and economic costs of measures necessary to stop its spread, are largely responsible for these negative health effects. However, there is also reason to believe that reduced time spent outside due to stay-at-home orders, and in particular reduced access to greenspace, might also have negatively affected the health and well-being of individuals and communities (Galea et al., 2020; Slater et al., 2020). In this paper greenspace is understood through definition and example based criteria (Taylor and Hochuli, 2017) as a spatial area with some degree of vegetation such as a park, tree-lined sidewalk, or yard. In order to understand how reduced access to greenspace impacts human health and well-being during conditions of crisis, it is important to develop a more nuanced understanding of greenspace access that accounts for the multiple dimensions of perceived accessibility, including perceptions of risk as affected by pandemics and other such disturbances. The goal of this paper is to advance such understanding by examining the effect of being outdoors on subjective well-being during the COVID-19 pandemic and how this relationship is affected by changes in perceived greenspace accessibility, including the perceived risk of going outside.

Subjective Well-Being and Greenspace Access

Improvements to subjective well-being are one of the many ecosystem services associated with greenspace (Herzog et al., 2003; Russell et al., 2013; Jennings et al., 2016; van den Bosch and Sang, 2017). Following the existing literature, we define subjective well-being (SWB) as a composite of an individual's perception of satisfaction with their life as a whole, their happiness at the present or given moment, and their level of stress and/or anxiety (Diener and Suh, 1997; Manderscheid et al., 2010; Das et al., 2020). Previous research has identified direct relationships between greenspace and improved SWB. Important factors influencing SWB include the quantity of available greenspace (van Dillen et al., 2012; Houlden et al., 2018; Cleary et al., 2019), frequency of visits to greenspace (Fretwell and Greig, 2019; Grilli et al., 2020), biodiversity of the greenspace (Carrus et al., 2015; Cameron et al., 2020), perceived restorativeness of greenspace (Grahn and Stigsdotter, 2010; Lin Y.-H. et al., 2014; Subiza-Pérez et al., 2020), and feelings of connectedness to nature (Nisbet et al., 2011). Frequency of greenspace use has also been shown to be mediated by greenspace design, landscape attributes, and amenities—factors which also influence the perceived accessibility of greenspace (McCormack et al., 2010; Roberts et al., 2019; Grilli et al., 2020).

Perceived accessibility, which is conceived of including both the ability to physically access a space and the extent to which it is socially acceptable or desirable to do so, is in turn associated with changes in SWB (Deng et al., 2019; Wang et al., 2019). Perceived accessibility is thus influenced by greenspace access—understood here as the relative ability of an individual to have contact with a vegetated area—as well as individual, social, and cultural factors, all of which can interact in spatially and temporally specific ways. As such, perceived accessibility is subject to change with respect to social and environmental context, public norms, and individual perceptions; moreover, which factors most influence perceived accessibility are also subject to change in similar ways. Thus, rather than conceive of perceived accessibility as a two-dimensional continuum (from low to high), in this paper we present perceived accessibility as an attribute of greenspace that possesses multiple dimensions, which shift in importance with respect to time, space, and social position of greenspace users.

During the COVID-19 pandemic, stay-at-home orders and concerns about the risks of disease transmission have potentially decreased both the availability and perceived accessibility of greenspace. While emerging research documents changes to greenspace use (Ugolini et al., 2020) and the demographic profiles of park users (Derks et al., 2020; Rice and Pan, 2020; Uchiyama and Kohsaka, 2020), recent studies also document increases in the number of people going to greenspaces (Derks et al., 2020; Fisher and Grima, 2020; Rice and Pan, 2020; Venter et al., 2020; Geng et al., 2021). It remains to be seen whether changes to availability, perceived accessibility, and frequency of use in a time of stress translate into changes in the ecosystem services provided by greenspace, including individual SWB.

Moreover, the pandemic is also potentially affecting factors known to negatively influence the relationship between greenspace and SWB. Foremost among these previously identified factors are concerns with safety and perceived safety (Lai et al., 2020). Here, both vegetation and spatial arrangement of greenspace have been identified as influencing the degree of perceived safety (Jorgensen et al., 2002; Jansson et al., 2013; Sreetheran and Van Den Bosch, 2014; Lis et al., 2019;

Mouratidis, 2019). Greenspaces with lower levels of perceived safety, lack of physical access, and disamenities, such as poorly maintained facilities, litter, or unwelcome uses, are associated with lower measures of SWB and often result in lower rates of use (McCormack et al., 2010; Weiss et al., 2011; Wang et al., 2015; Zhang et al., 2015; Cheesbrough et al., 2019; Roberts et al., 2019; Groshong et al., 2020; Jarvis et al., 2020; Sonti et al., 2020). Moreover, physical access to greenspace in the US is disproportionately affected by race and socioeconomic status, with Black, Indigenous, and people of color (BIPOC) and those with incomes below the national median having lower access to greenspace than white, higher-than-median income individuals (Heynen et al., 2006; Wolch et al., 2014; Nesbitt et al., 2019). The COVID-19 pandemic has introduced additional barriers influencing greenspace access, such as crowding and park closures (Shoari et al., 2020; Ugolini et al., 2020), though these findings may not be conclusive (Rice and Pan, 2020). Overall, further information on the barriers to greenspace access, changes in perceived accessibility, and perceived risk is needed.

Population density and relative amount of greenspace can also impact SWB. While urbanites may have lower available greenspace area per capita than suburban or rural residents, population density itself has not been shown to be a factor influencing the relationship between greenspace and SWB (Maas et al., 2006; Dennis and James, 2017; Coldwell and Evans, 2018). For example, Tyrväinen et al. (2014) found both an urban park and a woodland outside the city had similar effects on psychological and physiological stress levels when compared to an unvegetated city center. This suggests general greenspace experiences, regardless of surrounding population density or built landscape, can have an important positive effect on a person's SWB (see also Van den Berg et al., 2014). Meanwhile, research on differences between public and private greenspace are mixed, with some studies suggesting public greenspaces provide well-being benefits—or "substitute"—where private greenspace is not available (Maat and de Vries, 2006), while other research indicates that users of private greenspace are also more likely to access public greenspace (Lin B. B. et al., 2014).

Due to stay-at-home orders and park closures during the COVID-19 pandemic individuals in less densely populated areas, and / or with access to private greenspace (such as a yard or rooftop garden), may have more available greenspace with a higher degree of perceived accessibility and safety than those with only access to publicly available greenspaces. Results from Poortinga et al. (2021) suggest that COVID-19 may be influencing the relationship of access to private greenspace—and thus the role of population density or degree of urbanicity—to SWB. It remains to be seen what greenspaces people are utilizing, the barriers to access, such as crowding or risk of disease transmission, they perceive, and the effect of both on SWB.

Understanding the role of perceived accessibility in people's subjective well-being during the COVID-19 pandemic is necessary for assessing the full impact of this event (McCunn, 2020; Samuelsson et al., 2020). Understanding how the provision of ecosystem services like SWB changes can in turn aid both continued response to this protracted pandemic (Salama, 2020), and responses to future social and ecological disturbance. Thus, we ask if and how disruptions to perceived greenspace accessibility affect SWB. We specifically investigate three questions: (1) What effect does going outdoors, for the purpose of being outside, have on subjective well-being during the COVID-19 pandemic?; (2) how has the perceived accessibility of greenspace changed during this period of disruption, particularly with respect to changes in perceived risk of going outdoors? and; (3) do these changes influence the observed relationship between greenspace and SWB?

METHODS

To investigate our research questions, we conducted an online survey and semi-structured video interviews with undergraduate and graduate students across the US. As campuses closed across the country in spring 2020, most students either returned home or remained in off-campus housing, resulting in a respondent population living in a wide range of landscape contexts. Furthermore, this population experienced a shared form of disruption from the closure of campuses and the switch to remote learning. We analyzed the quantitative and qualitative data from surveys and interviews alongside 2018 American Community Survey (ACS) Census socio-demographic data. Research design and instruments were approved by the Barnard College IRB and informed consent was used for both surveys and interviews.

Survey

The survey instrument featured 40 questions divided into five main sections: (1) general background, including location and living situation; (2) self-reported SWB; (3) greenspace use and perceived accessibility; (4) risk perception regarding COVID-19 and outdoor activity; and (5) demographics (**Supplementary Material 1**). We asked participants to rate, on a 1–10 scale, their SWB based on overall life satisfaction (hereafter "well-being overall"), momentary SWB at the time of survey (hereafter "well-being now"), and SWB during the last trip outdoors (hereafter "well-being outdoors").

Surveys were distributed online and were designed to be completed in $\sim$ 15 mins. Participation was anonymous. The survey was distributed through convenience snowball sampling through personal contacts and colleagues at higher educational institutions across the country, which resulted in participants from 71 academic institutions (Table 1 in **Supplementary Material 2**). Surveys were distributed between April 12, 2020 and May 15, 2020, and survey responses were received through May 23, 2020. Of the 1,130 responses, 85% ($n = 964$) of the respondents completed 98% of the survey and 8.5% ($n = 93$) completed at least 40% of the questions.

Survey respondents reported the zip code in which they were currently residing at the time of the survey. Using the zip code, we joined US ACS Census demographic data (2018 five year average) to calculate population density within each zip code. Following US Census designations, we classified zip codes as high population density urban (>1,159 persons km^{-2}), medium population density suburban (386–1,159 persons km^{-2}), and low density rural (<386 persons km^{-2}; U. S. Census, 1994). Survey responses were analyzed in R (R version 4.0.2) and graphed in

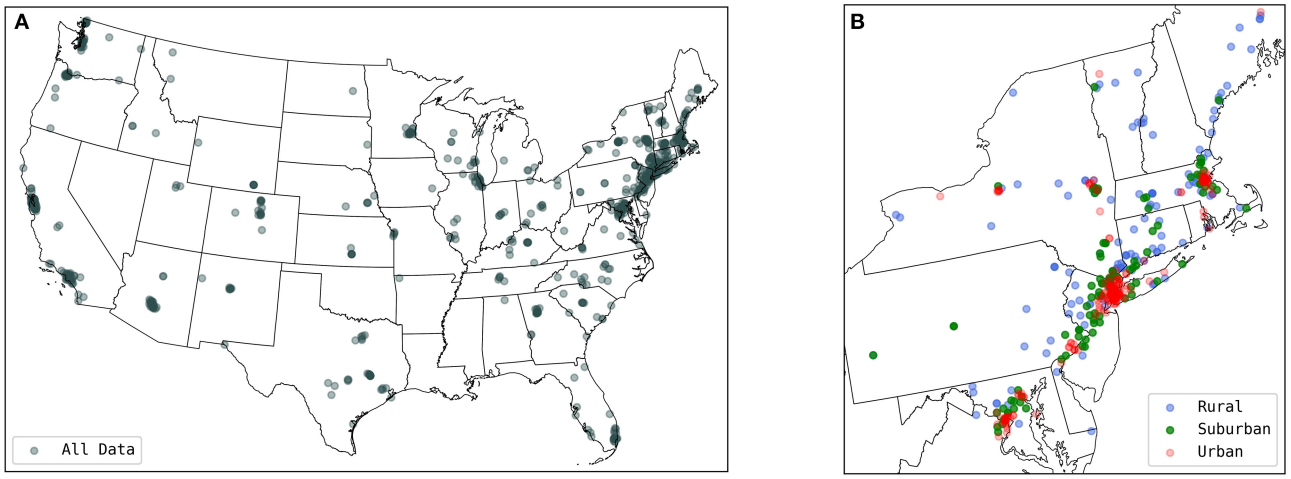

FIGURE 1 | Distribution of survey respondents. **(A)** Location of respondents from the conterminous United States. Darker colors indicate multiple respondents in the same zip code. **(B)** Location of respondents within the Northeastern United states. Colors indicate rural (purple), suburban (green), and urban (red) based on respondents' ZIP code classified by population density.

Python (3.6.6). Analyses were conducted using parametric *t*-test and one-way analysis of variance (ANOVA) analyses.

Study Population

Participants in this study were drawn from the population of students (undergraduate and masters level) attending US post-secondary educational institutions. The study sample was 57% white and 26.5% people of color, including 6.7% East/Southeast Asian, 3.7% Latinx, 3.5% South Asian, 2.2% Black/African American and 9.5% who reported more than one race (Table 3 in **Supplementary Material 2**). When compared to the undergraduate student population in the US, our sample aligns with national demographics for white and Asian students (55.2 and 7.3% of US-wide student population, respectively), but under-represents Black (13.4%), Hispanic (19.5%), and Native American students (0.7%) (NCES, 2019). Respondents were approximately evenly distributed by class year (13.7% in first year of school, 14.8% second, 19.5% third, 22.9% fourth, and 13.8% post-graduate) and 42% ($n = 470$) of the sample reported receiving some form of financial aid (Tables 4, 5 in **Supplementary Material 2**). As a result of the large participation ($n = 343$, 30%) by Barnard College students (an all-women institution), 67% of respondents identified as women, 15% as men, 1% as non-binary, and 16% did not report their gender (Table 2 in **Supplementary Material 2**). Our sample was distributed across 45 states, including Alaska, and 788 US zip codes (**Figure 1**). To further understand the spatial distribution of our sample, we classified individuals as living in rural ($n = 288$, 25.5%), suburban ($n = 221$, 19.6%), or urban ($n = 580$, 51.3%) areas based on the population density of their ZIP code following the US Census urban-rural classification (U. S. Census, 1994).

Interview

Survey respondents indicated if they were willing to volunteer for a follow-up interview. Four hundred sixty-nine survey participants (42.4%) answered yes and provided adequate contact information. To select interview participants, volunteers were sorted into six bins based on population density of reported ZIP code and self-reported risk associated with going outdoors. For the first round of interview requests, 20 individuals were contacted from each bin (120 individuals total). Individuals from each bin were selected based on the race and gender categories in order to best match the demographics of the US undergraduate population. Where the number of survey respondents was insufficient (e.g., number of men and BIPOC), additional individuals from other demographic categories (e.g., white and/or women) were sampled to achieve 20 individuals for that bin. First-round requests were distributed *via* email on May 12, 2020. The sampling process was repeated for two additional rounds, on May 17 and June 6. At this point interviews had reached saturation—that is, additional interviews were not generating novel responses or new themes. The total number of individuals contacted for interviews was 356 and the total number of completed interviews was 72.

Interviews were scheduled using the online service Calendly and conducted over Zoom. Consent forms were submitted *via* email. All interviews were recorded, but only the audio tracks of interviews were saved. All audio recordings were transcribed using the online service Rev. Interviews were semi-structured and consisted of 12 questions, covering topics of living situation, well-being, greenspace access, risk perception, and connection to nature (**Supplementary Material 1**). Interviews ranged in duration from 30 to 60 mins. Interviews were one-on-one, conducted by one of four research team members.

Interview transcripts were uploaded into the coding software Dedoose and a team of three researchers completed two rounds of content-based coding. The first round of coding used codes derived from the research questions and aligned with the survey questions. During this process emergent themes were identified and additional codes created. A second round of coding was

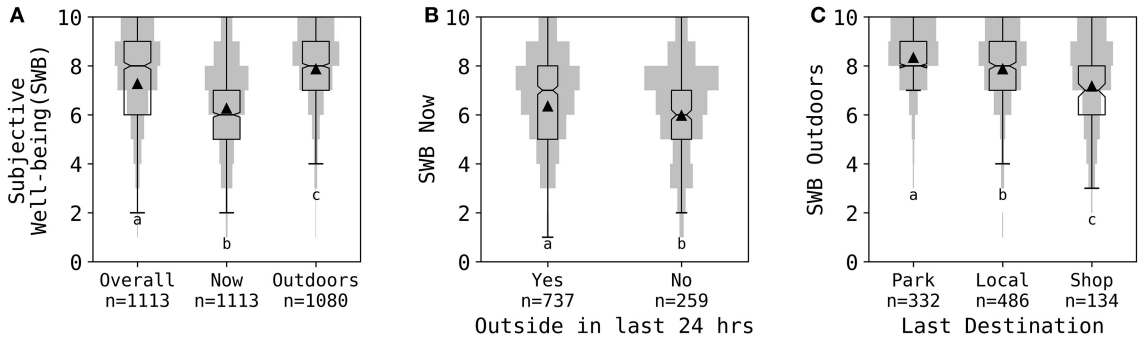

FIGURE 2 | Subjective well-being (SWB) given recent time outdoors and destination. **(A)** SWB ratings for overall life satisfaction (SWB overall), momentary happiness at time of survey (SWB now), and during their most recent trip outdoors (SWB outdoors); **(B)** SWB now as a function of being outdoors in the last 24 h; **(C)** SWB outdoors as a function of most recent destination (park or garden; local destination such as neighborhood walk or backyard; indoor shop). Lowercase letters indicate statistical significance between groups as determined using an ANOVA or *t*-test with a significance level of $p < 0.05$. Black triangles represent mean; boxplots indicate median (middle line) and first and third quartiles; gray shading highlights distribution of data.

completed in order to apply these inductively derived codes, as well as eliminate or combine deductive codes with little or no associated content.

Interview Respondent Population

While our interview population varied slightly with respect to the broader survey population, interviewee demographics remained skewed in similar ways with respect to race and gender (Tables 2, 3 in **Supplementary Material 3**). Our interview sample, however, included a higher proportion of graduate or professional students when compared to the survey population (Table 4 in **Supplementary Material 3**) and interviewees were also more likely to not receive financial aid (Table 5 in **Supplementary Material 3**).

RESULTS

Subjective Well-Being (SWB)

In the online survey, participants were asked (a) "On a scale of 1 to 10, rate your well-being right now (today)" (momentary happiness or "SWB now"); (b) "When you think about your life overall (not just today, but cumulatively), rate your well-being on a scale of 1 to 10" (life satisfaction or "SWB overall"); and (c) "On a scale of 1 to 10, rate your well-being during your most recent trip outdoors" ("SWB outdoors"). Average (±1SE) well-being at the time of survey was significantly lower (SWB now; 6.3 ± 0.05) than average SWB overall (7.3 ± 0.05) and average SWB outdoors (7.9 ± 0.05, $df = 2$, $p < 0.001$; **Figure 2A**).

Examining the demographic characteristics of survey respondents, we found women reported significantly lower SWB now ($p = 0.01$) and SWB overall ($p = 0.02$) than men; neither women nor men's SWB now or SWB overall were significantly different from gender non-binary respondents ($p > 0.05$). SWB outdoors did not differ by gender ($p = 0.3$). There were no significant differences in any reported SWB measure among different races and ethnicities, differences in financial aid, or in living situations at the time of survey (e.g., dorm, single, or multi-family unit; $p > 0.05$ for all). We found respondents who moved since the beginning of the pandemic reported a lower SWB now (6.0 ± 0.09) than respondents who did not relocate during the pandemic (6.5 ± 0.09; $p < 0.01$); yet there were no significant differences for ratings of SWB overall or SWB outdoors ($p > 0.05$).

We observed effects on SWB based on respondents' most recent destinations and how recently they went outdoors (**Figure 2**). 23% of survey respondents reported not going outdoors in the past 24 h, 29% reported going outdoors one time and 36% reported more than one trip outdoors in the past 24 h. Those who had been outside at least once in the last 24 h had significantly higher SWB now (6.4 ± 0.07) than those who had not been outdoors in the previous 24 h (6.0 ± 0.1; $p = 0.005$; **Figure 2B**). We also found the same trend for SWB overall, in which those who had been outside at least once in the last 24 h had significantly higher overall SWB compared to those who had not been outdoors ($p < 0.005$, data not shown). Moreover, SWB outdoors was highest for respondents who reported their last destination as a park or other extensive greenspace (survey options for park, garden), compared to other local outdoor destinations (with highly variable degree of green elements; survey options neighborhood, yard, porch, roof) or a shop (survey options store or restaurant) ($p < 0.05$; **Figure 2C**).

Risk Perception and Accessibility

In addition to the influence of physical access and outdoor destinations on SWB, we find that risk perception and perceived accessibility affect the degree to which going outdoors improves SWB. The risk individuals associated with going outside influenced their reported SWB outdoors (**Figure 3**). The majority of respondents (68%) associated at least some degree of risk with going outside (**Figure 3A**). We observe that as risk associated with going outside increases, SWB outdoors decreases significantly ($p < 0.05$; **Figure 3A**). SWB outdoors was significantly higher for those who associated no risk (8.4 ± 0.1), or considered going outside only somewhat risky (8.0 ± 0.1) compared with those reported going outdoors as risky (7.5 ± 0.1) or very risky (6.6 ± 0.3). Those who perceived a greater risk in

going outside were less likely to have been outdoors in the past 24 h; as perceived risk decreased, the likelihood of going outdoors in the last 24 h increased (**Figure 3B**).

The perception of risk associated with going outside influenced the perceived accessibility of outdoor spaces. Fifty percent of respondents Strongly Agreed or Somewhat Agreed with the statement "I would like to spend more time outdoors for the purpose of being outside, but I find it too risky because of COVID-19." Those who strongly agreed with this statement reported the lowest SWB outdoors (7.4 ± 0.1; **Figure 3B**). Those who Somewhat Agreed were indistinguishable from Neutral, which along with Somewhat Disagree and Strongly Disagreed (8.5 ± 0.1) had the highest SWB Outdoors (**Figure 3C**).

Barriers to Access and COVID-19

Four hundred forty-two survey participants reported in an open-ended question the obstacles they faced to spending time outdoors, for the purpose of being outside (**Figure 4**). A content coding analysis indicated that 65.2% of respondents cited obstacles directly related to COVID-19, including crowding or inability to maintain 6 feet physical distancing (24.7% of total identified obstacles), facility closures (13.6%), and an explicit fear of contracting or spreading COVID-19 (12.7%; **Figure 4**). The most commonly cited barriers to going outdoors not directly related to COVID-19 were time constraints (14.9%) and lack of greenspace and/or physical access (13.6%; **Figure 4**).

Population Density and SWB

We also found SWB varied based on current living location and population density. SWB now did not significantly vary for respondents living in urban, suburban, and rural locations ($p = 0.2$; **Figure 5A**). However, respondents living in rural locations had significantly higher SWB overall ($p = 0.02$) and SWB outdoors ($p < 0.01$) than those living in more densely populated urban locations (**Figures 5B,C**, respectively). Suburban landscapes did not have a significant impact on SWB (**Figure 6**). When examining the impacts of being outdoors through differences in SWB now compared to SWB outdoors (**Figure 6A**) and SWB overall compared to SWB outdoors (**Figure 6B**), we found no significant differences among locations of different population density ($p > 0.05$). In other words, this suggests that the difference to SWB resulting from going outside does not significantly vary with respect to location.

Type of Greenspace: Public vs. Private

Nine hundred sixty-eight survey respondents indicated the types of greenspace to which they felt they had access, including public benches (21%), porch or stoops (62%), private yards or gardens (69%), public parks (59%), plazas, playgrounds, or courtyards (21%), and public sidewalks (74%). Respondents living in urban areas reported lower access to greenspace, generally (69% with no access) and higher access to public parks (74% with access to public greenspace) when compared to suburban and rural respondents (**Figure 7A**). 53% of those with no reported access to greenspace considered going outside to be Risky or Very Risky, as compared to 34% of those with reported access to public greenspace only, 35% with private greenspace only, and 18% of those with access to both (**Figure 7B**).

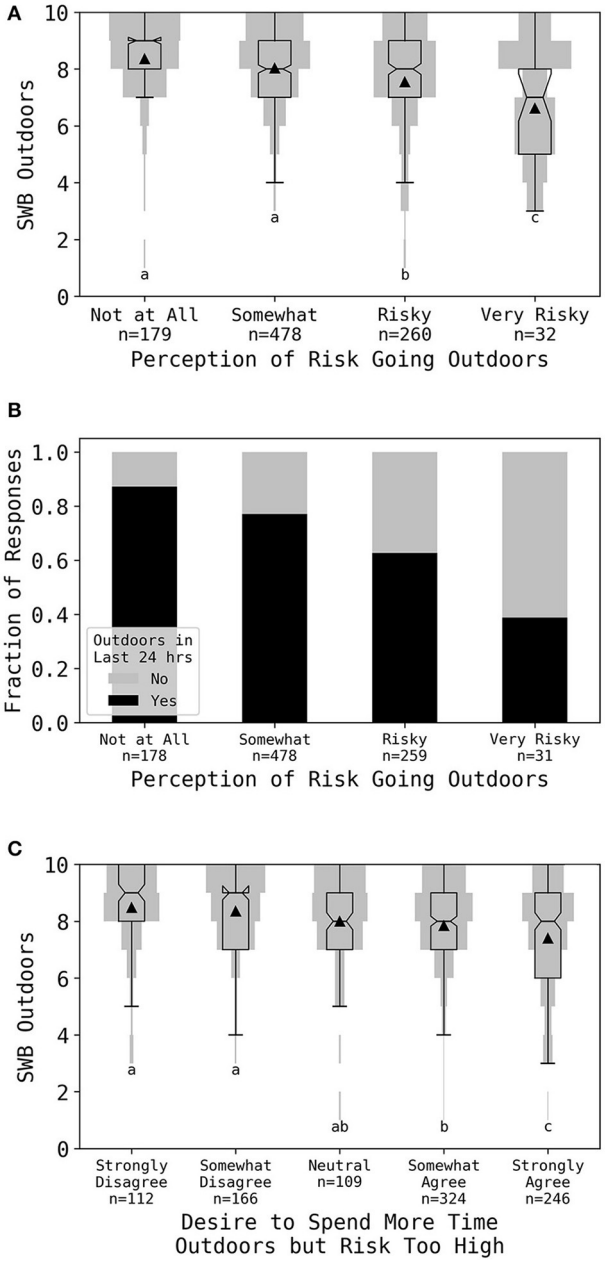

FIGURE 3 | Perceived risk of going outdoors and relationship to subjective well-being (SWB) and access. **(A)** SWB outdoors as a function of reported risk perception of going outdoors, for the purpose of being outside, due to COVID-19; **(B)** risk perception of going outdoors relative to trips outdoors in previous 24 h; and **(C)** SWB Outdoors as a function of a desire to spend more time outdoors but perceive it to be too risky to be outside. Lowercase letters indicate statistical significance between groups as determined using an ANOVA with a significance level of $p < 0.05$. Black triangles represent mean; boxplots indicate median (middle line) and first and third quartiles; gray shading highlights distribution of data.

Neither SWB today nor SWB outdoors varied significantly based on type of accessible greenspace; SWB did not differ by

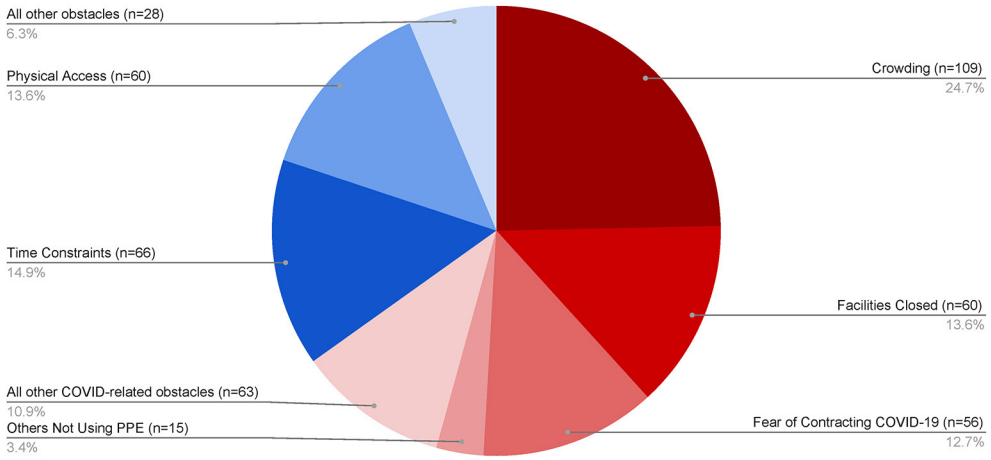

FIGURE 4 | Obstacles to spending time outdoors. Survey respondents self-reported obstacles to spending time outdoors, for the purpose of being outside ($n = 442$). Obstacles in red are directly related to COVID-19, including crowding, closed facilities, and fear of contracting COVID-19. Obstacles in blue indicate other obstacles to going outdoors, including physical access (e.g., lack of sidewalks) and time constraints (e.g., too much schoolwork) not related to COVID-19.

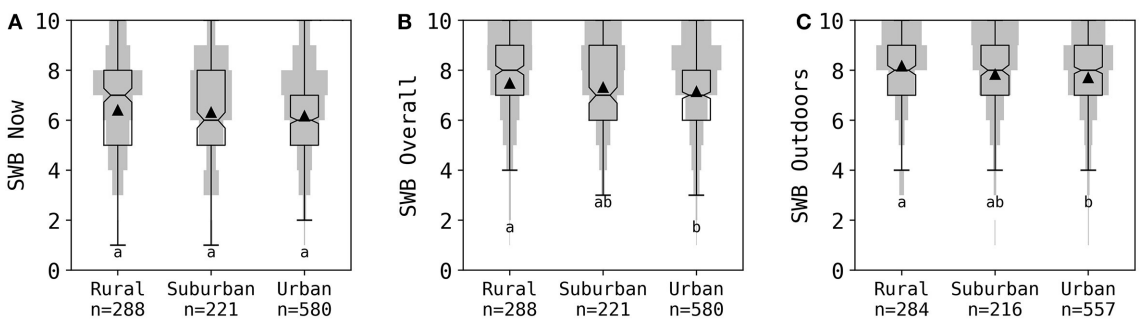

FIGURE 5 | Subjective well-being (SWB) based on population density. Population density was divided into three categories: rural (<386 persons km^{-2}), suburban (386–1,159 persons km^{-2}), and urban (>1,159 persons km^{-2}) based on census data and zip code (**Figure 1**). **(A)** SWB now as a function of population density. **(B)** SWB overall as a function of population density. **(C)** SWB outdoors vs. as a function of population density. Lowercase letters indicate statistical significance between groups as determined using an ANOVA with a significance level of $p < 0.05$. Black triangles represent mean; boxplots indicate median (middle line) and first and third quartiles; gray shading highlights distribution of data.

whether respondents reported access to only public greenspace (i.e., respondent did not selected "private yard or garden" but did select "public benches," "porch or stoop," "public park or garden," "plaza, playground or courtyard," and/or "public sidewalks"), only private (i.e., respondent selected "private yard or garden"), or both types of greenspace ($p > 0.05$; **Figures 7C,D**). However, respondents with no reported access to greenspace—public or private—had significantly lower SWB now and SWB outdoors when compared to those with access to some kind of greenspace ($p < 0.05$; **Figures 7C,D**).

Interview Results

Analysis of interview data identified five key findings relating to perceived greenspace accessibility, SWB, and risk perception. First, going outdoors was reported to improve SWB by providing a chance to get out, an opportunity to have contact with nature, and offering a sense of variety, comfort, and/or normalcy. Second, interviewees reported decreases in the perceived accessibility of greenspace due to risk perception associated with COVID-19, in particular lack of available space and crowding. Just over one-third (37%, $n = 29$) of interviewees reported going outside less. Third, we found that issues of limited physical access and sociocultural barriers persisted. For example, interviewees in low-income, majority-BIPOC neighborhoods continued to have few greenspaces available to them. Relatedly, racial identity itself emerged from our interview data as a barrier to access. Interviewees who identified as Asian-American also reported that their perceived accessibility of greenspace (and public space generally) had declined in response to incidents of racial harassment and violence. Fifth and finally, interviewees reported accessing multiple types of greenspace, both public and private, and valuing this variety.

DISCUSSION

Our results suggest that limitations to greenspace accessibility associated with social-ecological disturbances have an effect on subjective well-being (SWB). We find that spending time outside

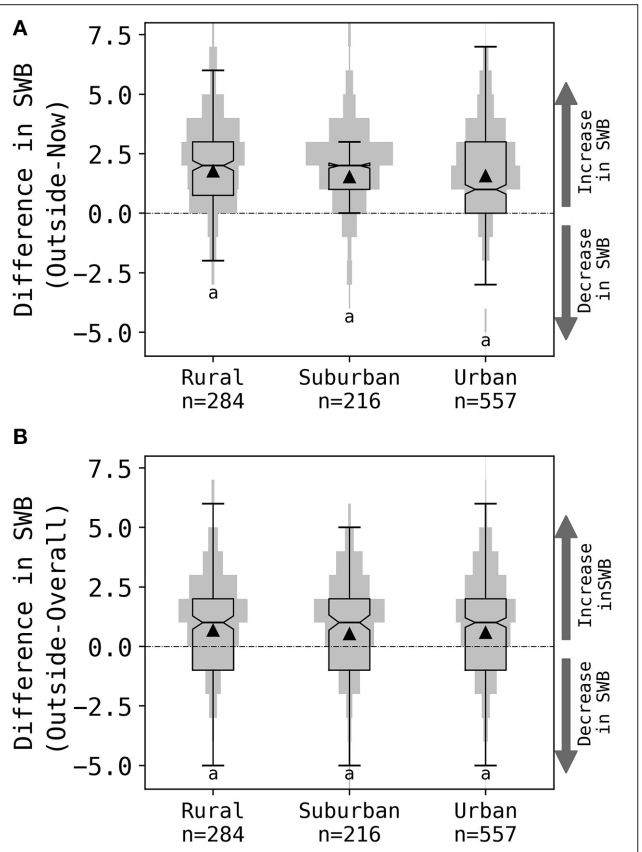

FIGURE 6 | Difference in subjective well-being (SWB) by population density. **(A)** Difference in SWB between SWB outside and SWB Now. A positive value indicates that your SWB is higher outside than now. **(B)** Difference in SWB between SWB outside and SWB overall. A positive value indicates that your SWB is higher outside than overall. Lowercase letters indicate statistical significance between groups as determined using an ANOVA with a significance level of $p < 0.05$. Black triangles represent mean; boxplots indicate median (middle line) and first and third quartiles; gray shading highlights distribution of data.

is associated with higher levels of SWB for individuals during the COVID-19 pandemic. In particular, we find the highest levels of SWB among those who spent time in an outdoor greenspace, and those who had been outdoors in the previous 24 h. While going outdoors is associated with higher SWB, the majority of people associated some degree of risk with going outdoors and cited obstacles to spending time outside directly related to COVID-19. Moreover, those who associated greater risk with going outside had lower SWB while outdoors than those who perceived very little risk. We do not find demographic variables or type of greenspace access (public or private) to affect SWB while outdoors. Finally, while those living in high density urban areas had lower SWB outdoors than those living in more rural locations, we find respondents experienced the same degree of benefit to SWB in going outdoors regardless of where they lived. We conclude that strategies for creating and maintaining safe access to outdoor greenspaces are a much-needed component of institutional responses to both the COVID-19 pandemic and future social-ecological disturbance.

Previous research has established that improvements to SWB are a key ecosystem service provided by greenspace (Russell et al., 2013; Jennings et al., 2016; Houlden et al., 2018), and indicates that contact with greenspace can lead to reductions in stress and anxiety and increases in happiness (Herzog et al., 2003; van den Bosch and Sang, 2017). While these studies were conducted under normal (i.e., non-pandemic) conditions, our results suggest that the relationship between greenspace and SWB holds during the COVID-19 pandemic. We found levels of SWB during respondents' most recent trip outdoors to be higher than both SWB overall (life satisfaction) and SWB now (at time of survey; momentary happiness). We also found that those who had been outdoors within the past 24 h reported higher levels of SWB now than those who had not. Data from follow-up interviews provide some further insight into these results. For many, the benefit of going outside was simply a chance to get out: "extremely good to get outta the house" (A76, white woman in rural area, 5/29/2020). For others, it was the presence of nature: "I love seeing all the different shades of green. That gives me a happiness-base everyday" (A68, demographics not reported, 6/11/2020). Finally, there were those for whom going outside to a greenspace provided a sense of variety, comfort, and even normalcy.

> It's really comforting, I've been finding, to be able to go outside and see trees and see people biking and going on walks and walking their dogs. Like, even though to my knowledge everyone's practicing the proper precautions and they have masks on and they're keeping space, there's something just really nice about being in a space with other human beings and being outside, and I think that that's really done wonders for my mental health and has made me just feel, like, you can carve out a simulation of normalcy even in these circumstances and it can still be safe. (A27, white woman in urban area, 5/28/2020)

Together, these results suggest that greenspace continues to play an important role in maintaining and improving SWB, even during the COVID-19 pandemic. This conclusion is supported by findings in recent studies that suggest individuals are identifying well-being benefits to going outdoors in the context of COVID-19 (Fisher and Grima, 2020; Lopez et al., 2021; Poortinga et al., 2021), as well as studies of the important role of nature for well-being during previous crisis events (Van den Berg et al., 2010; Campbell et al., 2016; McMillen et al., 2016).

While barriers to accessing greenspace—such as perceived (non-COVID related) safety (Cheesbrough et al., 2019; Lai et al., 2020) and lack of physical access (Wolch et al., 2014; Zhang et al., 2015)—are present in our study, we do not find that these represent the primary barriers to access identified during the COVID-19 pandemic. Rather we find that the perceived risk of going outdoors, specifically due to COVID-19, is decreasing perceived accessibility. Participants indicated that the perceived risk of going outdoors resulted in less than the desired amount of time outside, and the most frequently cited barriers to access were directly related to COVID-19. For many, these obstacles

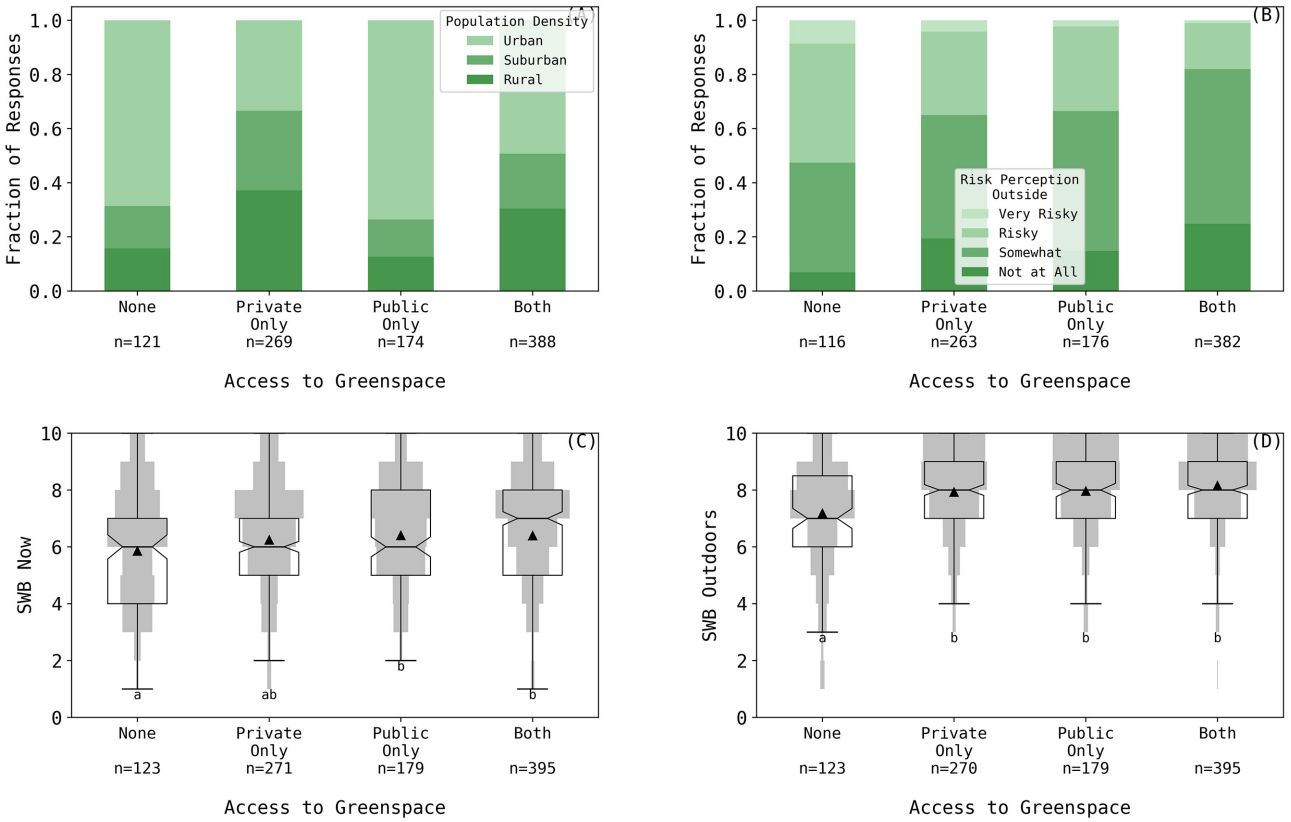

FIGURE 7 | Type of accessible greenspace and relationship to population density, risk perception, and subjective well-being (SWB). **(A)** Population density by type of accessible greenspace (no easy and safe accessible greenspace, access to private greenspace only, access to public greenspace only, access to both private and public greenspace); **(B)** risk perception of being outdoors by type of accessible greenspace; **(C)** SWB now as a function of type of accessible greenspace; and **(D)** SWB outdoors as a function of type of accessible greenspace. Lowercase letters indicate statistical significance between groups as determined using an ANOVA with a significance level of $p < 0.05$. Black triangles represent mean; boxplots indicate median (middle line) and first and third quartiles; gray shading highlights distribution of data.

centered on the amount of available space and included crowding or inability to maintain six feet distance, as well as others not wearing masks. As one interviewee explained their concern for going outside:

> Mostly just fear of coming across people and, like, tight trails and [people] who aren't wearing masks, cause people here are not wearing masks. It is hard because I wanna be spending all this time in green space for, like, my mental health, but I am trying really hard to social distance to protect my older family members. There is always an anxiety and a fear there. And it has kept me, several times, from going out on, like, the nicest days, because I know it's gonna be more populated, with people that I probably can't avoid. (A65, white suburban woman, 6/8/2020)

Park closures were also a COVID-19 induced barrier to spending time outdoors mentioned by both survey respondents and interviewees. For example, when one interviewee (A32, white suburban man, 6/12/2020) was asked if he was going to any greenspaces, he replied: "It depends on the timeline." He noted he had no access to greenspace for roughly three months while parks were closed, except for a few times he snuck into a park to go bird-watching.

While time spent outdoors, particularly in greenspace, is an important contributor to SWB during the COVID-19 pandemic, risk perception associated with the pandemic is a moderating variable. This point was driven home by interviewees who reported on the negative effects of observing strict quarantines, or the inability to sustain long periods of indoor isolation. For example, one interviewee (A61, white non-binary individual in suburban area, 6/15/2020) described their family living in a tiny apartment observing a strict cycle of 2-week quarantine periods. They had been easing up on this regime, and when asked why, they explained: "It [COVID-19] didn't totally blow up [here]. And the other thing is just I think at a certain point of being stuck in a tiny little space for a really long time, you just kind of hit your limit...I'm willing to accept a little more risk." Other studies offer some support for these findings, observing concerns about crowding, decreased time outdoors and reduced accessibility of greenspace as responses to COVID-19 that also represent additional stressors to health and well-being (Galea et al., 2020; Slater et al., 2020; Ugolini et al., 2020).

Our findings support a multi-dimensional understanding of perceived accessibility, which is subject to change with respect to social and environmental context, public norms, and individual perceptions. Moreover, these findings indicate that access is intersectional (Powers et al., 2020), and that issues of physical or sociocultural access persisted. Those who lived in neighborhoods with little available greenspace continued to struggle with physical access: "I'm in like South East Bronx. So there's not a lot of green space. It's just mainly residential housing. In order to get to any green space we have to drive. Or take the train, or just walk a really long time" (A71, Latina woman in urban area, 6/9/2020). This lack of access had very real consequences for SWB, as those who reported no access to greenspace had significantly lower levels of SWB today and SWB outdoors than those who did have access to public or private greenspace.

Physical access was also limited by inadequate infrastructure in both rural and urban areas:

> The closest park is I think like two miles but because I don't have a car I can't really get there easily and in this area, it's kinda dangerous even just to walk because we don't really have sidewalks. I've heard stories of people getting hit by cars, their pets being hit by cars in broad daylight. (A30, biracial woman in rural area, 6/1/2020)

Finally, general safety was a persistent sociocultural barrier. "Being a woman it's just not safe to run through those parks at those times [early morning and late evening]" (A16, Latina urban woman, 5/31/2020). This quote gestures to the important intersection of gender identity and safety (Jorgensen et al., 2002; Campbell et al., 2016). It is important to note that in our study, while we find that women reported lower overall SWB and SWB now when compared to men—a finding consistent with previous research (Batz and Tay, 2018)—these differences disappear when assessing SWB outdoors. This suggests that going outside ameliorates gender-based differences in SWB. In total, non-COVID specific barriers associated with physical access and safety represented 19.9% of those mentioned by survey respondents.

Race/ethnicity did not affect SWB in our survey responses, however interviewees did reflect on persistent macro-sociocultural issues and barriers. For example, several Asian-American individuals reported experiencing or observing incidences of racism and expressed increased reluctance or anxiety associated with going outdoors. After being harassed on public transit and witnessing a friend being assaulted, one interviewee stated she was increasingly afraid of going outside (A56, East Asian woman in urban area, 6/2/2020). Another stated that after enduring several incidents of people being "physically aggressive in my space" she was glad she had started carrying pepper spray and a knife (A44, East Asian woman in urban area, 5/25/2020). As demonstrated in these excerpts, racism persisted as a barrier to greenspace access for many, highlighting that not all bodies were considered 'neutral' presences in public space—a reality echoed and witnessed in the continued harassment and murder of BIPOC during our study (Cohen, 2020; Ho, 2021).

The persistence of barriers, such as racism, to greenspace access is not necessarily independent of COVID-19—in the case of anti-Asian racism, it is intimately tied to it. The relationship of new challenges presented by COVID-19 to persistent barriers to access, however, requires careful presentation. Our surveys and interviews indicate that COVID-19 revealed new dimensions to perceived accessibility and introduced new barriers to access. While barriers created by racism (among other sociocultural and physical barriers) continued to be a influential component of access and perceived accessibility, during the COVID-19 pandemic issues of risk perception and disease-related safety became primary. In other words, those with racialized bodies, and/or living in majority-BIPOC or lower-than-median-income neighborhoods experienced further declines in greenspace accessibility, compounding the already unequal toll of the COVID-19 pandemic and structural racism in the USA (McPhearson et al., 2021).

Though prior research suggests that population density does not have an effect on the relationship between greenspace and SWB (Maas et al., 2006; Dennis and James, 2017; Coldwell and Evans, 2018), these studies were undertaken during normal (i.e., non-pandemic) conditions. Given contemporaneous research on greenspace accessibility and usage (Derks et al., 2020; Fisher and Grima, 2020; Rice and Pan, 2020; Ugolini et al., 2020; Venter et al., 2020; Geng et al., 2021), and anecdotal accounts of park closures and crowding in cities across the country, we expected to find residents of higher density areas and those without access to private greenspace to have higher perceived risk of going outdoors and lower SWB, particularly while outside. Likewise, while previous research on the effects of public vs. private greenspace are mixed (Maat and de Vries, 2006; Lin B. B. et al., 2014), during the COVID-19 pandemic, private greenspace seems to play an important role in compensating for decreased accessibility of public greenspace and maintaining individuals' SWB (Poortinga et al., 2021). We find that access to a private greenspace is associated with lower risk perception and higher likelihood of having gone outside in the last 24 h. These differences in access to public vs. private greenspaces did not translate into a significant effect on SWB while outside; access to any form of greenspace, public or private, had a statistically similar effect on SWB outdoors. Overall, going outdoors, regardless of the type of greenspace, was associated with positive differences in SWB. This finding supports Poortinga et al.'s (2021) conclusion that private gardens increase perceived accessibility of greenspace, but indicates that this perception does not translate into significant differences in SWB when actually going outdoors. Likewise, while residents in rural ZIP codes had higher access to greenspace, lower perceptions of risk associated with going outside, and higher levels of overall SWB and SWB while outdoors, differences based on population density disappeared when considering differences in SWB between SWB outdoors and SWB overall and today. The degree of difference in SWB upon going outside did not vary significantly with respect to population density, which concurs with previous findings (Maas et al., 2006; Tyrväinen et al., 2014; Van den Berg et al., 2014; Dennis and James, 2017; Coldwell and Evans, 2018).

We find neither population density nor type of greenspace (public vs. private) have a significant effect on the benefits to SWB of going outdoors during the COVID-19 pandemic, a finding consistent with that of Rice and Pan's study (2020). Interview results provide further insight, with interviewees actually reporting that they enjoyed a variety of greenspaces.

> My backyard and we have a vegetable garden, and then I have the park behind my house. I spend a lot of time there. There's also other little parks in the neighborhood, and there's another hill that you can go up and there's a water tower and I go up there, sometimes. I also just like... I don't know. ... walking around and seeing people's gardens, because it's spring and everyone's flowers are in bloom. So, it's not just parks, but just walking around and seeing what people have growing in the yards. (A42, white rural woman, 5/25/2020)

Indeed, for many, the greatest contribution of greenspace to their SWB was, as one interviewee put it, "the fact that it exists" (A67, white suburban man, 6/16/2020). The salutary effect of greenspace *via* "simply existing" is also supported by studies that find positive or maintenance effects on SWB associated with visually accessing greenspace (Velarde et al., 2007; Amerio et al., 2020). While this study did not assess visual access, results clearly suggest the benefit of spending time outdoors appears to derive simply from accessing a greenspace, regardless of type or context.

Limitations

We identify two meaningful limitations to this study: study population and sampling time-frame. Firstly, our study is limited by the utilization of only university students as a research population. This population potentially introduces biases around age (of particular relevance for COVID-19 risk perception) and education level, and is not representative of the broader US population. Secondly, our study utilizes data from one point in time, during the first wave of the COVID-19 pandemic. As such, our results are not able to speak to changes in risk perception and outdoor access, and their effect on SWB, over the course of the pandemic.

RECOMMENDATIONS FOR FUTURE SOCIAL-ECOLOGICAL DISTURBANCE

Based on these findings, we draw two primary conclusions and subsequent recommendations. First is that access to greenspace is multidimensional. That is, several different dimensions shape the perceived accessibility of greenspace, and those which are present and more influential change over time and with context. Our results show both that maintaining and improving subjective well-being (SWB) during the COVID-19 pandemic is an important ecosystem service provided by greenspace, and that risk perception played a role in decreasing perceived accessibility of greenspace and SWB while outdoors. The association between outdoor greenspace and SWB is well-documented during normal conditions, and our results demonstrate that it persists during the pandemic. Prior scholarship has also shown the important role greenspace plays in supporting well-being during other crisis events (Van den Berg et al., 2010; Campbell et al., 2016; McMillen et al., 2016). Our results suggest, however, that the persistence of the positive relationship between greenspace and SWB is only one part of the story. While this relationship remains unchanged during crisis events, dimensions of accessibility do not. The COVID-19 pandemic revealed barriers to access related to concerns with the safety and acceptability of outdoor recreation, blanket closure policies that severely reduced greenspace access for many individuals, fears over contracting or spreading the virus, and worries over the behaviors of others in public space. These barriers to access were the most frequently cited for our study participants. However, prior barriers, such as time constraints, lack of physical access, and racism, did not go away; COVID-19 specific barriers were layered on-top, adding more dimensions to greenspace accessibility and further inhibiting access to greenspace for many already marginalized, vulnerable people.

Given that we can expect further instances of social-ecological disturbance and social duress, particularly as a result of the ongoing climate crisis, the role of greenspace and the importance of ecosystem services like SWB, and the ways accessibility shifts and the multiple dimensions of accessibility shift with respect to one another, should not be overlooked. While maintaining the health and safety of the population during crisis events, particular outbreaks of infectious disease, is challenging and requires responses made with incomplete information, we argue that the important role of greenspace in SWB, as well as the mental and physical health of the population, should be taken into account (Samuelsson et al., 2020). Both public health messaging and planning for greenspace design and management should include the role of greenspace in maintaining and improving SWB, and should include provisions for the important role of greenspace, and changing greenspace accessibility, during future crisis events (Honey-Rosés et al., 2020; McCunn, 2020). Such provisions should also take account of the heightened vulnerability of BIPOC and impoverished peoples in such events (Watson et al., 2020; McPhearson et al., 2021).

Our second conclusion follows from this attention to the multidimensional nature of greenspace accessibility. We conclude there is a continued need for efforts toward creating and maintaining public greenspaces and their concomitant ecosystem services. Spending time in a greenspace has a positive effect on SWB regardless of the type of greenspace. Urban park or rural preserve, private yard or public space—we do not observe meaningful differences in levels of improvement to SWB associated with time spent in these outdoor spaces. Indeed, the most important thing appears to be simply spending time outside amidst vegetation. While access to a private greenspace, such as a yard, is beneficial, continued and increased provisioning of public greenspaces offers these benefits to the widest population. Moreover, expanding access to greenspace, particularly with attention to equitable distribution and community engagement in planning, can address critical issues regarding environmental justice and the disparities in access based on race and socioeconomic status observed in other studies (Heynen et al., 2006; Wolch et al., 2014; Nesbitt et al., 2019). Finally, the most frequently cited barrier to greenspace

access that we observed was the perceived risk of going outdoors due to COVID-19, and in particular, concerns about crowding. More greenspace, and more readily available public greenspace, has the potential to alleviate this concern by relieving pressure on existing greenspaces.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Barnard College IRB. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MM, EC, and BM: equal contribution to research, analysis, and writing. LY and OV: equal contributions to research and analysis. BO and PC: equal contributions to research and writing. 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/frsc.2021.709997/full#supplementary-material

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