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Neighbourhood greenspaces and mental wellbeing among university students in England during the COVID-19 pandemic: an online survey under lockdown

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ABSTRACT

The COVID-19 pandemic mobility and socialization restrictions and the switch to online learning impacted the day-to-day life of university students in England, a group previously identified as at risk for low wellbeing. In April–May 2021, during the tail end of the third 'lockdown' in England, we implemented an online questionnaire to better understand mental wellbeing in relationship to use of outdoor green space among university students. This article presents the results from 424 responses collected across 4 universities in Oxford and Southampton. Analyses include descriptive results of indicators and hierarchical multiple linear regression models. Findings revealed that quality of greenspace had a greater importance on mental wellbeing than use and quantity of greenspace, even when controlling for sociodemographic factors. Also, neighbourhood greenspace quality contributed to wellbeing above and beyond sociodemographc, physical activity and social support. This result held true even among students with prior mental health difficulties. Findings underscore the importance of greenspace access for wellbeing. Neighbourhoods and university campuses should be planned with the notion in mind that greenspace matters and contributes to health.

HIGHLIGHTS

- No gender differences were identified in mental wellbeing.
- Access to quality greenspaces appears to be more important for wellbeing than quantity.
- Greenspace quality was a significant predictor of positive mental wellbeing above and beyond physical activity and social connectedness.

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Introduction

The coronavirus (COVID-19) pandemic affected all facets of life. While the full extent of the burden experienced by individuals and societies is difficult to determine in its totality, numerous studies have attempted to qualify and quantify the effects of the pandemic, notably the mental health and wellbeing tolls (Robinson *et al.* 2022). Recognizing the hardships of the pandemic, we believe the novel situation offered a unique opportunity to better understand the relationships between use of green environments and wellbeing during times of social isolation. Strengthening our grasp of the nexus of health and urban planning is crucial and can be done by pulling lessons from the recent plight; a stronger integration of health perspectives may lead to news ways of planning (Honey-Rosés *et al.* 2021).

From the early days of the pandemic, experts encouraged governments to safeguard access to public urban greenspaces despite COVID-19 restrictions in order to encourage physical and mental wellbeing and to ensure equity of access to outdoor environments. For instance, McCunn (2021) called attention to the body of evidence on the ways physical and emotional connections with nature positively affect psychological wellbeing, and highlighted the importance of preserving public access to outdoor spaces to help maintain the sense of community threatened by the loss of indoor social hubs (McCunn 2021). Other experts questioned whether the COVID-19 situation would change our relationships with public spaces and expect a surge in demand for small neighbourhood parks (Honey-Rosés *et al.* 2021). Aligned with these perspectives we set out to investigate use of neighbourhood greenspace and wellbeing among university students, a group particularly at risk for lower wellbeing, during the mobility and socialization restrictions phases of the pandemic. We designed a health questionnaire made available online across four universities in England, and we present results here. After discussing the relevant literature on greenspace and wellbeing, we identify gaps in knowledge and provide context for the study while laying out our research objectives. We describe our results on the

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relationship between greenspace and wellbeing and contextualize findings within the broader purpose of planning urban space for healthy living.

How are greenspace and wellbeing linked?

Conceptualizing relationships

The relationship between green environment and human health is now largely discussed in the literature. The field has grown considerably in the 2000's onwards, as documented by the important increase in scientific publications and worldwide involvement (Hartig *et al.* 2014). Hartig *et al.* (2014) attribute this growth, in part, to the conceptual expansion of the definition of 'nature' to include urban (built) green environments, like parks and community gardens, and to the incremental adoption of the multidimensional biopsychosocial perspective of health. The rise of interdisciplinary work, including the coupling of public health and urban planning, has also helped nourish advancements and provide a wider readership for the field.

A number of conceptual models have been proposed to untangle the complexities of the relationships at hand, such as those put forward by Markevych (Markevych *et al.* 2017), Kuo (2015) and Nieuwenhuijsen (Nieuwenhuijsen *et al.* 2017). Generally, three broad sets of perspectives about the role of greenspace on health are accepted: (i) reduction in harm (e.g. reduction in air and noise pollution, minimization of heat), (ii) restoring capacities (e.g. attention restauration, psychophysiological stress recovery) and (iii) building capacities (e.g. supporting physical and recreational activities and facilitating social cohesion). While distinct, these mechanisms are not mutually exclusive. They are likely to operate simultaneously, have synergetic effects and engender feedback loops.

Of importance for our work, the building capacity perspective suggests that greenspaces provide low cost, attractive, and safe environments for people to engage in physical activity and social interactions, and that participation in these activities can, in turn, lead to greater health and psychological outcomes. Under this perspective, we aimed to further explore how greenspaces can provide such support for wellbeing in a time of crisis such as the COVID-19 pandemic. Two main questions underlie the work: how does one characterise green space and how do we define benefits?

Greenspace environmental characteristics

We start by summarizing how greenspace is characterized and measured in the literature. Markevych *et al.* (2017) identifies two broad domains of characterization: *quantity and quality*.

Quantity of greenspace, sometimes referred to as 'availability', is broadly defined as the amount of greenspace one is able to interact with, visually or physically, within a unit of space. Studies have assessed quantity of greenspace in many ways, often rooting the decision in data availability and researcher expertise. Assessments are either objective or subjective self-reported. Objective assessments may be conducted using remote sensing methods for instance, in calculating the normalized difference vegetation index (NDVI), or by using geographic information systems (GIS), for instance to calculate the percentage or number of greenspaces within buffer areas, the distance to the nearest greenspace, the presence of trees and street vegetation and more. Other assessments methods include the use of land type datasets and researcher field observations (Houlden *et al.* 2018, Davis *et al.* 2021, Nguyen *et al.* 2021). Objective measures allow for more consistent assessments of greenspace quantity across study samples, increasing the internal validity of the work. Subjective self-reported assessments by participants is another frequently used method, in which respondents typically rate their perception of the greenspace or 'greenness' or provide their perceived distance to a nearest greenspace (Houlden *et al.* 2018, Wolf *et al.* 2020, Davis *et al.* 2021). In such instances, composite measures offer more robust assessments than single-item questions. To date, the majority of urban green space research focuses on quantity (van den Berg *et al.* 2015, Knobel *et al.* 2019) and is assessed within residential settings (Dzhambov *et al.* 2020). Aside from availability, actual use of greenspace is less often looked at and often dealt with by asking a single item question.

Quality of greenspace, on the other hand, focuses on the presence of attributes within green environments. Few studies initially focused on quality of greenspaces, however, a shift in the literature is apparent and more studies are starting to do so. Bedimo-Rung *et al.* (2005), proposes six themes to characterize the quality of greenspace environments: (i) features (as related to different types of usage), (ii) conditions (i.e. level of maintenance, presence of incivilities), (iii) access (i.e. ease of getting to a park, ability to move around inside the park), (iv) aesthetics (i.e. perceived attractiveness and appeal), (v) safety (i.e. perception of safety or crime rates), and (vi) policies (i.e. park design policies, park management practice) (Bedimo-Rung *et al.* 2005). No gold standard exists in measuring quality of greenspaces (Zhang *et al.* 2017). One method is through field observations by trained reviewers. To this effect, a number of in-situ observational tools were developed, and while these differ in terms of attributes assessed, purpose, validity and length, most show acceptable inter-rater reliability (Knobel *et al.* 2019). This method is, however, resource and time intensive. Alternatively, quality of greenspaces can be reported by participants directly through surveys and interviews, either using single

item questions (Agyemang *et al.* 2007) or more elaborate multidimensional composite measures (Zhang *et al.* 2017).

Findings suggest that reported characteristics such as well-maintained park facilities, esthetically pleasing environments and good accessibility promotes engagement, while lack of perceived safety and incivilities can reduce use (Knapp *et al.* 2019). Seeing healthy behaviors modeled in parks may also encourage uptake. Further, an Australian study found that quality of open public space within a neighbourhood was more important to mental health than quantity of space (Francis *et al.* 2012). Although less technically specific than physical measurements, self-reported evaluation of greenspace can serve as a valid indicator.

Association between greenspace characteristics and health-related outcomes

The multidisciplinary nature of the topic has contributed to an eclectic body of research. Numerous systematic reviews have attempted to consolidate information into digestible and comprehensible works. To get an appreciation for the variety of nature exposure measures and health outcomes studied, as well as the strength and limitation of each, see the works from Yang *et al.* (2021), van den Berg *et al.* (2015), Twohig-Bennett and Jones (2018) and Nguyen *et al.* (2021). A central take away from these work relates to the methodological challenges of the field. Difficulties defining and measuring exposure to nature, selecting appropriate short-term and long-term health outcomes, untangling synergistic effects, properly controlling for confounders, demonstrating causality, establishing effect sizes and more renders the study of greenspace and wellbeing difficult (Hartig *et al.* 2014, Markevych *et al.* 2017). Notwithstanding these challenges, three broad stokes of greenspace-related research findings support the building capacities perspective: *physical activity, social connectedness, and wellbeing.*

Physical activity is well recognized to contribute to general health and wellbeing, and can lead to a reduction in symptoms of depression, anxiety and stress, even at low doses (Mikkelsen *et al.* 2017, Teychenne *et al.* 2020). The literature further suggests that exercising in nature environment has salutogenic benefits above and beyond simply exercising in indoor gym environments (Thompson Coon *et al.* 2011). A study using survey data in Turkey showed that nearest distance and quality of urban green spaces (i.e. maintenance and cleanliness) were associated with greater physical activity frequency (Akpinar 2016). Another study using New Zealand Health Survey data also found that physical activity was greater in greener neighbourhood, however they caution it did not fully explain the green space and health relationship (Richardson *et al.* 2013). In such studies, self-reported physical activity has been recorded in a number of ways. Some assessed average frequency (never to daily) and duration (<15 min to >2 h) of physical activity (Mytton *et al.* 2012, Akpinar 2016), others looked at activity intensity (low, moderate, vigorous) (Richardson *et al.* 2013). The findings remain the same.

Social connectedness and social relationships are also widely accepted in the scientific community as having a beneficial influence on health outcomes, including wellbeing (Maas *et al.* 2009). While in comparison to physical activity, the link between social connectedness and greenspace has been much less studied, it is thought that greenspaces provide an environment to facilitate social interactions. One study by Maas *et al.* (2009) conducted in the Netherlands demonstrated that less greenspace in residential areas coincided with greater feelings of loneliness and with lower perceived feelings of social support, even after adjusting for socio-economic and demographic characteristics (Maas *et al.* 2009). Similarly, Sugiyama *et al.* (2008) found that perceived greenness of neighbourhood was associated with perceived social coherence and local social interactions (Sugiyama *et al.* 2008).

Lastly, *wellbeing* is a holistic concept that emerged from the evolution of our understanding of mental health beyond the absence of mental illness (Hernández-Torrano *et al.* 2020). It refers to one's own subjective evaluation of their life (Diener and Ryan 2009). Wellbeing encompasses hedonic and eudaimonic philosophies, constituting high levels of positive affect, low levels of negative affect, and satisfaction of life, with self-realization (Ryan and Deci 2001, Ryff and Singer 2008). It should be conceptualized as a continuum from low to high (Dodge *et al.* 2012, Linton *et al.* 2016). Mental health and wellbeing outcomes are some of the most commonly studied outcomes with regards to greenspace (Yang *et al.* 2021). Findings indicate that higher perceived greenness of neighbourhood is associated with higher physical and mental health scores (Sugiyama *et al.* 2008). Among studies that assessed quantity of greenspace objectively using NDVI, higher greenspace was associated with reduced scores on anxiety and depression scales (Dzhambov *et al.* 2019). One study comparing the quantity and quality of greenspaces in the Netherlands found that despite similar amounts of greenspace, residents in neighbourhood with greater greenspace quality reported greater neighbourhood attachment and greater mental health (Zhang *et al.* 2015). Similarly, Richardson *et al.* (2013) found that neighbourhood greenspace was linked to better mental health, independent of other individual risk factors (Richardson *et al.* 2013). Even mere greater quantity and quality of streetscape greenery was related to better perceived mental health (de Vries *et al.* 2013).

Beyond observational studies, findings from experimental design are consistent. A systematic review of 38 nature experiments found that urban greenspace interventions with dual approach (i.e. a physical change to improve a greenspace and a promotion/marketing program to increase use) were positively associated with greater mental health and wellbeing outcomes in participants (Hunter *et al.* 2019). In another systematic review of 26 experimental studies, findings suggested that seated relaxation and walking in natural environments may both be associated with improved acute psychophysiological stress responses (Mygind *et al.* 2021).

Suggested routes for future research include assessing in a comprehensive fashion both quantity and quality of greenspaces and documenting the impact across different sub populations and regions (van den Berg *et al.* 2015, Nguyen *et al.* 2021). Studies rarely include both physical activity and social connectedness simultaneously. Therefore, we aimed to examine quantity and quality of greenspace as well as physical activity and social connectedness, in view of wellbeing, under the demanding stressful condition of the COVID-19 pandemic within the young adult student population.

COVID-19 pandemic context and study population

The coronavirus disease, caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), placed much of the world in standstill since its early detection in 2019 (Lotfi *et al.* 2020). As cases surged worldwide and our understanding of transmission mechanisms increased, focus was placed on non-pharmaceutical interventions to limit spread of disease before vaccination became available. Beyond hand washing and mask wearing, emphasis was placed on physical distancing, reducing social contacts, and limits to daily mobility and travel.

In England, various measures were put in place by the government to limit daily movements and achieve large scale physical distancing, including three national 'lockdowns'. While the term 'lockdown' is used worldwide, it often refers to varying levels of restrictions; in England specifically, and hereinafter, 'lockdowns' refer to government defined periods of stay-at-home orders with limited access to most recreational and social venues. The first 'lockdown' began in March 2020. Individuals could only leave their homes for essential reasons and all nonessential shops were closed. Gradual easing of restrictions began in June 2020 and lasted throughout the summer. In September 2020, a 'rule of six' was introduced, whereby indoor and outdoor social gatherings of more than six people were prohibited. A second national 'lockdown' was introduced in early November 2020, lasting four weeks. A third national 'lockdown' began in early January 2021, with stay-at-home orders in its early days, and an eventual gradual stepwise easing of restrictions that lasted until July 2021 (Institute for Government 2021). These measures substantially impacted the day-to-day of the general and student population.

Prior to the pandemic, higher education students in England were already identified through population surveys as an at-risk group for lower levels of wellbeing than the general young adult population and student mental health had been the focus of multiple reports (Thorley 2017, Universities UK 2017, 2018, Hewitt 2019, Hubble and Bolton 2020, Insight Network 2020). In fact, data from the Office of National Statistics (ONS) and the Student Academic Experience Survey (SAES) showed that full time undergraduate students reported lower levels of wellbeing in terms of life satisfaction, life worthwhileness, and happiness than the general population aged 20 to 24 across all years from 2016 to 2020 (Neves and Hewitt 2020). As the pandemic forced universities to pivot to online education, limit access to campus, and restrict socialization within campus accommodation settings, concern grew that the unique situation would further the risk of student isolation and low wellbeing.

In November 2020, the UK Higher Education Policy Institute (HEPI) surveyed over 1,000 full-time undergraduates to learn more about students' experiences during the pandemic. Weighted results (on age, gender and university type) showed that 58% of students reported worsening mental health since the beginning of the pandemic and a third saying they spend all or almost all of their time in their accommodation (Higher Education Policy Institute 2020). The National Union of Students (NUS) noted similar findings in their November 2020 Coronavirus Students Survey phase III. Weighted results (on sex) from a sample of more than 4,000 students showed that 52% of respondents reporting worsening mental health and wellbeing compared to pre-pandemic times and 20% reporting seeking mental health support during the pandemic (National Union of Students 2020). Similarly, in November 2020, the ONS invited more than 100,000 students form all universities across England to complete their Student Covid Insight Survey. Results indicated that 57% reported their wellbeing and mental health as slightly or much worse than at the start of the term, and overall students reported lower levels of life satisfaction, life worthwhileness and happiness, and higher levels of anxiety in comparison to the general population at a similar point in time. Further, over half reported being dissatisfied with their social life due to limited social or recreational activities, limited opportunities to meet others and limited access to sports and fitness facilities (Office for National Statistics 2020).

Importantly, few studies focused on wellbeing experiences in relation to neighbourhood green environments during the pandemic among university students despite the growing literature on the association between greenspace and wellbeing and despite the fact that greenspaces were some of the few locations that remained open during the high mobility restriction phases of the pandemic (Lemyre *et al.* 2023). Our aim is to contribute to the existing body of literature on outdoor greenspace and wellbeing, in support of neighbourhood public green planning.

Research objectives

The overall aim of this observational study was to describe the role of greenspace in view of wellbeing under the COVID-19 pandemic mobility and socialization restrictions among university students in England. This study sits within a social-ecological framework, where the interplay between individual, interpersonal, community and societal contexts is recognized (Stokols 1996).

From this, two research objectives were identified and framed our analyses.

(1) Document the extent to which neighbourhood greenspace is related to greater mental wellbeing.
(2) Test the unique contribution of greenspace to mental wellbeing beyond physical activity and social connectedness.

Our main hypothesis was that self-reported mental well-being was positively related to quantity, quality and use of neighbourhood greenspace, and that these relationships were significant above and beyond physical activity and social connectedness.

Method

This article presents online survey results from April to May 2021. At the time of survey, England was in the tail end of the third national 'lockdown' (specifically 'Step 2'). Nonessential retail and public buildings were open, as were some outdoor venues and some indoor leisure premises. However, while many students were living in university accommodation, most campus communal spaces were closed, indoor household mixing was not allowed and most courses were held exclusively online.

Study design

In April–May 2021, during the tail end of the third national lockdown, we implemented a self-administered online questionnaire study, capturing information on (i) sociodemographic and situational characteristics, (ii) quantity, quality and use of neighbourhood greenspaces, (iii) physical activity, (iv) social connectedness and (v) and mental wellbeing. To participate, individuals had to be at least 18 years old, and enrolled at either Oxford Brookes University, the University of Oxford, the University of Southampton or Solent University. The four universities in the cities of Oxford and Southampton were selected to capture a wide range of student experiences, while taking into consideration our research resources, access to student bodies, and the time-sensitive nature of the recruitment efforts under COVID-19. No restrictions on department, course, level of study, or nationality was imposed. Written informed consent was obtained from all participants. Ethics approval was granted by the University of Oxford Central University Research Ethics Committee (reference number: SSH_OSGA_C1_21_004). We conducted *a priori* statistical power analyses to determine a target sample size for our planned comparisons and multiple regressions. For t tests, chi-square and ANOVA with a medium effect size, an alpha of 0.05 and a power of 0.8, a minimum of 160 participants were needed. For multiple linear regression with at most 12 predictors no less than 150 participants were needed (Cohen 1988). As such, a target of 250 participants was set to guide recruitment, allowing for non-complete responses and drop outs.

Data collection

The questionnaire was programmed on the online platform Qualtrics XM. The survey link was primarily disseminated by email to students through departmental and college administrators. The link was also shared on select student WhatsApp messaging groups, Facebook pages and Twitter, and students could share the link with peers. To encourage participation, students were informed they could enter a lottery draw for one of many £10-£50 Amazon vouchers upon completion of the questionnaire. All questions, excluding eligibility-related ones, were voluntary.

Questionnaire measurement tools

In selecting instruments, we balanced the need for efficiency, good internal validity and comparability with other studies.

Sociodemographic and situational characteristics

Questions on age, sex at birth, gender identity, ethnicity and sexual orientation were asked using the England 2021 Census wording (Office for National Statistics 2021). Other questions included study level, student status, year of study, primary teaching

medium (online or in person), accommodation type, and household living arrangement at time of survey.

To establish socioeconomic status, it is recognized that for young adults and students in particular, their personal revenue is not an adequate estimate of their socioeconomic status and that parental education should be taken into account. It is suggested to use an index based on various personal and parental indicators (Duncan *et al.* 2002, Galobardes *et al.* 2006, Cowan *et al.* 2012). As asked in other student surveys, participants rated their ability to meet their expenses in the past year on a scale from 1 to 5 (Extremely difficult to Extremely easy) (Dzhambov *et al.* 2018). Participants also provided the highest education level of their mother and father (no education, secondary school or less, some college/university, bachelor degree, master/PhD/professional degree, I don't know) (Dzhambov *et al.* 2018, UCL 2019). We constructed a socioeconomic background index using these three variables. The ordinal responses from the three questions were treated as a continuum, from 1 to 5, and summed, creating an overall score ranging from 3 to 15, with greater values indicating higher socioeconomic background. Where parental education was unknown, responses were imputed with the median. Cronbach's alpha, a measure of internal consistency for a set of questionnaire items, with greater values demonstrating greater internal consistency, was 0.56 (range 0–1).

We thought critical to include COVID-19 related questions to better understand feelings and experiences of COVID-19. The 7-item Fear of COVID-19 scale, developed to assess fear of COVID-19 among the general population, was used (Ahorsu *et al.* 2020). All items are rated on a 5-point scale (Strongly disagree to Strongly agree) and an overall score was calculated by totaling each item. Cronbach's alpha was 0.84. Additionally, participants indicated if they had ever taken a COVID-19 test, ever tested positive for COVID-19 or if they knew anyone personally who had gotten very sick or died of COVID-19. 'I don't know' responses were treated as missing.

Quantity, quality and use of neighbourhood greenspaces

Greenspace was defined as any area of vegetated land, including public and private spaces such as parks, gardens, playing fields, children's play areas, woods and other natural areas, grassed areas, cemeteries and allotments, and green corridors (Public Health England 2020). Building on priorities identified by Markevych *et al.* (2017), we focused on three facets of greenspace exposure: *quantity*, *quality and use*.

Perceived quantity of neighbourhood greenspace was assessed using a 5-item Likert scale from 1 to 5 (Strongly disagree to Strongly agree) adapted from Dzhambov *et al.* (2018, 2019). Items included (i) perceived neighbourhood greenness ('*My neighbourhood is green*'); (ii) proximity to greenspace ('*I can easily walk from my home to a nearby greenspace*'); (iii) quantity of greenspace (positive) ('*I consider my neighbourhood to have many greenspaces*'); (iv) visible greenery from home ('*I can see green vegetation through the windows of my home*'); and (v) quantity of greenspace (negative) ('*I consider my neighbourhood to have too few greenspaces*'). The last item was reverse coded and an overall score was calculated, with higher scores indicating greater perceived quantity of neighbourhood greenspace. Cronbach's alpha was 0.75.

Perceived quality of neighbourhood greenspace was assessed using a 6-item Likert scale from 1 to 5 (Strongly disagree to Strongly agree) adapted from Zhang *et al.* (2017). Items included (i) facilities ('*My neighbourhood greenspaces contain enough recreational facilities (e.g. play equipment, hard court, grass pitches for football)*'); (ii) amenities ('*My neighbourhood greenspaces provide amenities for sitting, picnic table, litter bins, signs and lighting in the night*'); (iii) natural features ('*My neighbourhood greenspaces have good natural features such as grass, trees and flower beds*'); (iv) incivilities ('*My neighbourhood greenspaces are free of incivilities (e.g. general litter, graffiti, dog mess, evidence of alcohol, drug use, broken glass and noise)*'); (v) accessibility ('*My neighbourhood greenspaces are easily accessed, there are many access points and enough walking paths, and roads around are not busy*'); and (vi) maintenance ('*My neighbourhood greenspaces are poorly maintained*'). The last item was reverse coded and an overall score was calculated, with higher scores indicating greater neighbourhood greenspace quality. Cronbach's alpha was 0.68.

Use of greenspace was investigated around three components, as it is in the People and Nature survey for England (Natural England 2020) : frequency of visits, average duration of visits and reasons of visits. Frequency of greenspace visits was measured with six options, from never to daily, treated as a Likert scale on a continuum from 0 to 5, where 0 corresponds to never and 5 to daily visits. Change in frequency of visits in comparison to before the pandemic was also assessed.

Physical activity

We constructed a single-item question to assess frequency of physical activity, as is done in other related survey studies (Akpinar 2016). Physical activity was defined as a minimum of 20 continuous minutes of any form of exercise. Selecting from five options, from never to daily, participants reported how many times per week they exercised. For regression analyses, responses were treated as Likert scale on

a continuum from 0 to 4, where 0 corresponds to no exercise and 4 to daily exercise.

Social connectedness

Questions were adapted from the New Zealand General Social Survey (NZGSS) (Frieling *et al.* 2018). To measure socialization participants were asked if they were a member of a group, club or organization. To capture social support, participants reported if they had friends, family members or a partner they could rely on if they had a serious problem, with 'I don't know' responses included as 'No'.

Mental wellbeing

The well-established 14-item Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS) was used to evaluate self-reported mental wellbeing (Taggart *et al.* 2015). Validated for use in populations aged 16 years and above in the United Kingdom, the WEMWBS was developed by the Universities of Warwick, Edinburgh and Leeds in conjunction with NHS Health Scotland. It captures notions of positive mental wellbeing and covers both hedonic and eudaimonic perspectives, including positive affect, cognitive evaluation, satisfying interpersonal relationships and positive functioning. All 14 statements are scored on a 5-point Likert scale (None of the time to All of the time) and refer to the participant's experiences in the previous two weeks. An overall WEMWBS score is calculated by totaling each item score and ranges from 14 to 70, with higher scores indicating greater wellbeing (Tennant *et al.* 2007). Cronbach's alpha was 0.91. Lastly, we asked participants if they had ever been told by a health care professional they have a mental health condition. 'I don't know' responses were treated as 'No'.

Statistical analysis

All analyses were conducted in R (version 4.0.3) and R studio (version 1.3.1093). Mean and standard deviation were calculated for numeric indicators and frequencies and percentages were generated for categorical indicators, overall and by gender. To examine gender differences, Chi-square, Kruskal-Wallis and ANOVA tests were run and effect sizes were calculated for significant variables to show the magnitude of effect (Cramer's V, epsilon squared (ϵ^2)). Post-hoc Dunn tests for multiple comparisons were applied when appropriate. For the first objective, investigating how neighbourhood greenspaces related to mental wellbeing, Pearson correlations were calculated between greenspace measures and WEMWBS scores, followed by multivariate regressions controlling for sociodemographic confounders. Then, for the second objective, to assess the unique contribution of greenspace to mental wellbeing beyond physical activity and social connectedness, we ran hierarchical multiple linear regressions, including significant bivariate controls. Both unstandardized and standardized betas were calculated and model goodness of fit was assessed using adjusted R^2. Tests were run with two-sided probability and an alpha of 0.05 to determine statistical significance. Participants who responded 'Prefer not to say', refused to answer or who skipped a question were excluded from each individual analysis.

Results

Recruitment and inclusion criteria

To be included in the analysis, participants had to have completed the questionnaire between 27 April 2021 and 16 May 2021, the last day of the Step 2 'lockdown' period in England (Institute for Government 2021). Further, participants had to have answered at minimum Sections 1 and 2 and be aged 18–35 years old. The final dataset contained 424 participants (Figure 1).

Participant characteristics

Sex at birth, age and ethnicity sample proportions were compared to data retrieved from the 2020–2021 Higher Education Student Statistics (Higher Education Student Statistics 2019), the last year for which the data was available. The sample is broadly similar to that of the higher education English population, with the exception of slightly greater female and white sample proportion (HESA: 20 years old and under, 39%; female, 57%; white, 70%). Participant characteristics, overall and by gender, are presented in Table 1.

Sociodemographic and situational characteristics (overall and by gender)

The majority of participants were women (62.3%), white (75.5%) and heterosexual (74.7%). Mean age was 22.2 years old (SD 3.36). In reporting gender identity, 5.2% said their gender was different from their sex at birth, and identified either as trans man, trans femme, agender, gender fluid, non-binary, queer or gender questioning. In describing ethnicity, 4.4% reported being mixed or of multiple ethnic group, 14% Asian or Asian British, 3.4% Black, African, Caribbean or Black British, and 2.7% identified as other ethnic group. Further, 7.6% identified as gay or lesbian, 13.9% as bisexual and 3.8% as other sexual orientation. In terms of academic characteristics, most were undergraduates (64.6%), full-time students (97.9%) and had all or most of all their teachings online (88.2%). While most participants lived in Oxford (41.5%) and Southampton (40.6%) at time of survey, a small

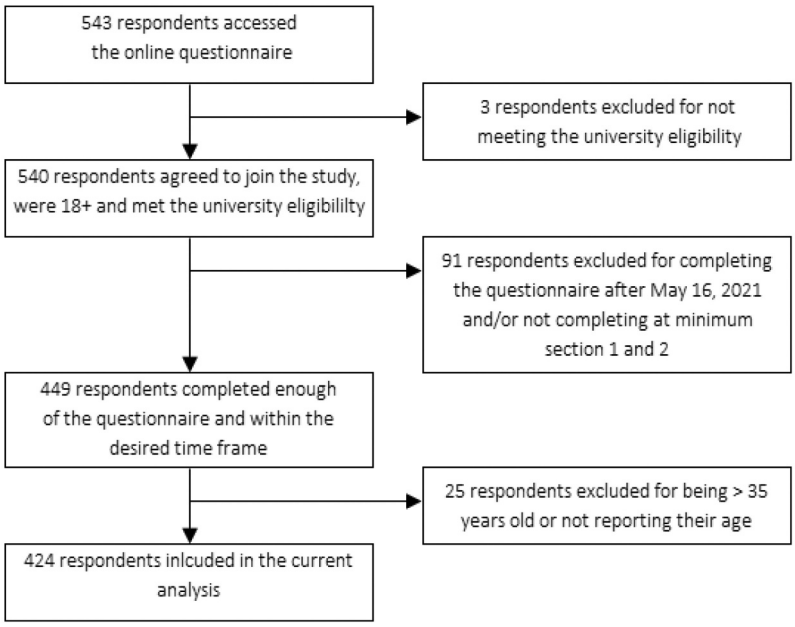

Figure 1. Flow chart of data inclusion criteria.

Table 1. Characteristics of sample of university students, overall and by gender.

		Overall ($n = 424$)	Women ($n = 264$)	Men ($n = 138$)	Gender Diverse ($n = 22$)	W vs M vs GD
	N	%/Mean (SD)	%/Mean (SD)	%/Mean (SD)	%/Mean (SD)	*p* value (Effect Size)[a]
Sociodemographic						
Age						
Range 18-35	424	22.2 (3.36)	22.3 (3.29)	22.1 (3.43)	22.0 (3.87)	0.55
Sex at birth						
Females	279	65.8%	100.0%	0.0%	68.2%	n/a
Males	145	34.2%	0.0%	100.0%	31.8%	
Gender identity						
Women	264	62.3%	100.0%	0.0%	0.0%	n/a
Man	138	32.5%	0.0%	100.0%	0.0%	
Gender diverse	22	5.2%	0.0%	0.0%	100.0%	
Ethnicity[b]						
White	312	75.5%	76.7%	72.6%	81.0%	0.57
Non white	101	24.5%	23.3%	27.4%	19.0%	
Sexual orientation[b]						
Heterosexual	296	74.7%	76.5%	81.2%	10.0%	<0.001***
Non heterosexual	100	25.3%	23.5%	18.8%	90.0%	(0.35)
Accommodation type						
University	233	55.0%	53.8%	59.4%	40.9%	0.22
Private	191	45.0%	46.2%	40.6%	59.1%	
Living arrangement[b]						
Living alone	41	9.7%	9.1%	12.3%	0.0%	0.17
Living with someone	383	90.3%	90.9%	87.7%	100.0%	
Socioeconomic background index						
Range 4–15	423	10.6 (2.54)	10.5 (2.59)	10.7 (2.43)	10.7 (2.71)	0.76
COVID-19 Experiences						
Fear of COVID-19 scale						
Range 7–31	410	14.0 (5.27)	14.8 (5.16)	12.5 (5.22)	13.6 (4.89)	<0.001*** (0.05)
Ever tested positive for COVID-19						
Yes	37	9.1%	9.5%	8.3%	9.5%	0.92
No	370	90.9%	90.5%	91.7%	90.5%	
Know someone personally who was very sick or died of COVID-19						
Yes	112	33.6%	36.2%	28.6%	33.3%	0.40
No	221	66.4%	63.8%	71.4%	66.7%	

***($p \leq 0.001$); **($0.001 < p \leq 0.01$); *($0.01 < p \leq 0.05$).
[a]Effect Size Cramer's V for Chi-Square: Weak (ES ≤ 0.2); Moderate (0.2 < ES ≤ 0.6); Strong (ES > 0.6).
[a]Effect Size Epsilon squared (ϵ^2) for Kruskal Wallis: Weak (0.01 < ES < 0.08); Moderate (0.08 ≤ ES < 0.26); Strong (ES ≥ 0.26).
[b]Dichotomous version of variable presented.

proportion lived in other areas of England (13.9%) or worldwide (4%). Most lived in university accommodation (55%) and few lived alone (9.7%).

In terms of COVID-19 experiences, participants were asked to complete the 7-item Fear of COVID-19 scale. Mean score was 14 (SD 5.27; range 7–31), with significantly lower scores among men (Kruskal–Wallis $p < 0.001$; $\epsilon^2 = 0.05$). A high percentage reported having ever taken a COVID-19 test (88.3%) and 9.1% reported having ever tested positive for COVID-19 at the time of survey (April–May 2021). Lastly, a third (33.6%) said they knew someone personally who had gotten very sick or died of COVID-19.

Key variables (overall and by gender)

The remaining key variables captured in the questionnaire are presented in Table 2. Perceived quantity of neighbourhood greenspace had a mean score of 19.4 (SD 3.94; range 8-25). Gender differences were identified, albeit with a small effect size, with women and men reporting less green space in their neighbourhood than gender diverse individuals (Kruskal–Wallis $p < 0.001$; $\epsilon^2 = 0.03$). Perceived quality of neighbourhood greenspace had a mean score of 22.6 (SD 3.89; range 10–30). Greenspace use frequency score ranged from 0 to 5 with a mean of 3.18 (SD 1.24). Some gender differences were noted, where use of greenspace was more important among women than other genders (Kruskal–Wallis p 0.02; $\epsilon^2 = 0.02$).

Most participants reported exercising daily, 4–6 times a week or 1–3 times a week (21.4%, 31.3%, 31.6%, respectively) and few reported exercising less than once a week or never (12.0%, 3.6%, respectively). This information was transformed into a physical activity frequency score, ranging from 0 to 4, where 0 corresponds to no exercise and 4 to daily exercise. Mean score was 2.55 (SD 1.07) and some gender differences were noted with women reporting more frequent exercise (Kruskal–Wallis p 0.003; $\epsilon^2 = 0.03$).

In terms of social connectedness, the majority (71.4%) reported currently being a member of a social group, association or club, of which most (83.7%) said they were meeting online (35.0%), in person (32.7%) or both (16.0%) despite the pandemic. Overall social support was high, with the majority (89.1%) reporting having friends, family members or a partner they could rely on if they had a serious problem. Of note, however, gender diverse individuals reported less support availability (Chi-square p 0.03; Cramer's V = 0.13).

For mental wellbeing, the mean WEMWBS score was 43.2 (SD 9.24; range 14–70). Scores were normally distributed (Shapiro–Wilk p value 0.52), with no gender differences (ANOVA p 0.2). Lastly, 29.4% reported having ever been told by a doctor or other health care professional they had a mental health condition, of which the most frequently reported conditions were depression, anxiety and general anxiety disorder (GAD). Differences in gender identified a moderate effect size with gender diverse being more diagnosed

Table 2. Characteristics of sample of university students, overall and by gender.

		Overall ($n = 424$)	Women ($n = 264$)	Men ($n = 138$)	Gender Diverse ($n = 22$)	W vs M vs GD
	N	%/Mean (SD)	%/Mean (SD)	%/Mean (SD)	%/Mean (SD)	*p* value (Effect Size)[a]
Greenspace						
Quantity of neighbourhood greenspace						
Range 8–25	418	19.4 (3.94)	19.7 (3.65)	18.4 (4.34)	21.5 (3.25)	<0.001*** (0.03)
Quality of neighbourhood greenspace						
Range 10–30	415	22.6 (3.89)	22.7 (3.80)	22.2 (4.11)	22.3 (3.67)	0.64
Greenspace use frequency						
Range 0–5	420	3.18 (1.24)	3.29 (1.22)	3.06 (1.23)	2.57 (1.47)	0.02** (0.02)
Physical Activity						
Physical activity frequency						
Range 0–4	415	2.55 (1.07)	2.68 (1.05)	2.37 (1.04)	2.10 (1.18)	0.003** (0.03)
Social Connectedness						
Availability of social support						
Yes	367	89.1%	89.9%	90.2%	71.4%	0.03*
No	45	10.9%	10.1%	9.8%	28.6%	(0.13)
Member of a group						
Yes	294	71.4%	71.7%	69.9%	76.2%	0.82
No	118	28.6%	28.3%	30.1%	23.8%	
Wellbeing						
WEMWBS						
Range 14–70	411	43.2 (9.24)	43.0 (9.12)	44.0 (9.48)	40.3 (8.91)	0.20
Prior mental health diagnosis						
Yes	119	29.4%	32.8%	18.7%	57.1%	<0.001***
No	286	70.6%	67.2%	81.3%	42.9%	(0.20)

***($p \leq 0.001$); **($0.001 < p \leq 0.01$); *($0.01 < p \leq 0.05$).
[a]Effect Size Cramer's V for Chi-Square: Weak (ES ≤ 0.2); Moderate (0.2 < ES ≤ 0.6); Strong (ES > 0.6).
[a]Effect Size Epsilon squared (ϵ^2) for Kruskal Wallis: Weak (0.01 < ES < 0.08); Moderate (0.08 ≤ ES < 0.26); Strong (ES ≥ 0.26).

than men and women (Chi-square $p < 0.001$; Cramer's V = 0.20). Just under half of those who reported a condition had been diagnosed in the past 12 months (12.6%) during the pandemic.

Greenspace and mental wellbeing

We investigated the relationship between greenspace and mental wellbeing. First, we report descriptive statistics on greenspace use. Few participants (16%) reported visiting greenspaces daily; however, most reported going 4–6 times a week (19.5%) or 1–3 times a week (45.2%). About 10% reported going once every 2 weeks, 3.6% once a month, and 5.5% never or almost never. The average time spent in parks was 10–30 minutes (27.3%) and 30–60 minutes (39.9%). In terms of reasons, most stated visiting greenspace for social interactions (60.4%), to engage in physical activity (60.3%), and for relaxation (77.1%). Less than 5% reported using greenspace to walk animals, garden or produce food. Lastly, 53.8% reported visiting greenspaces more or a lot more compared to before the pandemic. Our three primary greenspace indicators, perceived quantity, quality and frequency of use of neighbourhood greenspace, were all significantly correlated to mental wellbeing (WEMWBS scores) at the 0.001 level ($r = 0.18$, $r = 0.28$, $r = 0.19$, respectively).

We ran multivariate regression to quantify the relationship between our green scores and the outcome of interest, while controlling for sociodemographic factors. To do so, we first identified sociodemographic variables from Table 1 related to WEMWBS. Age was significantly correlated to higher mental wellbeing (r = 0.12; p 0.02), while sex and gender were not. Those who reported their sexual orientation as heterosexual showed greater wellbeing than those who reported not being heterosexual (t test $p < 0.001$; Cohen's d = 0.43). Greater socioeconomic background was correlated to greater wellbeing (r = 0.2; $p < 0.001$). Interestingly, having ever tested positive for COVID-19 or knowing someone personally who had gotten very sick or died of COVID-19 was not significantly related to lower wellbeing, contrary to what might have been expected. However, a greater score on the Fear of COVID-19 scale was associated with lower wellbeing (r = −0.18; $p < 0.001$). Table 3 shows the results from three multivariate regressions, controlling for age, gender, sexual orientation and socioeconomic background. While gender was not associated with the outcome, it was included as a control. Both Betas (B) and standardized betas (β) are presented, allowing for a comparison of the relative importance of each coefficient, along with adjusted R^2 and incremental R^2 values. At a time when COVID-19 restrictions were still in effect and only outdoor gatherings were permitted, perceived quality of greenspace had a greater importance on mental wellbeing than frequency of use and quantity.

Greenspace and mental wellbeing beyond physical activity and social connectedness

The next research objective was to test the unique contribution of greenspace to mental wellbeing beyond physical activity and social connectedness. To this effect, we investigated correlations between variables (see Supplementary Appendix A). Identifying as heterosexual, having greater socioeconomic standing, experiencing less fear for COVID-19, being physically active, being a member of a group, having social support, living in aneighbourhood with higher quantity and quality of greenspaces and visiting greenspaces more frequently were all factors significantly correlated to greater mental wellbeing. Having no prior mental health condition also correlated with current wellbeing. Physical activity, group membership and social support were all significantly correlated with quality of neighbourhood greenspace and frequency of neighbourhood greenspace use.

We ran hierarchical multiple linear regressions models on complete cases ($n = 372$) using the WEMWBS score as the dependent variable. In Table 4, adjusted R^2 values per block are shown, as are between block adjusted R^2 differences (Δ) and associated p values (ANOVA). In the first block, the sociodemographic variables age, gender, heterosexual orientation and

Table 3. Multivariate regressions between the outcome WEMWBS scores and greenspace indicators, controlling for sociodemographic factors.

	B (SE)	β[a]	Adjusted R^2 (Δ Adjusted R^2)
Step 1: Sociodemographic controls			
Age	0.33 (0.14)	0.12*	
Gender (Men)	0.95 (0.98)	0.05	
Sexual orientation (Heterosexual)	3.47 (1.06)	0.16**	
Socioeconomic background index	0.82 (0.18)	0.22***	
			0.08***
Step 2: Greenspace indicators			
(a) Quantity of neighbourhood greenspace	0.40 (0.12)	0.17***	0.11*** (Δ 0.03)
(b) Quality of neighbourhood greenspace	0.61 (0.12)	0.26***	0.14*** (Δ 0.06)
(c) Greenspace use frequency	1.13 (0.37)	0.15**	0.10*** (Δ 0.02)

***($p \leq 0.001$); **($0.001 < p \leq 0.01$); *($0.01 < p \leq 0.05$).

Table 4. Hierarchical multiple regression models.

	Step 1		Step 2		Step 3		[Additional step 4]	
	Sociodemographic controls		Physical activity and social connectedness		Greenspace		[Prior Mental Health]	
	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β
Age	0.33 (0.14)	0.12*	0.38 (0.13)	0.14**	0.37 (0.13)	0.14**	0.42 (0.12)	0.15***
Gender (Men)	0.95 (0.98)	0.05	1.39 (0.93)	0.07	1.77 (0.92)	0.09	0.97 (0.89)	0.05
Sexual orientation (Heterosexual)	3.47 (1.06)	0.16**	2.53 (1.02)	0.12*	2.46 (1.00)	0.12*	1.20 (0.98)	0.06
Socioeconomic background	0.82 (0.18)	0.22***	0.52 (0.18)	0.14**	0.45 (0.18)	0.12*	0.43 (0.17)	0.12*
Physical activity frequency			1.49 (0.42)	0.17***	1.36 (0.46)	0.16**	1.25 (0.44)	0.14**
Member of a group			1.75 (0.97)	0.09	1.27 (0.98)	0.06	1.07 (0.94)	0.05
Availability of social support			7.47 (1.44)	0.25***	6.92 (1.44)	0.24***	6.20 (1.39)	0.21***
Quantity of neigh. greenspace					0.18 (0.13)	0.08	0.14 (0.12)	0.06
Quality of neigh. greenspace					0.39 (0.13)	0.17**	0.40 (0.12)	0.17**
Greenspace use frequency					−0.10 (0.41)	−0.01	0.01 (0.39)	0.00
No prior mental health diagnosis							5.34 (0.94)	0.26***
Adjusted R^2	0.08***		0.18***		0.22***		0.29***	
Δ Adjusted R^2			0.10***		0.04***		0.07***	

***($p \leq 0.001$); **($0.001 < p \leq 0.01$); *($0.01 < p \leq 0.05$).

socioeconomic background were included as controls. In block 2, physical activity, and two social connectedness predictors were added, capturing social support and socialization. This significantly improved the model (Δ adjusted $R^2 = 0.10$; $p < 0.001$). In the third step, the three greenspace measures were included (Δ adjusted $R^2 = 0.04$; p value < 0.001). Only quality of neighbourhood greenspace remained significant once combined with the other two. In all, 22% of the variance was explained.

To demonstrate an accrual protective factor of positive wellbeing, thereby helping identify vulnerability factors, prior mental health was included in an additional block. This addition significantly improved the model by 7% above and beyond all prior variables, and explained in total 29% of the variance in wellbeing. While greenspace quality remained a significant predictor of wellbeing, as well as physical activity and social support, the role of sexual orientation became redundant once prior mental health was included.

Discussion

Summary of findings

We observed that more than a quarter of our participants, predominantly women and gender diverse individuals, reported a prior mental health diagnosis (29.4%). By comparison, in a large pre-pandemic survey of 37,000 students across 140 UK universities, one-fifth of students (21.5%), most of which female, reported at least one mental health diagnosis in the past (Insight Network 2020). We suspect a greater proportion of diagnosis in our study is in part due to students seeking out more professional help during the pandemic in view of the greater hardships. In fact, among our sample, just under half of those who reported having ever been diagnosed with a condition were diagnosed in the past 12 months – during the pandemic. This aligns with results from the 2020 NUS study, whereby 20% of surveyed students sought mental health support during the pandemic. Results from this survey point to the strong desire for support and the need to have people to talk to (National Union of Students 2020). A key take away message stresses the basic need to connect with others, especially in times of hardship, and the apparent need for physical space to facilitate these connections.

Given the widely observed wellbeing impacts of the pandemic, as further established above, we set out to see how greenspace could contribute to positive mental wellbeing among this under-studied population. We observed in regression analyses that perceived quantity, quality and use of greenspace were each associated with mental wellbeing, even when controlling for socio-demographic factors. This finding is consistent with a number of wellbeing-related pre-pandemic studies among the general population, thereby highlighting the continued relevance of greenspace, even or more so in times of crises (Sugiyama *et al.* 2008, de Vries *et al.* 2013). We further observed that this relationship was stronger for quality of greenspace, more so than use and quantity, a finding supported by Francis *et al.* (2012), de Vries *et al.* (2013) and Zhang *et al.* (2015) (Francis *et al.* 2012, de Vries *et al.* 2013, Zhang *et al.* 2015). This relationship holding true in the context of the pandemic underscores the importance we attribute to well-planned spaces.

Our hierarchical regressions demonstrated that greenspace quality was associated with mental wellbeing above and beyond physical activity and social support during the tail end of the third national lockdown when indoor household mixing was still prohibited. Moreover, this held true for those with prior mental health conditions. Our research findings converge with the literature on the benefits of greenspace and the need for urban planning that emphasizes quality of greenspaces.

In terms Covid-specific literature, a number of studies have now been published, allowing for

various comparisons. Findings are generally consistent with results from other studies. Using results from the 2020 People and Nature Survey and social media analyses, Natural England explored the impact of COVID-19 on engagement with green and natural spaces. They found that urban green spaces were the most commonly visited sites during the pandemic, in comparison to country side, woodlands and more, and that walking was the most common activity in greenspaces. While 'active' activities like cycling and running remained popular, 'slower' social activities like picnicking and wildlife watching gained traction (Natural England, & Kantar Public 2021). Similarly, in our own survey, high proportions reported visiting greenspaces for both 'active' and 'slow' activities, including social interactions (60.4%), physical activity (60.3%), and relaxation (77.1%). Further, in our work, we observed an increase in reported use of greenspace compared to pre-pandemic times, with 53.8% saying they visited greenspaces more or a lot more than before the pandemic. This trend varies across studies, with some, by contrast, actually reporting a decrease in greenspace visits. For instance, in a nationally representative survey of 2,252 adults in the UK in May 2020, 63% of respondents reported visiting greenspaces less following the introduction of Covid restrictions (Burnett *et al.* 2021). Similarly, a Canadian study observed a significant decrease in greenspace use three months into the pandemic (Borkenhagen *et al.* 2021). One explanation for the contrast between past studies and our results may relate to the study timeline and pandemic stage. Indeed, we surveyed student in April–May 2021, one year into the pandemic, when much of the immediate shock and fear may of had settled, while most studies focused on the initial phases of the pandemic. Lastly, a pandemic time study in the United States observed that spending a lot of time in greenspaces was significantly associated with lower anxiety and depression. This result was true for both objectively assessed and self-reported greenspace quantity and quality near residences (Reid *et al.* 2022). This is particularly interesting given the study used a very similar greenspace quantity metric. Other COVID-19 studies found mental health benefits for green visibility from home (Soga *et al.* 2021, Spano *et al.* 2021), quantity (Lõhmus *et al.* 2021), access (Spano *et al.* 2021) and usage (Ribeiro *et al.* 2021) of greenspace during the pandemic. While comparisons remain challenging and should be done with caution given the differences in public health orders by region and time, our results and those from other studies support maintaining access to greenspaces in time where social connections are threatened, as was advocated by some experts at the onset of the pandemic (Slater *et al.* 2020, McCunn 2021).

Strengths and limitations

Our study addresses a niche nexus of topics not frequently explored simultaneously to link greenspace with wellbeing. Validated instruments with theoretical relevance were selected. A satisfactory large sample size was obtained avoiding online survey duplication through the use of cookies. Further, our sample was similar to the higher education population in England. Analyses controlled for demographic variables to prevent spurious effects. Lastly, data was collected at a critical period, adding to the relevance of the study and allowing for a unique set of lessons. Limitations remain. Sampling was restricted to four universities due to the need to capture a wide range of student experiences while balancing the time-sensitive nature of our recruitment efforts and our access to student bodies. Of course, with more time and research resources, a randomly selected nationally representative sample of university students in England would confer more robust and generalizable results. Data was collected during the spring, which may have an impact on the self-reported mental wellbeing states. A longitudinal design would control for seasonal differences in experiences of mental wellbeing. Further, as the study draws on a non-random convenience sample of self-selected participants, respondents may differ from non-respondents in terms of greenspace exposure and mental wellbeing predictors, limiting the generalizability of observations. This also makes comparisons with national data challenging. Moreover, all indicators were self-reported, which may bring bias, although hierarchical regressions alleviate this.

Implications

Our results confirm the beneficial role of greenspace and wellbeing. It suggests urban planning should design quality focused spaces. Greenspace fosters physical activity and as well as social connectedness. More specifically, university students seem to benefit from greenspace, including those with a prior mental health concern. It opens avenues for population-based prevention interventions.

The mental health and wellbeing of students are high-priority areas for higher education institution, as evidenced in multiple reports (Thorley 2017, Universities UK 2017, 2018, Hewitt 2019, Hubble and Bolton 2020, Insight Network 2020) and the recent adoption of the 2019 'Student Minds University Mental Health Charter' (Hughes and Spanner 2019) and the 2020 'Mentally Healthy University Framework' (Universities UK 2017). These initiatives encourage universities to be healthy settings that promote healthy behaviors and healthy environments. In planning campus spaces, importance should be placed on ensuring the provision of quality greenspaces to encourage physical activity and social connectedness among students.

In the future, a number of other crisis like scenarios may highlight the necessity of well planned space that allow for physical activity and flourishing social interactions.

Future directions

Our design and sample size did not allow us to test mediation pathway with respect to the role of physical activity and social connectedness: future research should investigate how much green infrastructure can act as a conduit of positive social support and lifestyle behaviors. Further investigation should include the use of longitudinal and intervention study designs to allow for causal interpretation (Hartig *et al.* 2014, Markevych *et al.* 2017). Of course, results findings should be replicated on wider populations. Future research would benefit from incorporating a GIS or other physical objective characterization of space. This would provide specific evidence for urban design.

Conclusion

This study focused on a sub-population particularly afflicted by the pandemic, yet rarely investigated for its relationships with greenspace (Lemyre *et al.* 2023). While we did not assess physical greenspaces on student campuses, we believe our results at the neighbourhood level generalize to the campus-level ecosystem. Our results showed that quality of greenspace related significantly to wellbeing and notably above and beyond the benefits of physical activity and social connectedness. It also appeared that vulnerable groups, such as those with prior mental health issues particularly benefited from greenspace. In all, our work supports the interconnection between environment and health outcomes.

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No potential conflict of interest was reported by the author(s).

Notes on contributors

The research team is composed of an interdisciplinary group of academic experts in the fields of health geography, psychology, epidemiology, urban planning, and social policy, established across both the University of Oxford and the University of Southampton. Our interests converge at the nexus of human-environment interactions in health and wellbeing.

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Data availability statement

Due to the sensitive nature of the questions asked in this study, survey respondents were assured raw data would remain confidential and would not be shared.

Credit authorship contribution statement

Anaïs Lemyre Conceptualization, Funding acquisition, Methodology, Project administration, Data curation, Formal analysis, Writing – original draft, Writing – review & editing.

Jane P. Messina – Conceptualization, Methodology, Project administration, Formal analysis, Writing – review & editing.

Emma Palmer-Cooper – Conceptualization, Methodology, Project administration, Formal analysis, Writing – review & editing.

Benjamin W. Chrisinger Formal analysis, Writing – review & editing.

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