

# GREEN SPACE EXPOSURE'S INFLUENCE ON MENTAL WELL-BEING DURING COVID-19 CAMPUS LOCKDOWNS: A SATISFACTION MEDIATING PATHWAY

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## Highlights:

- a framework for exposure perception of campus green space is proposed;
- subjective exposure in green space exposure was positively related to mental well-being, and objective exposure was not related to mental well-being;
- the theoretically indicated pathways of green space exposure, satisfaction, and mental health have been partially demonstrated during the epidemic lockdown of the campus;
- the results can be applied to the design or management of unstructured green spaces to support the mental well-being of students on campus.

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**Abstract.** Recent research indicates that exposure to green space may have positive effects on the mental health of students, potentially mediated by factors such as environmental satisfaction and social cohesion. However, the specific impact of green space exposure on students' mental health during the COVID-19 campus lockdowns unexplored. To investigate this relationship, a survey was conducted via social media among 346 current students residing on a locked-down campus, assessing their mental well-being, green space satisfaction, social environment satisfaction, subjective exposure and objective exposure to green space. A structural equation model (SEM) was employed to examine the relationships among various dimensions of green space exposure, satisfaction and students' mental well-being. The findings indicate that subjective exposure to green space has a positive impact on mental well-being and indirectly through social environment satisfaction. Additionally, objective exposure could indirectly influence mental well-being through green space satisfaction and social environment satisfaction.

**Keywords:** green space exposure, mental well-being, structural equation model, satisfaction, blocked campus, COVID-19.

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## 1. Introduction

University is a crucial stage in personal development, serving as a critical period for the formation of personality and worldview (Lattie et al., 2019). However, students frequently face significant academic and life pressures (Pedrelli et al., 2015), adversely impacting their mental health (Lipson et al., 2019). In China, which has the largest global student population, a substantial proportion of university students, ranging from 16% to 30%, grapple with mental health issues such as depression, anxiety, and other related challenges (Y. Li et al., 2021). This high prevalence highlights mental health problems as a major health challenge faced by Chinese university students, warranting further research.

Green space, as a significant component of public spaces, is increasingly recognized for its potential to en-

hance the individual physical and psychological well-being (Browning et al., 2022; Marselle et al., 2021). Research indicates that not just structural green spaces (parks and greenways, etc.), but also unstructured green spaces (street trees, lawns, etc.), can benefit mental health (de la Iglesia Martinez & Labib, 2023; M. Liu et al., 2023; Zuniga-Teran et al., 2019). Moreover, understanding of the mechanisms underlying these effects has evolved substantially. Initially focusing on reducing air pollution (Wang et al., 2021a) and promoting physical activity (Pasanen et al., 2019), studies now emphasize the importance of social cohesion (Y. Liu et al., 2019b) and environmental satisfaction (Xiao et al., 2021). Concurrently, a growing body of research utilizes frameworks incorporating multiple indicators to assess green space exposure (Helbich et al., 2021; J. Zhang et al., 2022).

Satisfaction with the built environment has emerged as a prominent research focus (Chan & Li, 2022; L. Li et al.,

2023; McCarthy & Habib, 2018), illuminating the desires and expectations of residents regarding their living spaces (Chen et al., 2019). Within this evolving domain, an emerging trend emerges is the growing emphasis on examining linkages between green spaces and resident satisfaction (Jiang & Huang, 2022; L. Li et al., 2023). Numerous studies now recognize that green spaces can influence mental well-being, largely through their moderating role in the domain of satisfaction (Qiao et al., 2021).

The COVID-19 pandemic has led to lifestyle changes and mental health impacts due to containment policies (Sun et al., 2021). Despite transmission control efforts, university campuses remain susceptible to periodic lockdowns due to the emergence of novel viral variants. Chinese university students primarily inhabit dormitories situated within campus communities (Q. Liu et al., 2022b). With mobility restrictions, students have lost previous autonomy of movement (Ma et al., 2023), as activities become confined to campus and dormitories (W. Zhang et al., 2023). In this constrained environment, students' mental well-being becomes increasingly vulnerable. Consequently, green spaces as pivotal social public areas and satisfaction as a vital criterion take on heightened significance for students' mental well-being during lockdowns.

The aim of this study was to elucidate the association between exposure to campus green space, environmental satisfaction, and mental health during campus lockdown. Building upon synthesizing prior green space exposure frameworks, this study developed and tested a tailored multidimensional exposure model for unstructured green spaces on campus, examining the mediating influence of satisfaction on relationships between green space exposure and mental well-being.

## 2. Conceptual framework and hypotheses

### 2.1. Literature review

Theories such as the biophilia-hypothesis, prospect and refuge theory and the savannah hypothesis posit that humans inherently favor natural plants (Anderson & Gerbing, 1988; Budd & Jensen, 2017), providing a foundation for environmental psychologists to demonstrate the substantial impact of green space exposure on individuals' mental well-being (Wang et al., 2021b; R. Zhang et al., 2021). Grounded in need hierarchy theory (Maslow, 1981), which holds that individuals life satisfaction rises with the fulfillment of needs, such as adequate housing, security, and social interaction. Based on this theory more and more studies have found that living environment satisfaction is related to mental well-being, with both social environment satisfaction (Mouratidis, 2020; Xiao et al., 2020) and physical space satisfaction (Baba et al., 2017; J. Chen & Chen, 2015). Within advancing human well-being research, green spaces as living environments are increasingly seen to influence mental well-being through mediating effects on both social environment satisfaction (Dong & Qin, 2017; Ruijsbroek

et al., 2017) and physical space satisfaction (McEachan et al., 2018; Qiao et al., 2021).

#### 2.1.1. Green space exposure influences mental well-being

While existing studies have shown that university green spaces can have a positive impact on the mental well-being of college students (Gulwadi et al., 2019; van den Bogerd et al., 2020), there has been limited examination of this relationship through a green space exposure framework, with most literatures focusing only on aspects of green space usage (Holt et al., 2019), attractiveness (Akpınar, 2016a) and perception (Hipp et al., 2016). The COVID-19 pandemic markedly confined students' mobility to campus boundaries, increasing exposure to green spaces within this campus environment. To clarify the link between green exposure and mental well-being, more studies need a multi-faceted exposure framework assessment (Xu et al., 2023).

Prior research by (J. Zhang et al., 2022) has delineated green space exposure into subjective and objective exposure. In this green space exposure framework, subjective exposure encompasses individualized interactions with green space, which includes factors such as frequency and duration (Vilcins et al., 2022). As (Krellenberg et al., 2014) found, health benefits of green space may vary depending on extent of natural environment contact. Frequency and duration of visits are widely recognized indicators of green spaces utilization (Bloemsmā et al., 2018). For example, research has improved mental health among adolescents with longer green spaces duration (Dadvand et al., 2019) and enhanced mental well-being, in college students who visited campus green spaces more often (Holt et al., 2019). Given their established links to usage patterns and well-being impacts across groups, frequency and duration of visits were selected as campus subjective exposure measures in this study's framework.

Objective exposure encompasses visibility, availability, accessibility, and attractiveness (Dzhambov et al., 2018; Hipp et al., 2016; J. Zhang et al., 2022). Availability is a quantitative measure used to assess the overall presence of greenness in the surrounding living environment (J. Zhang et al., 2022). Traditionally, availability was been measured by satellite images (de la Iglesia Martínez & Labib, 2023). However, human perceptions are increasingly used for smaller areas, given accuracy limitations and individual variances in usage (Reid et al., 2022; Yang et al., 2020). Under uniform campus green space availability during lockdown, students likely perceive surrounding green spaces differently. Thus, subjectively assessed availability was included as an objective exposure indicator, rather than absolute availability. This allowed for capturing differential perceptions of campus green space presence despite equivalent objective availability.

Green space attractiveness is a measure of quality of green space (J. Zhang et al., 2022). Prior research by (W. Liu et al., 2022c) found the attractiveness of green space encompasses factors such as green comfort, ra-

tional layout, scenic beauty, and plant diversity, which significantly impact mental well-being. Factors including plant mix, colour, rest space settings, and safety have been found to impact students' willingness to visit green spaces on university campuses (X. Li et al., 2019). As (Q. Liu et al., 2018) found positive correlation between natural attributes of university green spaces and college student mental well-being. Therefore, the attractiveness of green spaces is included as an objective exposure in the framework.

Green Space accessibility, primarily measured by distance to nearby structured green spaces (parks and greenways, etc.) (J. Zhang et al., 2022), is less relevant for campus environments with abundant unstructured vegetation. However, this study focused on unstructured green spaces (street trees, lawns, etc.) on the campus. Thus, accessibility was not an appropriate objective measure to use in a framework for measuring green exposure on campus.

Green space visibility refers to the perceptible extent of vegetation from a specific point (Labib et al., 2020), and captures pedestrian-level exposure unlike aerial green space assessments (Lu et al., 2018). Studies demonstrated that individuals engage with nature while occupying various locales (Cox et al., 2017). X. Li et al. (2015) found a direct connection between the visibility of road vegetation and perceived greenness. Moreover, A study by (Sugiyama et al., 2008) indicated that the perceived environment greenness influences mental well-being during walking. Considering evidence that visibility reflects perceived exposure and influences mental well-being, and call for incorporating visibility in campus green space research (Gulwadi et al., 2019). Thus, this study included visibility as an indicator in the framework for measuring campus green exposure.

Therefore, based on the former framework and researches, the green space exposure indicators that can be used in the campus were screened on this basis (Table 1).

**Table 1.** Types of green space exposure

Indicator type	Perception index	Perceptual measures
Subjective exposure	Duration	Time spent in green space
	Frequency	Frequency of visits to green space
Objective exposure	Availability	Perceived overall greenness
	Attractiveness	Assessing the quality of green space
	Visibility	When walking, perceive greenness in the field of vision

### 2.1.2. Satisfaction mediating green space exposure and mental well-being

Satisfaction, a prominent indicator in the realm of environmental design, has a longstanding history of application in the built environment (Francescato et al., 1989; Zimring, 1982). Within the public health paradigm of healthy cities, a growing body of research has turned its attention to

elucidating connections between mental well-being and built environment (Evans, 2003; Moore et al., 2018). This has led to investigations of relationships between satisfaction and mental well-being (L. Zhang et al., 2019). Studies have revealed that not only does satisfaction with the physical environment (Kley & Dovbishchuk, 2021; Leslie & Cerin, 2008), satisfaction with the social environment also relates to mental well-being (Barnett et al., 2020; Weckroth et al., 2022). Green spaces, as integral components of the built environment, have been found to shape mental well-being through both of these satisfaction pathways (Y. Liu et al., 2019a, 2020).

Green space satisfaction, encompassing aspects such as the quantity, quality, and willingness to utilize surrounding green spaces, serving as a reflection of residents' satisfaction with the physical environment of green spaces (McEachan et al., 2018; Qiao et al., 2021). Evidence indicates that when individuals express low satisfaction with the green spaces near their residences, which diminishes their motivation to visit green spaces and associates with depression (Mukherjee et al., 2017). Moreover, research conducted by (Y. Liu et al., 2019a) emphasized that satisfaction with green spaces can mediate the connection between psychological well-being and green space exposure. Within campus spaces contexts, these findings suggest that green space satisfaction could link campus green spaces to mental well-being, serving as an intermediary pathway.

The social environment plays a substantial role in shaping mental well-being (Sampson, 2003). Research shows green spaces can facilitate neighbourly socialization (Holtan et al., 2015) and community cohesion (Elliott et al., 2014), which associates with heightened mental well-being. Research conducted by (Dadvand et al., 2019) also indicates that green spaces influence mental well-being through fostering social cohesion. Moreover, studies by (Dong & Qin, 2017) and (Qin et al., 2021) provided valuable insights into the multidimensionality of indicators of neighbourhood social environments, finding that these dimensions reflect both social cohesion and satisfaction with the social environment. Therefore, in campus contexts, green space social environment satisfaction could link campus green space and mental well-being capturing cohesion and subjective perceptions of the campus social milieu shaped by green spaces.

Despite extensive research exists at the community level, a gap persists regarding the impacts of multidimensional university green space exposure on student mental well-being. The mediating effects of green space satisfaction also underexplored in campus contexts, though frequently studied in community settings. To address these gaps, this study constructed a theoretical model drawing on existing green exposure frameworks and satisfaction pathway evidence. Structural equation modelling was then utilized to analyze the relationships between green space exposure, satisfaction, and mental well-being among university students.

## 2.2. Conceptual model and hypotheses

The initial theoretical model synthesized insights from existing literature to examine interrelationships between five latent variables: subjective exposure, objective exposure, green space satisfaction, social environment satisfaction, and mental well-being (Figure 1). Subjective exposure comprised of two observed variables: frequency and duration. Objective exposure comprised of three observed variables: visibility, availability, and attractiveness. The study hypothesized that both objective and subjective exposure would positively influence mental well-being. Additionally, we proposed green space satisfaction and social environment satisfaction as mediators between green space and mental well-being, positing that these pathways may miti-

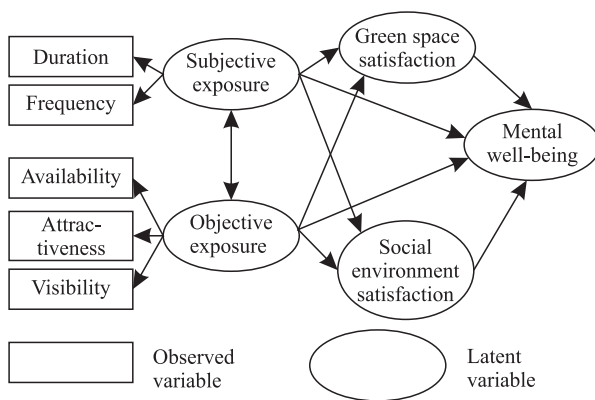


Figure 1. The initial theoretical model

gate risks to mental well-being. The following hypotheses were formulated:

H1: Subjective exposure positively influences college students' mental well-being during periods of campus lockdown. H2: Objective exposure positively influences college students' mental well-being during periods of campus lockdown. H3: Green space satisfaction positively influences the mental well-being of university students. H4: Subjective exposure metric positively influences green space satisfaction. H5: Objective exposure metric to green space positively influences green space satisfaction. H6: Green space social environment satisfaction positively influences university students' mental well-being. H7: Subjective exposure positively influences green space social environment satisfaction. H8: Objective exposure positively influences green space social environment satisfaction.

## 3. Material and methods

### 3.1. Study area

The cross-sectional study was conducted in December 2022, focusing on the China University of Mining and Technology as the designated study area. Situated in the eastern region of China, this university is a nationally recognized institution under the direct supervision of the Ministry of Education (Figure 2). The university comprises a diverse student body of 23,960 individuals from various regions of the country, and an area of 191 hm<sup>2</sup>. The university boasts a green coverage rate of 63.4%, which is

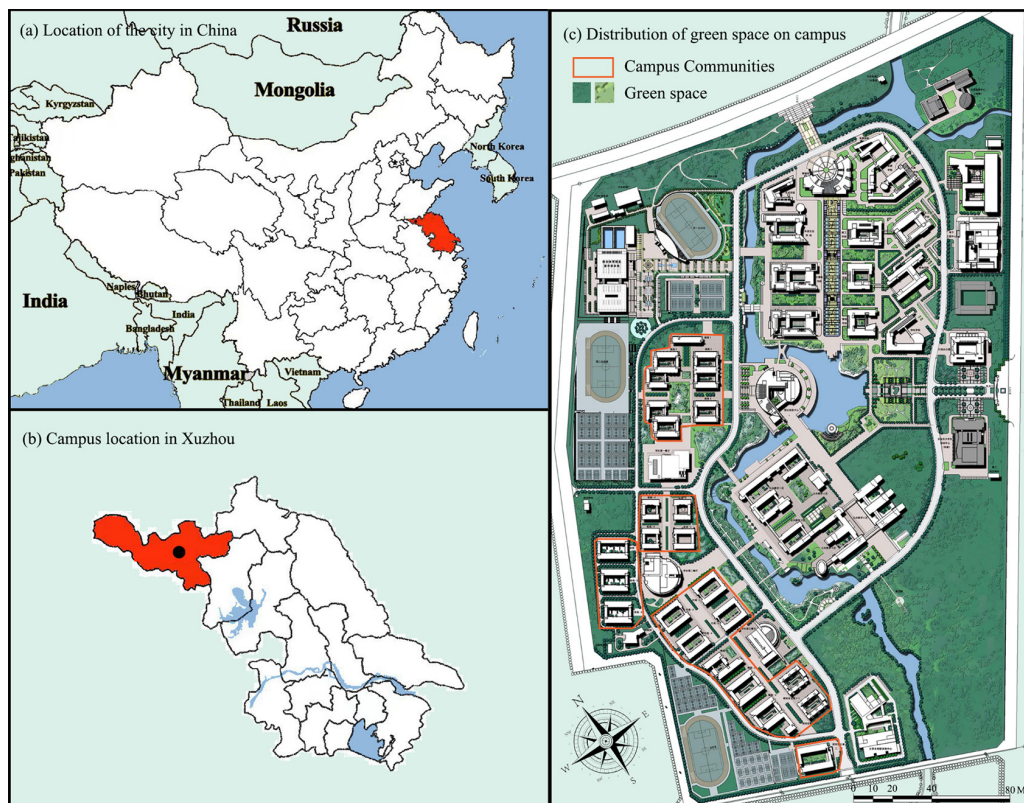


Figure 2. Locations of China University of Mining and Technology

comparable to other similar institutions in size and quality. Due to the occurrence and recurrence of the COVID-19 epidemic in Xuzhou, the university implemented a long-term campus closure from September to December. This measure aimed to restrict students from leaving the university premises for a duration of six months. As a result, the China University of Mining and Technology serves as a representative case for the study, capturing the characteristics of many other universities in China affected by campus closures and the pandemic. Questionnaires measured green space exposure, satisfaction, and mental health were disseminated among the student cohort at the China University of Mining and Technology. Prior to the main study, a pre-study was conducted in November 2022, involving the distribution of 30 questionnaires. Based on the pre-study, modifications were made to the scale questions to enhance their appropriateness. Subsequently, 346 questionnaires were spread to participants, taking into account the principle that the sample size should be between 10 and 15 times the number of observed variables. Post-exclusion of 37 invalid responses, the final submission of analytic sample was 309. Data compilation and analysis were performed using the SPSS 24.0 and Amos 24.0.

## 3.2. Data

### 3.2.1. Mental health outcome

The assessment of mental well-being in this study utilized the five-item World Health Organization Well-Being Index (WHO-5). The reliability and validity of the WHO-5 have

been demonstrated (Chan et al., 2022; Lara-Cabrera et al., 2020). This scale evaluates positive mental health across five dimensions including "Feeling happy", "Feeling relaxed", "Feeling active", "Being well rested", and "Living a full and interesting life" on a 5-point Likert scale, with total scores ranging from 0 to 25.

### 3.2.2. Green space exposure variables

Green space exposure refers to the extent to which natural environments are interacted with by individuals (or groups) (Bratman et al., 2019). There is a lack of consensus on the standardized measurement of green space exposure, despite an increasing number of studies on health and green space (Xiao et al., 2019). A growing number of studies highlight the value of human perception for assessing green space exposure (Gomm & Bernauer, 2023; Senanayake & King, 2019). Furthermore, measured greenness data also does not fully represent the human perception of green space (Jiang et al., 2017). For instance, Loder et al. (2020) showed weak correspondence between measured greenness data and perceived greenness on university campuses. During periods of campus lockdown, students primarily encountered unstructured green spaces (street trees, lawns, etc.), so the research on green exposure focuses more on perception indicators.

The questionnaire was designed to evaluate participants' perceived green space exposure. It was adapted through tabulation, categorization, and restructuring to align with the campus context (Table 2). In line with prior green space research, green space exposure was catego-

**Table 2.** Green space exposure indicator framework components and questionnaires

Construct measurement	Code	Statements	Item	Reference	
Subjective exposure	Frequency	IE1	About how often do you visit green spaces (e.g., playgrounds, lawns, landscaped walkways, gardens, etc.) in a week?	1 = Never 2 = 1~2 times 3 = 3~4 times 4 = 5~6 times 5 = Every day	(Akpinar, 2016b); (Markevych et al., 2017)
	Duration	IE2	How much time do you spend each time you visit green spaces (e.g., playgrounds, lawns, landscaped walkways, gardens, etc.) in a week?	1 = Less than 10 minutes 2 = 10~30 minutes 3 = 30~50 minutes 4 = 50~60 minutes 5 = More than 60 minutes	
Objective exposure	Availability	SE3	How "green" is the campus where you live (e.g., playgrounds, lawns, landscaped walkways, gardens, street trees, etc.)?	1 = No green at all 2 = Some green 3 = Moderately green 4 = Very green 5 = Extremely green	(Yang et al., 2020)
	Attractiveness	SE1_1	Do you think there is a wide variety of green space plants on campus?	1 = No at all 2 = Little 3 = Rather 4 = Much 5 = Completely	(W. Liu et al., 2022c)
		SE1_2	Do you think the campus green space is scenic?		
		SE1_3	Do you think that the green space on campus is well laid out and safe?		
SE1_4	Do you think the green space environment on campus is comfortable?				
Visibility	SE2	How much greenery (e.g., shrubs, landscaping, street trees, etc.) can you feel walking around the school?	1 = No green at all 2 = Some green 3 = Moderately green 4 = Very green 5 = Extremely green	(Sugiyama et al., 2008)	

rized into two dimensions: subjective exposure and objective exposure. The questionnaire included questions that employed a 5-point Likert scale with accompanying verbal descriptions, ensuring alignment with previous research conducted on university campus green spaces.

### 3.2.3. Satisfaction variables

The mediating roles of satisfaction will be assessed through perceived green space satisfaction and social environment satisfaction through a questionnaire. The questionnaire incorporated items adapted from settlement surveys and tailored to campuses contexts. It employed a 5-point Likert scale with corresponding verbal descriptions (Table 3). Green space satisfaction was evaluated based on quantity, quality, and availability (Y. Liu et al., 2019a). Social environment satisfaction was on dimensions like “acquaintance”, “getting along”, and “helpfulness” (Dong & Qin, 2017) and (Qin et al., 2021).

**Table 3.** Satisfaction indicator framework components and questionnaires

Construct measurement	Code	Statements	Item
Green Space Satisfaction	ES1	Are you satisfied with the quantity of the school's green space?	1 = Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly agree
	ES2	Are you satisfied with the quality of school's green space?	
	ES3	Are you satisfied with the availability of the school's green spaces?	
Social Environment Satisfaction	SS1	Do you know any students who go to green spaces?	1 = Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly agree
	SS2	Do you get on well with the other students who go to the green space?	
	SS3	Did you find the other students who went to the green space to be friendly and helpful to each other	

### 3.2.4. Demographic variables

To ensure alignment of the sample with the student population, three sociodemographic covariates were controlled for: education level (0 = Undergraduate, 2 = Master, 3 = Doctor) (Patwary et al., 2022), gender (0 = female, 1 = male), and time elapsed since returning to school (1 = ≤ one month, 2 = one month – two months, 3 = two months – three months, 4 = > four months) (Sun et al., 2021). Incorporating these demographic factors allowed for controlling compositional differences that may influence relationships between green space exposure, satisfaction, and mental health.

## 3.3. Methods

The analytical procedure encompassed several sequential steps. A confirmatory factor analysis (CFA) was executed to assess the extent how well the observed indicators reflected the latent variables, notably the subjective exposure, the objective exposure, social environment satisfaction, and green space satisfaction. Subsequently, SEM was employed to investigate and scrutinize the interrelationships between the objective exposure, the subjective exposure, two mediating variables, and mental well-being. The initial theoretical model was tested using SEM to elucidate the mechanisms connecting multidimensional green space exposure, mediating satisfaction variables, and the mental well-being of college students, while evaluating the stated hypotheses. This analytical approach aimed to provide insights into the nuanced direct and indirect associations shaping campus nature's influence on student mental health.

## 4. Results

### 4.1. Statistical analyses

The survey sample demonstrated balanced distribution across main socio-demographic factors (Table 4). Males accounted for 52.1% of the sample, while females accounted for 47.9%. In terms of educational background, undergraduates constituted 67.3% of the sample, followed by 29.4% masters and 3.3% PhD students, aligning with the composition of the university student population. Regarding the duration of returning to school, 5% were back for less than one month, 17% for one to two months, 30% for two to three months, and 48% for three to four months, indicating that the majority of students had returned to school within the normal timeframe. The mean of the WHO-5 was 17.92 (71.68% of the total), denoting approaching healthy levels as scores above 70% of the total scores signify normal mental health (Topp et al., 2015). These sample characteristics signify appropriate representation of college students strengthening the study's capacity to elucidate connections between green space and mental health within this campus context.

**Table 4.** Summary statistics of the study population (N = 309)

Variables	Proportion/Mean (Standard Deviation)
<b>Demographic variables</b>	
<b>Gender</b>	
Male	52.1%
Female	47.9%
<b>Grade</b>	
Undergraduate	67.3%
Master	29.4%
Doctor	3.3%

End of Table 4

Variables	Proportion/Mean (Standard Deviation)
<b>Time back to school</b>	
≤ one month	5%
one month – two months	17%
two months – three months	30%
> four months	48%
<b>Mental health outcome</b>	
WHO-5 (0–25)	17.92(5.743)
<b>Green Space Exposure Variables</b>	
<b>Objective exposure</b>	
Availability	3.87(0.791)
Attractiveness	3.91(0.671)
Visibility	3.96(0.803)
<b>Subjective exposure</b>	
Frequency	2.36(1.229)
Duration	2.17(1.106)
<b>Satisfaction Variables</b>	
<b>Social Environment Satisfaction</b>	3.52(0.741)
<b>Green Space Satisfaction</b>	3.88(0.746)

Regarding green space exposure, the findings are noteworthy. The mean frequency of visits of 2.36 indicates that, on average, students visited green spaces approximately two to three times per week. The mean duration of visits of 2.17 suggests that each visit lasted between 30 to 50 minutes on average. These findings highlight the regular interactions of students with green spaces on campus for relaxation, recreation, or other activities. The mean values

for the green space objective exposure of availability, visibility and attractiveness were 3.87, 3.91 and 3.96, indicating that green spaces on campus are abundant, visible and attractive. The mean value of green space satisfaction was 3.88, suggesting a considerable level of satisfaction with the green spaces on campus. Regarding social environment satisfaction on campus, the mean value was 3.52, suggesting a favourable perception of satisfaction with the social environment. Taken together, these results highlight pronounced green space exposure through frequent, moderate-length visits and satisfactory perceptions of both physical and social environmental qualities.

## 4.2. Measurement model

CFA validated the measurement model, evaluating the reliability and consistency of the data in the conceptual framework, which is imperative for the precision of each dimension's fit within the conceptual model. Table 5 shows: the standardized coefficients exceeded 0.6 the p-values at the 0.001 significance level for each variable and, confirming valid representation of the characteristics of latent variable. The Cronbach's alpha coefficient in each dimension was surpassed 0.7, indicating good stability of the questionnaire variables. The Composite Reliability (CR) for each dimension were above 0.7, indicating that each potential variable were internally consistent (Hair, 2009). Each of the latent variables had an Average Variance Extracted (AVE) value exceeded 0.5, indicating each dimension had good explanatory power for the measurement indicators, and confirming the good convergent validity of each dimension within the measurement model (Anderson & Gerbing, 1988).

The conceptual model underwent further refinement and optimization by means of Average Variance Extracted,

**Table 5.** Reliability and validity of the measurement models

Construct measurement	Code	Unstandardized estimates	S.E.	Z	Standardized estimates	Cronbach's $\alpha$	Composite reliability	Average Variance Extracted
Mental well-being	MH1	1			0.810	0.905	0.896	0.634
	MH2	0.937	0.057	16.317	0.756***			
	MH3	1.073	0.068	15.850	0.845***			
	MH4	0.963	0.076	12.740	0.713***			
	MH5	1.206	0.076	15.811	0.847***			
Objective exposure	SE1	1			0.800	0.805	0.812	0.592
	SE2	1.212	0.088	13.715	0.810***			
	SE3	1.020	0.091	11.174	0.692***			
Subjective exposure	IE1	1			0.775	0.718	0.722	0.565
	IE2	1.043	0.182	5.736	0.727***			
Green Space Satisfaction	ES1	1			0.832	0.805	0.807	0.584
	ES2	0.932	0.071	13.219	0.759***			
	ES3	0.860	0.073	11.708	0.696***			
Social Environment Satisfaction	SS1	1			0.613	0.777	0.789	0.558
	SS2	1.180	0.122	9.697	0.819***			
	SS3	1.203	0.120	9.994	0.792***			

Note: Significance levels: \*\*\*  $p < 0.01$ .

**Table 6.** Latent variable differential validity tests

Latent variable	Mean	SD	Objective exposure	Subjective exposure	Social Environment Satisfaction	Mental well-being	Green Space Satisfaction
Objective exposure	3.932	0.637	(0.769)	–	–	–	–
Subjective exposure	2.262	1.032	0.322	(0.752)	–	–	–
Social Environment Satisfaction	3.521	0.741	0.752	0.207	(0.764)	–	–
Mental well-being	3.584	1.148	0.515	0.328	0.381	(0.747)	–
Green Space Satisfaction	3.885	0.746	0.296	0.377	0.344	0.390	(0.796)

Note: The diagonal of the latent variable is the square root of the AVE and the lower triangle below the diagonal is the Pearson correlation coefficient between the latent variables.

verifying the unique characteristics which divergence from other variable. According to (Fornell & Larcker, 1981), the model's validity is deemed satisfactory when the square root of the AVE for each latent variable exceeds its correlation coefficient with other variables. Table 6 demonstrates that the measurement model achieves favourable overall discriminant validity.

### 4.3. Structural equation modelling

Table 7 displays the model fit indices confirmed adequate fit between the observed data and hypothetical theoretical model (Hu & Bentler, 1998; Iacobucci, 2010; Q. Liu et al., 2022a), supporting consistency between the proposed model and collected data. Table 8 showed that the hypothesis results were valid except for H2 (The objective exposure metric positively influences mental health.) and H4 (The subjective exposure metric positively influences green space satisfaction.). Specifically, significant positive effects are observed for the subjective exposure metric ( $\beta = 0.278$ ,  $p < 0.001$ ), green space satisfaction ( $\beta = 0.304$ ,  $p < 0.050$ ), and social environment satisfaction ( $\beta = 0.265$ ,  $p < 0.050$ ) on the mental well-being, validating hypotheses H1, H3, and H6. Furthermore, the subjective exposure

metric positively influences social environment satisfaction ( $\beta = 0.181$ ,  $p < 0.050$ ), confirming H7. Finally, the objective exposure metric exerts a positive effect on both green space satisfaction ( $\beta = 0.764$ ,  $p < 0.001$ ) and social environment satisfaction ( $\beta = 0.457$ ,  $p < 0.001$ ), supporting hypotheses H5 and H8.

Based on the hypothetical outcomes (Table 8), the final theoretical model was adapted (Figure 3). The standardised coefficients in the final model are presented, providing the path relationships and the corresponding coefficients (Figure 4). The SEM demonstrated a satisfactory fit to the data, as evidenced by the following goodness-of-fit indices:  $\chi^2/df = 1.911$ , AGFI = 0.903, CFI = 0.964, RMSEA = 0.054. Specifically, there was a positive and direct association between green space satisfaction and mental well-being ( $\beta = 0.191$ ,  $SE = 0.098$ ,  $p < 0.050$ ), as well as between social environment satisfaction and mental well-being ( $\beta = 0.228$ ,  $SE = 0.143$ ,  $p < 0.005$ ). Furthermore, the subjective exposure exhibited positive associations with social environment satisfaction ( $\beta = 0.191$ ,  $SE = 0.052$ ,  $p < 0.050$ ), and mental well-being ( $\beta = 0.259$ ,  $SE = 0.078$ ,  $p < 0.001$ ). Similarly, the objective exposure was positively associated with social environment satisfaction ( $\beta = 0.453$ ,

**Table 7.** Observed and suggested data for the model fit index

Goodness-of-fit indices	$\chi^2/df$	SRMR	RMSEA	GFI	AGFI	IFI	CFI	TLI
Reference values	<3	<0.080	<0.080	>0.900	>0.900	>0.900	>0.900	>0.900
Model 1 values	1.933	0.044	0.055	0.935	0.903	0.972	0.964	0.953

**Table 8.** Pathway relationship hypotheses test

Hypotheses	Pathways	Unstandardized estimates	S.E.	Z	Standardized estimates	Hypothetical result
H1	Subjective exposure → Mental well-being	0.335	0.097	3.457	0.278***	Support
H2	Objective exposure → Mental well-being	−0.305	0.249	−1.226	−0.159	No support
H3	Green space satisfaction → Mental well-being	0.437	0.165	2.654	0.304***	Support
H4	Subjective exposure → Green space satisfaction	−0.033	0.055	−0.599	−0.039	No support
H5	Objective exposure → Green space satisfaction	1.025	0.100	10.285	0.764***	Support
H6	Social environment satisfaction → Mental well-being	0.510	0.155	3.283	0.265***	Support
H7	Subjective exposure → Social environment satisfaction	0.113	0.052	2.168	0.181**	Support
H8	Objective exposure → Social environment satisfaction	0.457	0.079	5.770	0.457***	Support

Note: Significance levels: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .



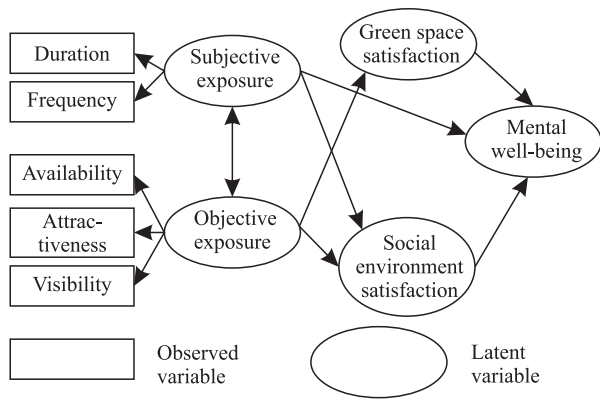


Figure 3. The final theoretical model

$SE = 0.078, p < 0.050$ ) and green space satisfaction ( $\beta = 0.749, SE = 0.092, p < 0.001$ ).

Table 9 shows objective exposure, which estimated an indirect influence of on mental well-being through social environment satisfaction was estimated to be 0.053, indicating that social environment satisfaction partially mediates the relationship between subjective exposure and mental well-being. In comparison, the corresponding direct effect was found to be 0.317, suggesting a substantial direct influence of subjective exposure on mental well-being. Regarding objective exposure, it exhibited an indirect effect of 0.274 on the mental well-being through green space satisfaction, indicating that green space satisfaction mediates the correlation between objective exposure and mental well-being. Additionally, objective exposure had an

indirect effect of 0.198 on the mental well-being through social environment satisfaction, indicating that social environment satisfaction also mediates the relationship between objective exposure and mental well-being. Taken together, the total indirect effect of objective exposure on mental well-being through the satisfaction variables was 0.472, while the direct effect was considered negligible.

Table 9. Standardized direct, indirect, and total effects of exposure metric on mental well-being

Pathways	Direct effect (95% CI)	Indirect effect (95% CI)	Total effect (95% CI)
Subjective exposure → Social Environment Satisfaction → Mental well-being		0.053* (0.004, 0.156)	
Subjective exposure → Mental well-being	0.317*** (0.095, 0.587)	0.053* (0.004, 0.156)	0.370*** (0.095, 0.587)
Objective exposure → Green Space Satisfaction → Mental well-being		0.274** (0.068, 0.493)	
Objective exposure → Social Environment Satisfaction → Mental well-being		0.198*** (0.055, 0.404)	
Objective exposure → Mental well-being		0.472*** (0.264, 0.698)	0.472*** (0.264, 0.698)

Note: Significance levels: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

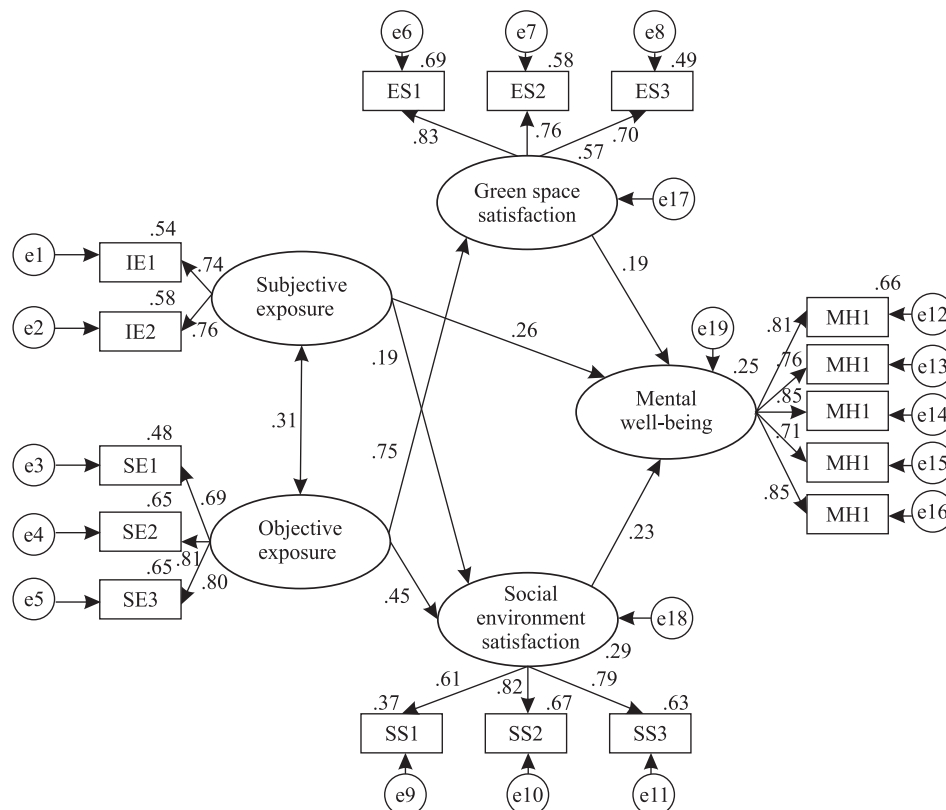


Figure 4. Final structural equation model with standardised coefficients

## 5. Discussion

The study was to advance understandings of campus green space and mental well-being connections amidst the COVID-19 epidemic through several contributions. First, the study synthesized prior green spaces exposure framework to propose applicable indicators tailored to unstructural campus green spaces. Second, the potential mediating influence of satisfaction with campus green spaces was investigated regarding links between multidimensional green space exposure and mental well-being. Additionally, the study utilized SEM to assess the influence of multidimensional green space exposure on mental well-being. By incorporating a multidimensional exposure assessment, evaluating satisfaction pathways, and leveraging advanced statistical modeling, this work provides enhanced insights into the mechanisms shaping campus green space exposure's impacts on student well-being during a public health crisis.

### 5.1. Green space exposure influences mental well-being pathways

The final theoretical model presents a direct and positive relationship between green space exposure and the mental well-being of students during a campus lockdown (H1). This aligns with pre-pandemic evidence, reinforcing the positive effects of the duration of time spent in and frequency of visits to campus green spaces on the mental well-being among adolescents (Holt et al., 2019). However, the hypothesized pathway of objective exposure influences mental well-being (H2) is not supported, contradicting some previous research (J. Zhang et al., 2022), but aligning with other findings suggesting no direct association (Qin et al., 2021). The high perceived availability of green spaces within the sampled campus community may explain the limited role of objective exposure. The findings highlight the continued importance of experiential and behavioural interactions with campus nature, even amidst lockdown restrictions limiting mobility.

Unlike prior research, objective exposure analysis revealed higher path coefficients for visibility and attractiveness compared to availability. This aligns with emerging evidence on street green space visibility (Ki & Lee, 2021) and campus green spaces attractiveness impacts (X. Li et al., 2019), suggesting visibility and attractiveness more strongly shaped the perception of objective exposure. This finding can be attributed to the fact that during the epidemic lockdown, students on campus increased their outdoor activities and engagement with green spaces like street trees, shrubs, and visually appealing green spaces to relieve anxiety. These nuanced findings provide valuable insights to guide future studies on green space exposure. Regarding the observed variables of the subjective exposure, the path coefficients associated with visit time and visit frequency exceed 0.7, indicating the significance of both variables as important individual exposure indicators. This finding consistent with previous studies highlighting

visit duration and frequency as reflective of individuals' natural experiences (Q. Liu et al., 2022b; Markevych et al., 2017). The consistent findings further validate the relevance of visit time and visit frequency for gauging subjective campus green space exposure levels.

### 5.2. Green space exposure, satisfaction and mental well-being pathways

The final theoretical model presents green space exposure positively influencing mental health through green space satisfaction and social environment satisfaction. Objective exposure influences green space satisfaction (H5) pathway corroborates the pre-pandemic research (Gozalo et al., 2018). Furthermore, the identified links from green space satisfaction to mental well-being (H3) and the confirmed pathways from objective exposure to social environment satisfaction (H5) suggesting that green space exposure impacts mental well-being through green space satisfaction, consistent with prior community-level studies (Y. Liu et al., 2019a; Qiao et al., 2021), and addressing a campus research gap.. Additionally, pathway of social environment satisfaction influences mental well-being (H6), objective exposure influences social environment satisfaction (H8), and subjective exposure influences social environment satisfaction (H7) were confirmed that social environment satisfaction can serve as a mediator between green space exposure and mental health. This finding consistent with previous studies from Chinese communities where green spaces enhanced residents' mental health by increasing social satisfaction (Dadvand et al., 2019; Jabbar et al., 2022). This highlights environmental satisfaction as a novel mediator between campus green space exposure and students' well-being.

Conversely, the pathways of subjective exposure influences green space satisfaction (H4) does not hold, consistent with pre-pandemic finding no relationship between time and green space satisfaction (McEachan et al., 2018). The lockdown of the campus during the pandemic, leading to increased time and frequency of student visits to campus green spaces, elevating familiarity. With heightened campus green spaces exposure, time spent may minimally influence satisfaction compared to others. This result indicates that during periods of restricted mobility in campus, subjective usage patterns may not shape green space satisfaction, unlike objective exposure. The pandemic context appears to have tempered the impact of experiential engagement on perceptions of campus green spaces.

Among the observed variables of satisfaction, the path coefficients for "getting along" and "helpfulness" in social environment satisfaction are higher compared to "acquaintance", which is different from previous studies (Qin et al., 2021). This highlights the salient role of "getting along" and "helpfulness" in shaping satisfaction with the social environment in campus green spaces. The COVID-19 epidemic has restricted students' activities primarily to outdoor campus green spaces. However, the high population density on campus, students may have increased en-

counter with unfamiliar individuals in these green spaces, which may diminish the influence of the factor related to "acquaintance". These results provide insights into how shifting social dynamics during campus lockdown may have altered influences on satisfaction with the campus social environment.

### 5.3. Strengths, limitations and future research

Despite the insights gleaned, this study has certain limitations to acknowledged and build upon. Firstly, the scalability of the findings needs to be further verified due to the sample size and the specific scope. Considering that the effects of exposure indicators on university students may vary across different geographical locations, it is essential to expand the sample size and conduct comparative studies in multi-cities to assess the external validity. Additionally, it is noted that the cross-sectional data used in current study, which may limit relationship building. Future research should consider incorporating longitudinal data to explore the temporal patterns of effects over time.

## 6. Conclusions and recommendations

The campus lockdown during the COVID-19 epidemic adversely impacted physical and mental well-being. Campus green spaces serve as important areas for various activities, such as social interaction, sports, and recreation, especially during unique circumstances like the campus lockdown. The validity of these hypotheses and observed variables suggest that modifying green spaces to attract university students, bolster satisfaction with green spaces and the social environment may enhance the mental well-being of students in future lockdowns. These hypotheses provide insights to guide planning of unstructured green spaces in colleges post-epidemic planning. Specifically, our observed variables suggest that more attention should be paid to the impact of attractiveness and visibility indicators on mental health when designing campus green space exposures after the end of the epidemic. Additionally, facets of observed variables such as "getting along" and "helpfulness" linked to improved mental well-being, highlighting the importance of green space as outdoor social environment on campus. The multidimensional green space exposure framework and observed variables provide direction for our future research on campus green space exposure.

The findings suggest several strategies to optimize unstructured green spaces on campus design for improving student mental health and resilience. Firstly, perception of objective exposure could be enhanced by boosting visibility and attractiveness. In response to emergencies contexts, visibility can be improved through strategically placement along campus transportation routes, incorporating green elements into teaching areas, and well-designed rest spots with surrounding greenery. Leverage greenways and walking paths could also enrich the distribution and heighten student interactions. Secondly, expanding the distribution and size of green spaces while elevating quality and visibil-

ity may be beneficial. Creating small-scale nodes designed for social gatherings could enable communal activities to foster social environment satisfaction, usage, and cohesion within the social environment. Finally, a multifaceted approach simultaneously improving visibility, attractiveness, distribution, amenities, and affordances for social and recreational usages could create resilient campus green spaces. This may nurture satisfaction, social connectivity, regular interactions, and mental well-being during public health crises when green spaces become vital outlets.

In conclusion, the study reveals the specific impact of a multidimensional green space exposure framework on students' well-being during the campus lockdown. The findings suggest strategies for elevating the perception of the objective exposure through enhancing visibility and attractiveness. Findings also signify that boosting social environment satisfaction by increasing the utilization and fostering social cohesion can enhance mental health. These insights make valuable contributions for the planning and design to support the mental well-being of students during public health crises.

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## Conflict of interest

The authors declare that they have no conflicts of interest related to the publication of this paper.

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