Article

Green Space for Mental Health in the COVID-19 Era: A Pathway Analysis in Residential Green Space Users

Hansen Li [1], Matthew H. E. M. Browning [2], Angel M. Dzhambov [3], Guodong Zhang [1,*] and Yang Cao [4,5]

1 Institute of Sports Science, College of Physical Education, Southwest University, Chongqing 400175, China; lhs510416413@swu.edu.cn
2 Department of Park, Recreation, and Tourism Management, Clemson University, Clemson, SC 29634, USA; mhb2@clemson.edu
3 Department of Hygiene, Faculty of Public Health, Medical University of Plovdiv, 4002 Plovdiv, Bulgaria; angel.dzhambov@mu-plovdiv.bg or angelleloti@gmail.com
4 Clinical Epidemiology and Biostatistics, School of Medical Sciences, Örebro University, 70182 Örebro, Sweden; yang.cao@oru.se
5 Unit of Integrative Epidemiology, Institute of Environmental Medicine, Karolinska Institutet, 17177 Stockholm, Sweden
* Correspondence: lygd777@swu.edu.cn; Tel.: +86-15730267257

Abstract: Residential green space is among the most accessible types of urban green spaces and may help maintain mental health during the COVID-19 pandemic. However, it is insufficiently understood how residents use residential green space for exercise during the epidemic. The pathways between residential green space and mental health also merit further exploration. Therefore, we conducted an online study among Chinese residents in December 2021 to capture data on engagement with urban green space for green exercise, the frequency of green exercise, perceived pollution in green space, perceptions of residential green space, social cohesion, depression, and anxiety. Among the 1208 respondents who engaged in green exercise last month, 967 (80%) reported that green exercise primarily occurred in residential neighborhoods. The rest (20%) reported that green exercise occurred in more distant urban green spaces. The most common reasons that respondents sought green exercise in urban green spaces were better air and environmental qualities. Structural equation modeling (SEM) was then employed to explore the pathways between the perceived greenness of residential neighborhoods and mental health among respondents who used residential green space for exercise. The final model suggested that residential green space was negatively associated with anxiety (β = −0.30, *p* = 0.001) and depression (β = −0.33, *p* < 0.001), mainly through indirect pathways. Perceived pollution and social cohesion were the two mediators that contributed to most of the indirect effects. Perceived pollution was also indirectly associated with green exercise through less social cohesion (β = −0.04, *p* = 0.010). These findings suggest a potential framework to understand the mental health benefits of residential green space and its accompanying pathways during the COVID-19 era.

Keywords: neighborhood; community; physical activity; mental health; urban greening

1. Introduction

Being exposed to nature is known to benefit mental and physical health [1–3]. However, expanding urbanization has reduced the connection between humans and nature, thus posing risks to human health [4–7]. In this context, urban green spaces have become increasingly important since they can improve the urban environment and offer residents opportunities to interact with natural elements [8]. Normally, public green spaces such as urban parks and urban woodlands are popular because they can provide cleaner environments for physical activities. For example, fresh air was a common reason mentioned by visitors to green spaces [9,10]. However, the unexpected COVID-19 pandemic has

significantly changed people's visitation of, attitudes toward, and behaviors in urban green spaces [11,12]. Determining the extent to which urban residents visit green spaces for physical activity and why visitors engage in exercise, specifically in urban green space during the pandemic, is not yet well understood.

China has been making arguably the most strict policies to curb the spread of the virus [13]. Though many public facilities have become available again as the virus has been gradually controlled, communities and university campuses are still frequently sealed off during the subsequent waves of disease, which may have threatened the mental health of Chinese residents [14]. In March 2022, the emerging Omicron variant caused blockades (lockdowns) in 571 regions and cities in China [15], extending the durative impact of the pandemic on mental health.

In Western countries, nature contact in urban parks or other public green spaces has been deemed an option to maintain mental health during such periods [16–19]. However, heading to an urban park may not be easy in China because of many cities' extremely high population density and insufficient urban park cover. When a new case is confirmed, travel within a city becomes restricted or forbidden, restricting outdoor activities. In this context, residential green space may be ideal for residents since they do not have to travel far or risk the increased probability of infection. Like other green spaces, residential green spaces are associated with lower depression and anxiety [20,21]. However, the associations between exposure and mental health still need more investigation during the pandemic, and potential pathways are not fully explored.

Conceptual Framework

Green spaces may reduce mental health issues in myriad ways [22]. Aside from direct associations [23,24], we proposed the following mediators: social cohesion, perceived pollution, and green exercise.

Social cohesion has many definitions [25]. For residential neighborhoods, social cohesion can be described as the social connections, trust, and solidarity among residents [26,27] that protect mental health [28,29], especially during the pandemic [30,31]. It has been suggested that urban green space can support social cohesion by increasing the likelihood of meeting others and the feelings of comfort that connects people to places and fellow visitors [32]. Furthermore, numerous studies suggest that social cohesion may mediate the association between green space and mental health [33–36], supporting our first hypothesized pathway across urban natural environments.

Air pollutants and noise are common forms of pollution that threaten mental health [37]. Perceived air and noise pollution are usually investigated by self-reported measures, which can resemble objectively measured pollution levels [38,39]. Interestingly, perceived pollution may impact people's behaviors more strongly than objectively measured pollution [40]. This may be because perceived pollution is related to individuals' sensitivity to pollution and acts as a mediator between measured pollution and psychological responses [41,42]. Green space may remove harmful gas and inhalable particles [43], attenuate noise pollution [44], and alter individuals' susceptibility to noise [45]. Green space may reduce both measured and perceived levels of air and noise pollution [46–49], which may further contribute to mental health [50–52]. These clues support our second hypothesized pathway between green space and mental health through perceived pollution.

Green exercise is a third viable factor, which refers to the combination of physical activity and nature exposure [53]. Green exercise has been assumed to be more beneficial than physical activity in urban "grey" areas [54,55]. Green spaces may encourage physical activity by increasing the restorative quality of the environment in which someone exercises [22,50,56] and may therefore increase the mental health benefits of exercise [36,57]. The frequency of visitation is often employed to measure green space utilization [58–60] and also serves as a critical dimension of physical activity associated with green spaces [61]. Closer and greener urban spaces may be associated with more frequent green exercise

among residents [62,63], which supports our third hypothesized pathway between green space and mental health through green exercise.

The three mediators above are likely to interrelate when modeled together with green space and mental health. Residents tend to perform walking and relaxation activities in urban green spaces with low noise levels [64]. In contrast, a space heavily affected by air and noise pollution may discourage participation in outdoor physical activity [65] because pollutants reduce environmental quality and are deemed harmful [50,66,67]. Pollutants may increase annoyance with urban environments and reduce social cohesion in those spaces [51,65,68]. Many studies have also shown that social cohesion may motivate physical activity [69,70], including in urban green spaces [33]. Therefore, perceived pollution may discourage green exercise by reducing social cohesion.

Our aim was to investigate the association of residential green space with depression and anxiety through three hypothesized mediators: social cohesion, perceived pollution (air and noise), and green exercise. In addition, we established a covariance link between depression and anxiety based on their strong association [71]. Given the possibility of confounding in these relationships, we control for the following:

(1) Age and gender, which may affect mental health conditions [72,73] and the chance for green exercise [74];

(2) Income, which may affect residential green space [75], physical activity [76], social cohesion [77], mental health [78], and benefits derived from green space [79];

(3) COVID-19 condition, which can impact mental health [80], social cohesion [81], and chances for green exercise [12,82].

Our conceptual framework is presented in Figure 1. We hypothesize the following:

Hypothesis 1 (H1). *Residential green space is the primary type of green space used by residents for green exercise; furthermore, high environmental quality is the stated reason to engage in green exercise in these spaces*.

Hypothesis 2 (H2). *Perceived residential green space impacts depression and anxiety directly and indirectly through perceived pollution, social cohesion, and green exercise*.
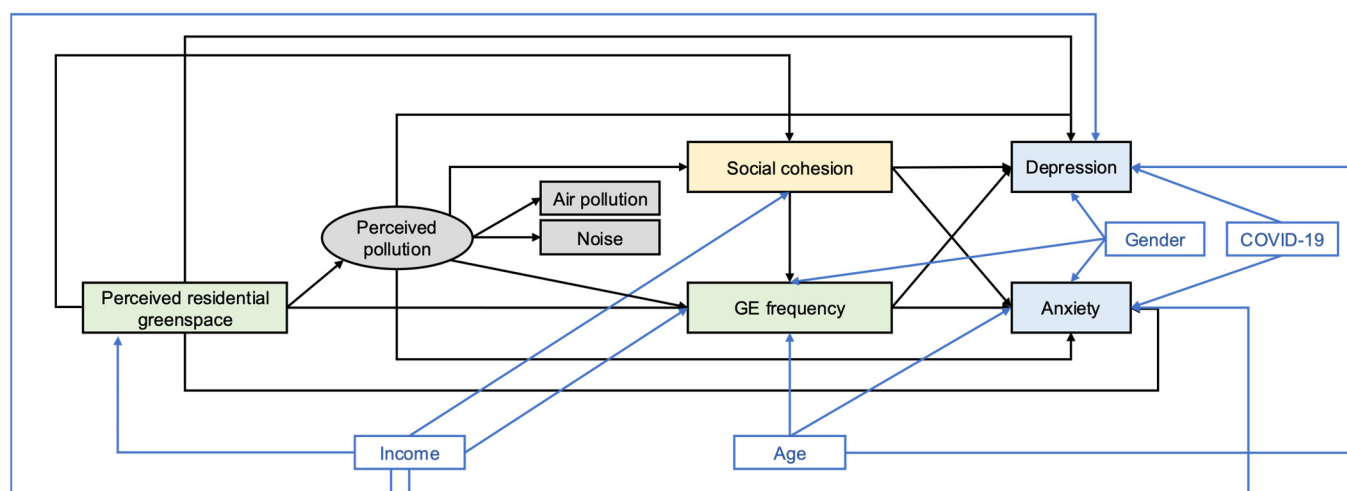

Figure 1. Conceptual framework. Note: GE, green exercise. Black lines indicate pathways between core variables (perceived residential green space, perceived pollution, social cohesion, green exercise frequency, depression, and anxiety). Blue lines indicate confounding pathways between core and control variables (income, age, gender, and COVID-19 condition).

2. Materials and Methods

2.1. Study Design and Participants

We conducted a cross-sectional survey in December 2021 when regional COVID-19 outbreaks reemerged in many areas of China. Our target population was Chinese urban residents with no restrictions on the province. The study was approved and supervised by the Ethics Review Board of University, China.

We distributed recruitment messages via online social media, including WeChat and Tencent QQ. We employed a snowball sampling technique that involved inviting middle-aged participants to spread information to people of similar ages or older. We described the study's topic as investigating the utilization of urban green space and mental health during the COVID-19 epidemic. Details of the research questions were not disclosed during participant recruitment. We offered compensation of CNY 5 (approximately USD 0.8) for completing the online. The participants used WeChat accounts linked with their personal IDs to fill out the questionnaires (the IP address, device, and account were restricted, and each participant could submit once). In total, 1329 questionnaires were collected. After removing incomplete questionnaires and those that failed human verification tests (to confirm that people carefully completed the questionnaire), a total of 1223 qualified questionnaires were included in the analysis.

2.2. Instruments and Measurements

2.2.1. Location of and Reasons for Green Exercise

The following question was used to identify the location of urban green spaces used for green exercise: "Where is the urban green space that you usually did physical activities (e.g., walking, running, biking, dancing, or ball games) in the last month?" Response options included the following: "Did not do physical activity in any urban green space in the last month"; "the green space in my residential neighborhood (in and around my community, only need a very few minutes of walk for arrival)"; or "other green places that are more distant (usually need to walk a while or even need a vehicle for arrival)."

The participants were also asked to briefly indicate their main reasons for green exercise in green space with a single sentence. An open-ended question was used to obtain their responses.

2.2.2. Frequency of Green Exercise

We measured the frequency of green exercise by asking, "How often did you do physical activities (e.g., walking, running, biking, dancing, ball games) in the mentioned green space during the last month?" Answers were provided on a 7-point Likert-type scale (1 = once per week or less to 7 = about days per week).

2.2.3. Perceived Pollution of Green Space

We measured the perception of pollution in green spaces among the respondents who claimed green exercise in residential green spaces by asking: "Please describe the general level of air pollution in the mentioned green space during the last month"; and "Please describe the general level of noise in the green space (where you usually did physical activities) during the last month." Answers were given using a 5-point Likert-type scale (1 = very low or almost imperceptible to 5 = very high or easily felt).

2.2.4. Perceived Residential Green Space

Based on the methods of Liu et al. [52] and Yang et al. [51], we asked the following to measure the availability of perceived residential green space: "How much green space (e.g., trees/plants) is there in your residential neighborhood?" Answers were given using a 5-point Likert-type scale (1 = very little or almost no greenness to 5 = very much or full of natural greenness).

2.2.5. Social Cohesion

Trust is a critical factor that affects the willingness to intervene for the common good at the neighborhood level [83]. It can be measured with the Sampson et al. [84] scale, which measures social cohesion/trust [85]. We used the highest-loading item from this scale, following another study that measured social cohesion in residential neighborhoods among Chinese populations [51]: "Do you think people in your residential neighborhood can be trusted?" on a 5-point Likert-type scale (1 = not at all, 5 = absolutely).

2.2.6. Anxiety

The Chinese version of the Generalized Anxiety Disorder 7-item (GAD-7) scale was used to measure anxiety conditions in the last month. The scale assesses how often a person is bothered by common symptoms of anxiety, such as nervousness and worries. Responses were given using a 4-point Likert-type scale (0 = not at all to 3 = nearly every day). The total score can be used for identifying anxiety symptoms (0–4 for minimal anxiety; 5–9 for mild anxiety; 10–14 for moderately severe anxiety, and 20–27 for severe anxiety). High internal reliability was observed in our sample (Cronbach α = 0.94).

2.2.7. Depression

The Chinese version of the Patient Health Questionnaire 9-item (PHQ-9) scale was used to measure depression conditions in the last month. The scale assesses how often a person is bothered by common symptoms of depression, such as fatigue and sleep problems. Responses were given using a 4-point Likert-type scale (0 = not at all to 3 = nearly every day). The total score can be used for identifying depression symptoms (0–4 for minimal depression; 5–9 for mild depression; 10–14 for moderately severe depression, and 20–27 for severe depression). In our sample, high internal reliability was again observed (α = 0.95).

2.2.8. Sociodemographic Characteristics

The gender of the respondents was categorized into two groups (1 = male, 2 = female). Age of respondents was categorized into eight levels (<18 year, 18–25, 26–30, 31–40, 41–50, 51–60, 61–70, >70). Monthly incomes were categorized into seven levels (no reported income, RMB ≤ 3000, RMB 3001–6000, RMB 6001–9000, RMB 9001–12,000, RMB 12,001–15,000, RMB >15,000). For reference, RMB 1 is approximately USD 0.8 or EUR 0.7.

2.2.9. COVID-19 Condition

The number of infections among different provinces was obtained from the China National Health Commission, provincial and municipal health commissions, provincial and municipal governments, and official channels (https://wp.m.163.com/163/page/news/virus_report/index.html, accessed on 25 December 2021). The number affects social restrictions in China and was used to control for the COVID-19 conditions for each respondent.

2.3. Analysis

2.3.1. Bivariate Correlations

Spearman's rank-order correlation (for correlations between two continuous variables) and point-biserial correlation (for correlations between a binary variable and a continuous variable) were used to detect the general pattern of associations between the variables.

2.3.2. Keywords for Green Exercise in Green Space

Natural language process (NLP) refers to the branch of artificial intelligence or AI that combines computational linguistics with statistical, machine learning, and deep learning models [86,87]. These functions enable computers to process human language in the form of text to uncover its full meaning. NPL is used for translation, sentiment analysis, text summarization, and more. Many companies have constructed AI platforms that offer NLP services.

In this study, the keywords in respondents' reasons for green exercise in green space were identified using the NLP engine empowered by Tencent Holdings Ltd. (Shenzhen, China). Since we required participants to briefly state their reasons in a single sentence, the same noun was not likely to appear twice in a single response (we manually confirmed this). After removing typos in the questionnaires, participants' responses were input together as a single file for keywords summarization without extra restriction.

2.3.3. Structural Equations Modeling

Structural equation modeling (SEM) was employed to examine the hypothesized directional paths in the conceptual framework presented in Figure 2 for the respondents who engaged in green exercise in residential green space. According to Bagozzi and Yi [88], the sample size for SEM should be twice the number of model parameters. Based on the parameters (*n* = 22) required to estimate in the framework, our sample size of 967 (respondents who reported green exercise in residential green space) was adequate. As performed in prior research on green space and mental health during the COVID-19 pandemic, the results of the GAD-7 and PHQ-9 were processed as continuous summary scores, while the levels of air pollution and noise were assumed to load onto one latent factor that we labeled as "perceived pollution" [51,52,71].
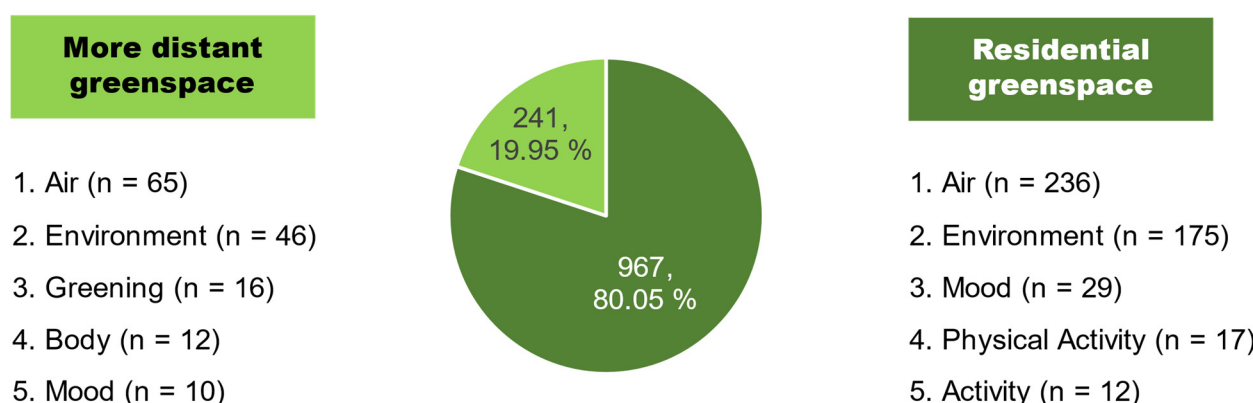

Figure 2. Proportion of respondents reporting green exercise in different urban green spaces and top five keywords for reasons to engage in green exercise (*n* = 1208). Note: *n*: times of the keywords appeared in respondents' answers.

Variance inflation factor (VIF) values smaller than 5.0 were considered evidence of the absence of multicollinearity. Based on this rule, no multicollinearity was observed among the independent variables (VIF < 3.0) [89].

Given our sample size and a high level of multivariate non-normality in the data, we used an asymptotically distribution-free (ADF)/weighted least squares (WLS) estimator for analysis [90,91]. The bootstrap method with 10,000 replications was used to generate corresponding standard errors and confidence intervals for all paths [92–94].

Based on the ADF/WLS estimator, the goodness of fit was assessed using the following indices [91,95]: standardized root mean square residual (SRMR) < 0.08; Tucker–Lewis index (TLI) > 0.95; and goodness-of-fit index (CFI) > 0.95. In addition, a root mean square error of approximation (RMSEA) < 0.05 was also considered because it is essential for maximum likelihood (ML) and generalized least squares (GLS) estimations that were later performed for sensitivity analysis [91]. We did not employ the χ2 test because it is strongly affected to sample size and violation of the multivariate normality assumption [96–98].

A factor loading for latent variables of the conceptual model > 0.5 was considered acceptable. An indirect effect (i.e., a product of coefficients for the constituent links) that significantly exceeded zero was evidence of mediation [99,100].

The Akaike information criterion (AIC) and Bayesian information criterion (BIC) were used for model selection, as they are useful for selecting the model with the least overfitting [101].

2.3.4. Model Modification

The initial model M0 resulted in a low TLI value (SRMR = 0.03; CFI = 0.96; TLI = 0.89; RMSEA = 0.04 [90%CI: 0.03, 0.06]; AIC = 143.53; BIC = 377.49). Thereafter, we removed the confounding paths without at least a marginal statistical significance ($p > 0.1$). The COVID-19 condition was removed from the model due to weak impacts on the core variables ($p > 0.1$). The TLI value of the modified model (M1) was still lower than an ideal but reached an acceptable level, as indicated in past research (SRMR = 0.04; CFI = 0.96; TLI = 0.90; RMSEA = 0.04 [90%CI: 0.03, 0.06]; AIC = 122.08; BIC = 307.30) [102–104]. Therefore, the model M1 was selected as the final model, and all non-significant pathways between the core variables were retained.

2.3.5. Sensitivity Analyses

Regarding keywords scanning, we switched to another NPL engine developed by the Baidu Holdings Ltd. (Beijing, China) to examine any changes in the identified keywords as a sensitivity analysis.

Given that ML and GLS estimators may be comparative to ADF/WLS estimator in some scenarios, even where normality is violated [91,105], we also applied two estimators to re-examine the robustness of the identified pathways between the core variables. Additionally, we established competing models by re-specifying localized points of theoretical causalities based on the following two theories (Figure S1):

(1) Model 2 (M2): The frequency of green space visitation predicting social cohesion [106];
(2) Model 3 (M3): A reciprocal relationship between green exercise and social cohesion (Jennings and Bamkole, 2019).

To check if the final model could fit different gender and ages, we ran subgroup analyses that stratified the respondents by gender and median age, respectively. All the statistical analyses were conducted in SPSS 25.0 and AMOS 20.0. software (SPSS Inc., Chicago, IL, USA).

3. Results

3.1. Characteristics of Respondents

A total of 1223 respondents were eligible for the final analysis, and 50% were males. More than 50% of the respondents were between 18 and 30 years old. Around 65% of the respondents had a monthly income between CNY 3000 and 9000. Only 1% reported no green exercise during the last month, and over 50% reported green exercise two or three times per week during the last month (Table 1).

3.2. Locations and Reasons for Green Exercise

A total of 1208 respondents claimed green exercise experiences during the last month. Specifically, 967 (80%) reported that green exercises were mainly in residential green spaces, whereas 241 (20%) reported green exercise in more distant spaces (Figure 2). The top five keywords drawn from respondents' answers showed that looking for better air and environment were the main reasons for performing green exercises in both residential and distant green spaces (Figure 2).

Table 1. Respondent characteristics (*n* = 1223).

Variable	Category	Mean (SD)	Percentage (*n*)
Gender	Male	-	49.71% (608)
	Female	-	50.29% (615)
Age (year)	<18	-	2.13% (26)
	18–25	-	24.45% (299)
	26–30	-	27.64% (338)
	31–40	-	31.40% (384)
	41–50	-	10.96% (134)
	51–60	-	3.19% (39)
	61–70	-	0.16% (2)
	>70	-	0.08% (1)
Monthly income (CNY)	None	-	5.15% (63)
	≤ 3000	-	12.92% (158)
	3001–6000	-	32.05% (392)
	6001–9000	-	32.71% (400)
	9001–12,000	-	11.53% (141)
	12,001–15,000	-	3.76% (46)
	>15,000	-	1.88% (23)
Residential greenness level	Little	-	2.13% (26)
	A little	-	10.79% (132)
	Moderate	-	18.72% (229)
	Much	-	40.39% (494)
	Very Much	-	27.96% (342)
Green exercise	None	-	1.23% (15)
	Once per week or less	-	14.39% (176)
	Twice per week	-	20.44% (250)
	Three times per week	-	29.35% (359)
	Four times per week	-	9.73% (119)
	Five times per week	-	8.58% (105)
	Six times per week	-	1.72% (21)
	Seven times per week	-	14.55% (178)
Anxiety	-	10.28 (3.89)	-
	Minimal anxiety		64.29% (786)
	Mild anxiety		29.60% (362)
	Moderate anxiety		4.66% (57)
	Severe anxiety		1.5% (18)
Depression	-	13.06 (5.00)	-
	Minimal depression		62.80% (768)
	Mild depression		27.80% (340)
	Moderate depression		5.81% (71)
	Moderately severe depression		1.80% (22)
	Severe depression		1.80% (22)

3.3. Correlations between Variables

Table 2 displays the correlations between the variables of interest among respondents who performed green exercise in residential green space during the last month (*n* = 967). Residential green space, physical activity in residential green space, social cohesion, and age were negatively correlated with anxiety and depression. COVID-19 conditions, perceived noise, and air pollution were positively correlated with anxiety and depression. Females showed lower levels of depression and anxiety than males.

Table 2. Bivariate Spearman or point-biserial correlations (*n* = 967).

Item	1	2	3	4	5	6	7	8	9	10	11
1. Gender (male = 1)	1.00										
2. Age	**0.18 ****	1.00									
3. Income	−**0.14 ****	**0.22 ****	1.00								
4. Infection	−**0.07 ***	−**0.12 ****	−0.02	1.00							
5. Residential greenspace	0.06	−0.05	**0.11 ****	−0.04	1.00						
6. Noise	−0.06	−0.06	−0.02	0.06	−**0.35 ****	1.00					
7. Air pollution	−**0.08 ***	0.03	−0.01	0.03	−**0.45 ****	**0.49 ****	1.00				
8. GE frequency	0.06	**0.08 ***	**0.17 ****	0.03	**0.30 ****	−**0.08 ***	−**0.15 ****	1.00			
9. Social cohesion	0.06	−0.02	**0.07 ***	−0.04	**0.56 ****	−**0.35 ****	−**0.49 ****	**0.26 ****	1.00		
10. Anxiety	−**0.16 ****	−**0.12 ****	−0.04	**0.06 ***	−**0.35 ****	**0.33 ****	**0.33 ****	−**0.23 ****	−**0.41 ****	1.00	
11. Depression	−**0.16 ****	−**0.11 ****	−0.03	**0.08 ***	−**0.35 ****	**0.35 ****	**0.35 ****	−**0.24 ****	−**0.41 ****	**0.82 ****	1.00

Note: *, *p* < 0.05; **, *p* < 0.01. GE: green exercise.

3.4. Results of the SEM Analysis

In the final SEM model (M2), we did not find a significant direct pathway between perceived residential green space and depression (β = −0.05, *p* = 0.325) (Figure 3). The pathway between perceived pollution and green exercise frequency was not significant either (β = −0.03, *p* = 0.440). All other pathways between the core variables were significant. The direct pathway between perceived residential green space and anxiety was significant but relatively weak (β = −0.09, *p* = 0.037).
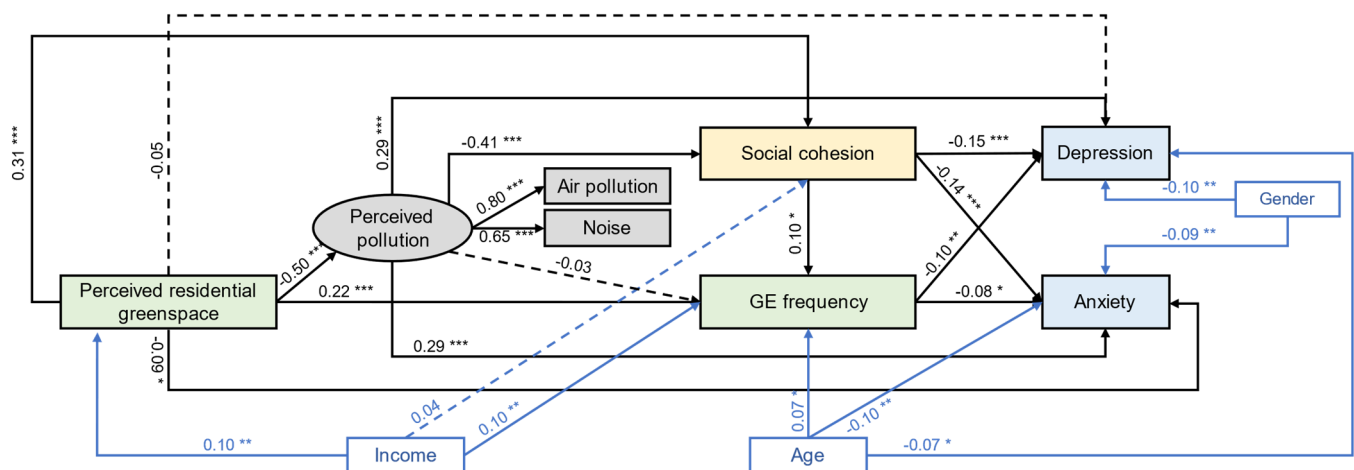
Model fit: SRMR = 0.04; CFI = 0.96; TLI = 0.90; RMSEA = 0.04 (90%CI: 0.03, 0.06); AIC = 122.08; BIC = 307.30

Figure 3. Final structural equation model (M2) with standardized regression weights (β) and significance levels (*n* = 967). **Note:** GE, green exercise. *, *p* < 0.05; **, *p* < 0.01; ***, *p* < 0.001.

Perceived residential green space had significant total effects on all variables of interest (Table 3). The total effects on social cohesion and green exercise frequency were mainly from direct effects, while those on depression and anxiety were mainly from indirect effects.

Table 3. Standardized total, direct, and indirect effects of perceived residential green space on the core variables.

Variable	Total β (95% CI)	*p*	Direct β (95% CI)	*p*	Indirect β (95% CI)	*p*
Perceived pollution	−0.50(−0.57, −0.42)	<0.001	−0.50 (−0.57, −0.42)	<0.001	—	—
Social cohesion	0.50 (0.44, 0.56)	0.001	0.30 (0.21, 0.38)	<0.001	0.20 (0.15, 0.27)	<0.001
Green exercise	0.29 (0.23, 0.34)	<0.001	0.22 (0.15, 0.30)	<0.001	0.07 (0.02, 0.12)	0.007
Depression	−0.30 (−0.37, −0.22)	0.001	−0.05 (−0.14, 0.05)	0.325	−0.25 (−0.31, −0.19)	<0.001
Anxiety	−0.33 (−0.39, −0.26)	<0.001	−0.09 (−0.18, −0.01)	0.037	−0.24 (−0.30, −0.18)	<0.001

The specific indirect pathways from perceived residential green space to mental health are shown in Table 4. Pathways mediated by perceived pollution had major contributions to the total effects (Pathways 1 and 7 in Table 4). Pathways mediated by social cohesion were relatively weaker but still made considerable contributions to the total effects (Pathways 3 and 9 in Table 4).

Table 4. Standardized indirect pathways from perceived residential green space to mental health.

Pathway	β (95% CI)	p
1. Residential green space → Pollution → Anxiety	−0.14 (−0.21, −0.08)	<0.001
2. Residential green space → GE → Anxiety	−0.02 (−0.04, −0.003)	0.014
3. Residential green space → Cohesion → Anxiety	−0.04 (−0.08, −0.02)	0.001
4. Residential green space → Pollution → Cohesion → Anxiety	−0.03 (−0.05, −0.01)	0.001
5. Residential green space → Cohesion → GE → Anxiety	−0.003 (−0.01, 0.00)	0.021
6. Residential green space → Pollution → Cohesion → GE → Anxiety	−0.002 (−0.01, 0.00)	0.020
7. Residential green space → Pollution → Depression	−0.15 (−0.22, −0.08)	<0.001
8. Residential green space → GE → Depression	−0.02 (−0.04, −0.01)	0.002
9. Residential green space → Cohesion → Depression	−0.04 (−0.08, −0.02)	0.002
10. Residential green space → Pollution → Cohesion → Depression	−0.03 (−0.05, −0.01)	0.001
11. Residential green space → Cohesion→ GE → Depression	−0.003 (−0.01, 0.00)	0.013
12. Residential green space → Pollution → Cohesion → GE → Depression	−0.002 (−0.01, 0.00)	0.012

Note: Residential green space, perceived residential green space; Pollution, perceived pollution; GE, green exercise; Cohesion, social cohesion.

3.5. Sensitivity Analyses

Identified keywords remained unchanged in the alternative NPL engine.

Regarding structural equation modeling, Acceptable model fits were obtained through the ML and GLS estimations (Table S1). Similar results were obtained for most pathways, except for the direct pathway between residential green space and anxiety, which was not significant in the ML (β = −0.07, $p > 0.10$) and GLS estimations (β = −0.07, $p > 0.10$).

The two competing models, Model M2 (where GE predicts social cohesion) and Model M3 (where a reciprocal relationship was tested between GE and social cohesion), showed acceptable fits (Figure S1 and Table S1). However, our final model (M1) retained the lowest AIC and BIC values, indicating a better fit than these alternative models.

In models stratified by gender, we found that both the unconstrained baseline model and model with constrained structural weights showed acceptable fits to the data, and no significant difference was found between the two models ($\Delta\chi^2$ = 10.53, p = 0.84). Likewise, no significant differences were observed in the subgroup analysis stratified by the median age ($\Delta\chi^2$ = 11.16, p = 0.89), indicating the final model M2 is suitable for these subgroups.

4. Discussion

The current study aimed to explore how residential green space was used and how it could benefit mental health during the COVID-19 pandemic. The results suggest that residential green space may be the main urban green space where young and middle-aged Chinese carry out green exercise. Further, residential green space was negatively associated with depression and anxiety through direct and/or indirect pathways. These findings underline the role of residential green space in promoting urban mental health during the COVID-19 pandemic.

4.1. Findings on Green Space Utilization

We found around 80% of green space users usually performed green exercise in residential green spaces. In Italy, most urban residents switched from urban parks to gardens or other residential green spaces during the pandemic due to social distancing and other regulations or restrictions on movement [12]. So far, there is little understanding of changes in green space use in China. What is known is that the demand for public green spaces has remained large throughout the pandemic [107]. Due to active restrictions on

social activities, urban residents in China may gradually have relied more on residential green spaces.

Aside from the pandemic, other reasons may explain the popularity of residential green space in our study. Before the pandemic, children in Shanghai, China, primarily carried out physical activity in residential green space [108]. Residential green spaces provide shorter travel distances than more distant public green spaces. Many studies have proved that distance is a crucial factor negatively associated with the frequency of green space visits [109,110], and the case of China appears not to be an exception.

Regarding the reasons for performing exercise in green space, better air and environmental conditions were mentioned as a rationale for both residential and other green space exercisers. This result partially supports our first hypothesis and is similar to previous studies in some Western countries, where better environmental conditions are critical reasons for visiting green space [9,10]. These findings imply that the key reasons for visiting green spaces remained unchanged during the pandemic, which underlines the role of urban green space in offering cleaner environments for residents' activities [22].

Several theories may help explain why green spaces are perceived as better/healthier environments. Green space can reduce air pollution and noise from traffic [22] by depositing air pollutants (e.g., PM10 and ozone) [111] and diffracting, absorbing, or destructing interference of sound waves [112]. These mechanisms can also apply to residential green space, making the neighborhood more suitable for physical activity. Unfortunately, residential green space is not a focus in some Chinese urban greening projects [113]. Chinese policymakers may need to prioritize residential green space construction and consider improving facilities for green exercise in neighborhoods to help fight against the mental health impacts of the COVID-19 pandemic. Moreover, since lower disturbance was the crucial reason mentioned for green exercise, using proper plant species and schemes may be a key point in residential greening. Some approaches in Chinese urban park planning can be applied to residential green space. For example, planting at least two types of small trees and shrubs in lines can enhance the aesthetic value and effectively absorb noise [114]. Recommended species include *Camellia sp.*, *Callistemon rigidus R. Br.*, and *Gordonia axillaris (Roxb. ex Ker Gawl.) D. Dietr.* These species are common shrubs or small trees in China and are usually planted for ornamental purposes. Moreover, they have been proved to have great potential in decontaminating air pollutants containing nitrogen, sulfur, and fluorine [115–117].

4.2. Findings on Pathways between Green Space and Mental Health

We did not observe a significant direct pathway between perceived residential green space and depression. When tested with different estimators, the direct association between perceived residential green space and anxiety was weak or non-significant. Nevertheless, multiple indirect pathways were identified, and perceived pollution of green space and social cohesion were the two critical mediators linking perceived residential green space and mental health issues. These results do not fully support our second hypothesis but are in line with previous analyses that perceived residential green space indirectly reduced mental health problems through enhancing social cohesion [51]. Therefore, these findings may collectively underline the mediatory role of social cohesion between residential green space and mental health.

In a previous framework by Liu et al. [52], walking behavior, social cohesion, and perceived pollution were mediators between neighborhood greenness and mental wellbeing, which is consistent with our final model. However, the previous study investigated the perceived pollution of residential neighborhoods. In contrast, we investigated the perceived pollution of green space due to our focus on green exercise. The pollution level in residential green space may also indicate the general pollution of residential neighborhoods because residential green space is part of the neighborhood and a reason for reduced pollution [22,49]. Therefore, our study may still support the framework by Liu et al. [52]

and underline a general mechanism of harvesting mental health benefits from residential green space.

Regarding relationships between the mediators, we did not observe a significant direct pathway between perceived pollution and green exercise. However, we observed a significant mediation effect between them through social cohesion. Multiple factors may explain this finding. Lower levels of urban pollutants have been associated with green space and may promote residents to be in contact with their neighbors more frequently, thus enhancing social cohesion [118]. Enhanced social cohesion may promote the adoption of healthy behaviors and utilization of community resources [70,119]. Last, a socially cohesive neighborhood may reduce conditions, such as crime and civil disorder, providing safer places for physical activity [84,120].

During the COVID-19 pandemic, various restrictions have limited people's basic human need for social interaction [121]. In this context, neighbors' interactions may have become essential because support from friends or family has been reduced for many people due to social blockades/lockdowns [122]. It is assumed that interactions among neighbors during the pandemic enhanced the sense of neighborhood cohesion among Chinese residents [123]. As discussed above, residential green space may enhance social cohesion by encouraging neighborly interactions. The pathway between residential green space and social cohesion is likely more apparent during the pandemic, making their subsequent mental health benefits more obvious. Svensson and Elntib [31] suggested that allowing community members access to green space and sensibly meeting others may help mediate the harmful effects of anxiety and stress. Based on our findings, residential green space can be an option for promoting mental health through encouraging physical activity and social interaction.

4.3. Limitations and Future Directions

This study has several limitations. The research topic was described during recruiting participants. It is possible that people who benefited from or cared about urban green spaces have responded disproportionately. This may have caused us to overestimate the connections between green spaces and mental health.

The age structure of our respondents was inconsistent with that of the general population of China. The China Bureau of Statistics has disclosed that the population over 60 years old accounted for 18.70% of the total pollution as of 2021. By contrast, only around 0.2% of our participants were in this age group. Further studies may hire professional marketing teams to recruit greater shares of older people. Offline recruitment in middle-aged and elderly communities may be helpful because many aged Chinese use less Internet than the younger generations.

We only used self-reported measures due to our limited experimental conditions, so reporting bias must have existed. Some variables, such as residential neighborhood, can be re-investigated with objective measures, such as land use/land cover (LULC), which can reflect plantation coverage and other urban properties. Using machine learning to capture data from street view maps may also be a promising method to measure exposure to green spaces [124].

Although we compared different causal relationships in sensitivity analyses, the cross-sectional feature of the data cannot verify the direction of causalities. This is an inherent limitation with using such data. To re-examine the causality in each path, longitudinal trials are warranted. For example, tracking changes in pollution, social cohesion, and green exercise in a community with constructing residential green spaces would serve this purpose.

5. Conclusions

This study aimed to investigate how the Chinese performed green exercise in urban green spaces and to propose a framework to understand associations between residential green space and mental health through green exercise, perceived pollution, and social

cohesion during the COVID-19 era. To achieve this goal, we checked how many survey respondents preferred to carry out green exercise in their residential neighborhood and obtained keywords from their reasons for choosing residential green space. Meanwhile, we carried out structural equation modeling to explore potential pathways among these residential green space "exercisers" with our cross-sectional data.

Our findings suggest residential green space may be the most popular green space for green exercise during the pandemic among young and middle-aged Chinese. Moreover, residential green space was negatively associated with anxiety and depression, mainly through mediators, including social interaction, less perceived pollution, and green exercise. These findings reinforce other research showing that residential green space is a health resource for urban residents during the COVID-19 era.

Based on our findings, we call for a focus on residential greening in China to meet the demand of its residents in the COVID-19 era. Although causal relationships between studied variables could not be confirmed due to the nature of our cross-sectional data, our survey and model indicate that better environmental qualities, including less noise and air pollution, can support mental health. Future urban planning should utilize existing plant-based strategies (e.g., plant purification or phytoremediation) to protect residential environments and physical activity experiences. Recognizing the limitations of our study, we also call for future research to examine and extend our tentative theoretical conclusions in larger populations using longitudinal study designs.

References

1. Trøstrup, C.H.; Christiansen, A.B.; Stølen, K.S.; Nielsen, P.K.; Stelter, R. The effect of nature exposure on the mental health of patients: A systematic review. *Qual. Life Res.* **2019**, *28*, 1695–1703. [CrossRef] [PubMed]
2. Stanhope, J.; Breed, M.F.; Weinstein, P. Exposure to greenspaces could reduce the high global burden of pain. *Environ. Res.* **2020**, *187*, 109641. [CrossRef] [PubMed]
3. Li, H.; Zhang, X.; Wang, H.; Yang, Z.; Liu, H.; Cao, Y.; Zhang, G. Access to Nature via Virtual Reality: A Mini-Review. *Front. Psychol.* **2021**, *12*, 725288. [CrossRef] [PubMed]
4. Grant, M.; Brown, C.; Caiaffa, W.T.; Capon, A.; Corburn, J.; Coutts, C.; Crespo, C.J.; Ellis, G.; Ferguson, G.; Fudge, C. Cities and health: An evolving global conversation. *Cities Health* **2017**, *1*, 1–9. [CrossRef]
5. Turner, W.R.; Nakamura, T.; Dinetti, M. Global urbanization and the separation of humans from nature. *Bioscience* **2004**, *54*, 585–590. [CrossRef]
6. Moore, M.; Gould, P.; Keary, B.S. Global urbanization and impact on health. *Int. J. Hyg. Environ. Health* **2003**, *206*, 269–278. [CrossRef]
7. Coutts, C.; Horner, M.; Chapin, T. Using geographical information system to model the effects of green space accessibility on mortality in Florida. *Geocarto Int.* **2010**, *25*, 471–484. [CrossRef]
8. Heidt, V.; Neef, M. Benefits of urban green space for improving urban climate. In *Ecology, Planning, and Management of Urban Forests*; Springer: Berlin/Heidelberg, Germany, 2008; pp. 84–96.
9. Schipperijn, J.; Ekholm, O.; Stigsdotter, U.K.; Toftager, M.; Bentsen, P.; Kamper-Jørgensen, F.; Randrup, T.B. Factors influencing the use of green space: Results from a Danish national representative survey. *Landsc. Urban Plan.* **2010**, *95*, 130–137. [CrossRef]

10. Fongar, C.; Aamodt, G.; Randrup, T.B.; Solfjeld, I. Does Perceived Green Space Quality Matter? Linking Norwegian Adult Perspectives on Perceived Quality to Motivation and Frequency of Visits. *Int. J. Environ. Res. Public Health* **2019**, *16*, 2327. [CrossRef]

11. Ugolini, F.; Massetti, L.; Calaza-Martínez, P.; Cariñanos, P.; Dobbs, C.; Ostoić, S.K.; Marin, A.M.; Pearlmutter, D.; Saaroni, H.; Šaulienė, I.; et al. Effects of the COVID-19 pandemic on the use and perceptions of urban green space: An international exploratory study. *Urban For. Urban Green.* **2020**, *56*, 126888. [CrossRef]

12. Ugolini, F.; Massetti, L.; Pearlmutter, D.; Sanesi, G. Usage of urban green space and related feelings of deprivation during the COVID-19 lockdown: Lessons learned from an Italian case study. *Land Use Policy* **2021**, *105*, 105437. [CrossRef]

13. Müller, O.; Lu, G.; Jahn, A.; Razum, O. COVID-19 Control: Can Germany Learn From China? *Int. J. Health Policy Manag.* **2020**, *9*, 432–435. [CrossRef]

14. Gan, Y.; Ma, J.; Wu, J.; Chen, Y.; Zhu, H.; Hall, B.J. Immediate and delayed psychological effects of province-wide lockdown and personal quarantine during the COVID-19 outbreak in China. *Psychol. Med.* **2020**, *52*, 1321–1332. [CrossRef]

15. CDC of Henan, China The List of High-Risk Areas in the National Epidemic Has Increased to 571. Available online: https://tanghe.gov.cn/thyw/61528.html (accessed on 22 March 2022).

16. Slater, S.J.; Christiana, R.W.; Gustat, J. Recommendations for Keeping Parks and Green Space Accessible for Mental and Physical Health During COVID-19 and Other Pandemics. *Prev. Chronic Dis.* **2020**, *17*, E59. [CrossRef]

17. Pouso, S.; Borja, Á.; Fleming, L.E.; Gómez-Baggethun, E.; White, M.P.; Uyarra, M.C. Contact with blue-green spaces during the COVID-19 pandemic lockdown beneficial for mental health. *Sci. Total Environ.* **2021**, *756*, 143984. [CrossRef]

18. Astell-Burt, T.; Feng, X. Time for 'Green' during COVID-19? Inequities in Green and Blue Space Access, Visitation and Felt Benefits. *Int. J. Environ. Res. Public Health* **2021**, *18*, 2757. [CrossRef]

19. Lanza-León, P.; Pascual-Sáez, M.; Cantarero-Prieto, D. Alleviating mental health disorders through doses of green spaces: An updated review in times of the COVID-19 pandemic. *Int. J. Environ. Health Res.* **2021**, 1–18. [CrossRef]

20. Dzhambov, A.M.; Hartig, T.; Tilov, B.; Atanasova, V.; Makakova, D.R.; Dimitrova, D.D. Residential greenspace is associated with mental health via intertwined capacity-building and capacity-restoring pathways. *Environ. Res.* **2019**, *178*, 108708. [CrossRef]

21. Beyer, K.M.; Kaltenbach, A.; Szabo, A.; Bogar, S.; Nieto, F.J.; Malecki, K.M. Exposure to neighborhood green space and mental health: Evidence from the survey of the health of Wisconsin. *Int. J. Environ. Res. Public Health* **2014**, *11*, 3453–3472. [CrossRef]

22. Markevych, I.; Schoierer, J.; Hartig, T.; Chudnovsky, A.; Hystad, P.; Dzhambov, A.M.; De Vries, S.; Triguero-Mas, M.; Brauer, M.; Nieuwenhuijsen, M.J. Exploring pathways linking greenspace to health: Theoretical and methodological guidance. *Environ. Res.* **2017**, *158*, 301–317. [CrossRef]

23. Nutsford, D.; Pearson, A.L.; Kingham, S. An ecological study investigating the association between access to urban green space and mental health. *Public Health* **2013**, *127*, 1005–1011. [CrossRef]

24. Cohen-Cline, H.; Turkheimer, E.; Duncan, G.E. Access to green space, physical activity and mental health: A twin study. *J. Epidemiol. Community Health* **2015**, *69*, 523. [CrossRef]

25. Chan, J.; To, H.-P.; Chan, E. Reconsidering social cohesion: Developing a definition and analytical framework for empirical research. *Soc. Indic. Res.* **2006**, *75*, 273–302. [CrossRef]

26. Comstock, N.; Dickinson, L.M.; Marshall, J.A.; Soobader, M.-J.; Turbin, M.S.; Buchenau, M.; Litt, J.S. Neighborhood attachment and its correlates: Exploring neighborhood conditions, collective efficacy, and gardening. *J. Environ. Psychol.* **2010**, *30*, 435–442. [CrossRef]

27. Jennings, V. Social Cohesion and City Green Space: Revisiting the Power of Volunteering. *Challenges* **2019**, *10*, 36. [CrossRef]

28. Kingsbury, M.; Clayborne, Z.; Colman, I.; Kirkbride, J.B. The protective effect of neighbourhood social cohesion on adolescent mental health following stressful life events. *Psychol. Med.* **2020**, *50*, 1292–1299. [CrossRef]

29. Fone, D.; White, J.; Farewell, D.; Kelly, M.; John, G.; Lloyd, K.; Williams, G.; Dunstan, F. Effect of neighbourhood deprivation and social cohesion on mental health inequality: A multilevel population-based longitudinal study. *Psychol. Med.* **2014**, *44*, 2449–2460. [CrossRef]

30. Robinette, J.W.; Bostean, G.; Glynn, L.M.; Douglas, J.A.; Jenkins, B.N.; Gruenewald, T.L.; Frederick, D.A. Perceived neighborhood cohesion buffers COVID-19 impacts on mental health in a United States sample. *Soc. Sci. Med.* **2021**, *285*, 114269. [CrossRef]

31. Svensson, S.J.; Elntib, S. Community cohesion during the first peak of the COVID-19 pandemic: A social antidote to health anxiety and stress. *J. Appl. Soc. Psychol.* **2021**, *51*, 793–808. [CrossRef]

32. Peters, K.; Elands, B.; Buijs, A. Social interactions in urban parks: Stimulating social cohesion? *Urban For. Urban Green.* **2010**, *9*, 93–100. [CrossRef]

33. Jennings, V.; Bamkole, O. The relationship between social cohesion and urban green space: An avenue for health promotion. *Int. J. Environ. Res. Public Health* **2019**, *16*, 452. [CrossRef] [PubMed]

34. Van den Berg, M.M.; van Poppel, M.; van Kamp, I.; Ruijsbroek, A.; Triguero-Mas, M.; Gidlow, C.; Nieuwenhuijsen, M.J.; Gražulevičiene, R.; van Mechelen, W.; Kruize, H. Do physical activity, social cohesion, and loneliness mediate the association between time spent visiting green space and mental health? *Environ. Behav.* **2019**, *51*, 144–166. [CrossRef] [PubMed]

35. Sugiyama, T.; Leslie, E.; Giles-Corti, B.; Owen, N. Associations of neighbourhood greenness with physical and mental health: Do walking, social coherence and local social interaction explain the relationships? *J. Epidemiol. Community Health* **2008**, *62*, e9. [CrossRef] [PubMed]

36. Zhang, R.; Zhang, C.-Q.; Rhodes, R.E. The pathways linking objectively-measured greenspace exposure and mental health: A systematic review of observational studies. *Environ. Res.* **2021**, *198*, 111233. [CrossRef]

37. Ventriglio, A.; Bellomo, A.; di Gioia, I.; Di Sabatino, D.; Favale, D.; De Berardis, D.; Cianconi, P. Environmental pollution and mental health: A narrative review of literature. *CNS Spectr.* **2021**, *26*, 51–61. [CrossRef]

38. Peng, M.; Zhang, H.; Evans, R.D.; Zhong, X.; Yang, K. Actual Air Pollution, Environmental Transparency, and the Perception of Air Pollution in China. *J. Environ. Dev.* **2019**, *28*, 78–105. [CrossRef]

39. Baranzini, A.; Schaerer, C.; Thalmann, P. Using measured instead of perceived noise in hedonic models. *Transp. Res. Part D Transp. Environ.* **2010**, *15*, 473–482. [CrossRef]

40. Xu, X.; Reed, M. Perceived pollution and inbound tourism for Shanghai: A panel VAR approach. *Curr. Issues Tour.* **2019**, *22*, 601–614. [CrossRef]

41. Kou, L.; Tao, Y.; Kwan, M.-P.; Chai, Y. Understanding the relationships among individual-based momentary measured noise, perceived noise, and psychological stress: A geographic ecological momentary assessment (GEMA) approach. *Health Place* **2020**, *64*, 102285. [CrossRef]

42. Rotko, T.; Oglesby, L.; Künzli, N.; Carrer, P.; Nieuwenhuijsen, M.J.; Jantunen, M. Determinants of perceived air pollution annoyance and association between annoyance scores and air pollution ($PM_{2.5}$, NO_2) concentrations in the European EXPOLIS study. *Atmos. Environ.* **2002**, *36*, 4593–4602. [CrossRef]

43. Selmi, W.; Weber, C.; Rivière, E.; Blond, N.; Mehdi, L.; Nowak, D. Air pollution removal by trees in public green spaces in Strasbourg city, France. *Urban For. Urban Green.* **2016**, *17*, 192–201. [CrossRef]

44. Fan, Y.; Zhiyi, B.; Zhujun, Z.; Jiani, L. The investigation of noise attenuation by plants and the corresponding noise-reducing spectrum. *J. Environ. Health* **2010**, *72*, 8–15.

45. Dzhambov, A.M.; Dimitrova, D.D. Green spaces and environmental noise perception. *Urban For. Urban Green.* **2015**, *14*, 1000–1008. [CrossRef]

46. Zapf, V. Influence of green space design on individual noise perception. In Proceedings of the INTER-NOISE and NOISE-CON Congress and Conference Proceedings, Washington, DC, USA, 1 August 2021; pp. 3130–3142.

47. Cetin, C.; Karafakı, F. The influence of green areas on city-dwellers' perceptions of air pollution: The case of Nigde city center. *J. Environ. Biol.* **2020**, *41*, 453–461. [CrossRef]

48. Margaritis, E.; Kang, J. Relationship between green space-related morphology and noise pollution. *Ecol. Indic.* **2017**, *72*, 921–933. [CrossRef]

49. Liu, H.-L.; Shen, Y.-S. The impact of green space changes on air pollution and microclimates: A case study of the Taipei metropolitan area. *Sustainability* **2014**, *6*, 8827–8855. [CrossRef]

50. Dzhambov, A.; Hartig, T.; Markevych, I.; Tilov, B.; Dimitrova, D. Urban residential greenspace and mental health in youth: Different approaches to testing multiple pathways yield different conclusions. *Environ. Res.* **2018**, *160*, 47–59. [CrossRef]

51. Yang, M.; Dijst, M.; Faber, J.; Helbich, M. Using structural equation modeling to examine pathways between perceived residential green space and mental health among internal migrants in China. *Environ. Res.* **2020**, *183*, 109121. [CrossRef]

52. Liu, Y.; Wang, R.; Grekousis, G.; Liu, Y.; Yuan, Y.; Li, Z. Neighbourhood greenness and mental wellbeing in Guangzhou, China: What are the pathways? *Landsc. Urban Plan.* **2019**, *190*, 103602. [CrossRef]

53. Rogerson, M.; Brown, D.K.; Sandercock, G.; Wooller, J.-J.; Barton, J. A comparison of four typical green exercise environments and prediction of psychological health outcomes. *Perspect. Public Health* **2016**, *136*, 171–180. [CrossRef]

54. Lee, J.-Y.; Lee, D.-C. Cardiac and pulmonary benefits of forest walking versus city walking in elderly women: A randomised, controlled, open-label trial. *Eur. J. Integr. Med.* **2014**, *6*, 5–11. [CrossRef]

55. Elsadek, M.; Liu, B.; Lian, Z.; Xie, J. The influence of urban roadside trees and their physical environment on stress relief measures: A field experiment in Shanghai. *Urban For. Urban Green.* **2019**, *42*, 51–60. [CrossRef]

56. Astell-Burt, T.; Feng, X.; Kolt, G.S. Green space is associated with walking and moderate-to-vigorous physical activity (MVPA) in middle-to-older-aged adults: Findings from 203,883 Australians in the 45 and Up Study. *Br. J. Sports Med.* **2014**, *48*, 404–406. [CrossRef]

57. McEachan, R.R.C.; Prady, S.L.; Smith, G.; Fairley, L.; Cabieses, B.; Gidlow, C.; Wright, J.; Dadvand, P.; van Gent, D.; Nieuwenhuijsen, M.J. The association between green space and depressive symptoms in pregnant women: Moderating roles of socioeconomic status and physical activity. *J. Epidemiol. Community Health* **2016**, *70*, 253. [CrossRef]

58. Holt, E.W.; Lombard, Q.K.; Best, N.; Smiley-Smith, S.; Quinn, J.E. Active and Passive Use of Green Space, Health, and Well-Being amongst University Students. *Int. J. Environ. Res. Public Health* **2019**, *16*, 424. [CrossRef]

59. Sugiyama, T.; Giles-Corti, B.; Summers, J.; du Toit, L.; Leslie, E.; Owen, N. Initiating and maintaining recreational walking: A longitudinal study on the influence of neighborhood green space. *Prev. Med.* **2013**, *57*, 178–182. [CrossRef]

60. Bloemsma, L.D.; Gehring, U.; Klompmaker, J.O.; Hoek, G.; Janssen, N.A.; Smit, H.A.; Vonk, J.M.; Brunekreef, B.; Lebret, E.; Wijga, A.H. Green space visits among adolescents: Frequency and predictors in the PIAMA birth cohort study. *Environ. Health Perspect.* **2018**, *126*, 047016. [CrossRef]

61. Hug, S.-M.; Hartig, T.; Hansmann, R.; Seeland, K.; Hornung, R. Restorative qualities of indoor and outdoor exercise settings as predictors of exercise frequency. *Health Place* **2009**, *15*, 971–980. [CrossRef]

62. Tan, C.L.Y.; Chang, C.-C.; Nghiem, L.T.P.; Zhang, Y.; Oh, R.R.Y.; Shanahan, D.F.; Lin, B.B.; Gaston, K.J.; Fuller, R.A.; Carrasco, L.R. The right mix: Residential urban green-blue space combinations are correlated with physical exercise in a tropical city-state. *Urban For. Urban Green.* **2021**, *57*, 126947. [CrossRef]

63. Akpınar, A. Green Exercise: How Are Characteristics of Urban Green Spaces Associated with Adolescents' Physical Activity and Health? *Int. J. Environ. Res. Public Health* **2019**, *16*, 4281. [CrossRef]

64. Gozalo, G.R.; Morillas, J.M.B.; González, D.M.; Moraga, P.A. Relationships among satisfaction, noise perception, and use of urban green spaces. *Sci. Total Environ.* **2018**, *624*, 438–450. [CrossRef] [PubMed]

65. Dzhambov, A.; Tilov, B.; Markevych, I.; Dimitrova, D. Residential road traffic noise and general mental health in youth: The role of noise annoyance, neighborhood restorative quality, physical activity, and social cohesion as potential mediators. *Environ. Int.* **2017**, *109*, 1–9. [CrossRef] [PubMed]

66. Lü, J.; Liang, L.; Feng, Y.; Li, R.; Liu, Y. Air Pollution Exposure and Physical Activity in China: Current Knowledge, Public Health Implications, and Future Research Needs. *Int. J. Environ. Res. Public Health* **2015**, *12*, 14887–14897. [CrossRef] [PubMed]

67. Foraster, M.; Eze, I.C.; Vienneau, D.; Brink, M.; Cajochen, C.; Caviezel, S.; Héritier, H.; Schaffner, E.; Schindler, C.; Wanner, M.; et al. Long-term transportation noise annoyance is associated with subsequent lower levels of physical activity. *Environ. Int.* **2016**, *91*, 341–349. [CrossRef]

68. Subiza-Pérez, M.; García-Baquero, G.; Babarro, I.; Anabitarte, A.; Delclòs-Alió, X.; Vich, G.; Roig-Costa, O.; Miralles-Guasch, C.; Lertxundi, N.; Ibarluzea, J. Does the perceived neighborhood environment promote mental health during pregnancy? Confirmation of a pathway through social cohesion in two Spanish samples. *Environ. Res.* **2021**, *197*, 111192. [CrossRef]

69. Kim, J.; Kim, J.; Han, A. Leisure Time Physical Activity Mediates the Relationship Between Neighborhood Social Cohesion and Mental Health Among Older Adults. *J. Appl. Gerontol.* **2019**, *39*, 292–300. [CrossRef]

70. Cradock, A.L.; Kawachi, I.; Colditz, G.A.; Gortmaker, S.L.; Buka, S.L. Neighborhood social cohesion and youth participation in physical activity in Chicago. *Soc. Sci. Med.* **2009**, *68*, 427–435. [CrossRef]

71. Dzhambov, A.M.; Lercher, P.; Browning, M.; Stoyanov, D.; Petrova, N.; Novakov, S.; Dimitrova, D.D. Does greenery experienced indoors and outdoors provide an escape and support mental health during the COVID-19 quarantine? *Environ. Res.* **2021**, *196*, 110420. [CrossRef]

72. Afifi, M. Gender differences in mental health. *Singap. Med. J.* **2007**, *48*, 385.

73. Mirowsky, J.; Ross, C.E. Age and depression. *J. Health Soc. Behav.* **1992**, *33*, 187–205. [CrossRef]

74. Bolte, G.; Nanninga, S.; Dandolo, L. Sex/Gender Differences in the Association between Residential Green Space and Self-Rated Health—A Sex/Gender-Focused Systematic Review. *Int. J. Environ. Res. Public Health* **2019**, *16*, 4818. [CrossRef]

75. Chang, C.-c.; Oh, R.R.Y.; Le Nghiem, T.P.; Zhang, Y.; Tan, C.L.; Lin, B.B.; Gaston, K.J.; Fuller, R.A.; Carrasco, L.R. Life satisfaction linked to the diversity of nature experiences and nature views from the window. *Landsc. Urban Plan.* **2020**, *202*, 103874. [CrossRef]

76. Shuval, K.; Li, Q.; Gabriel, K.P.; Tchernis, R. Income, physical activity, sedentary behavior, and the 'weekend warrior' among U.S. adults. *Prev. Med.* **2017**, *103*, 91–97. [CrossRef]

77. Delhey, J.; Dragolov, G. Happier together. Social cohesion and subjective well-being in Europe. *Int. J. Psychol.* **2016**, *51*, 163–176. [CrossRef]

78. Zimmerman, F.J.; Katon, W. Socioeconomic status, depression disparities, and financial strain: What lies behind the income-depression relationship? *Health Econ.* **2005**, *14*, 1197–1215. [CrossRef]

79. Rigolon, A.; Browning, M.H.; McAnirlin, O.; Yoon, H.V. Green space and health equity: A systematic review on the potential of green space to reduce health disparities. *Int. J. Environ. Res. Public Health* **2021**, *18*, 2563. [CrossRef]

80. Pfefferbaum, B.; North, C.S. Mental health and the COVID-19 pandemic. *N. Engl. J. Med.* **2020**, *383*, 510–512. [CrossRef]

81. Borkowska, M.; Laurence, J. Coming together or coming apart? Changes in social cohesion during the COVID-19 pandemic in England. *Eur. Soc.* **2021**, *23*, S618–S636. [CrossRef]

82. Erdönmez, C.; Atmiş, E. The impact of the COVID-19 pandemic on green space use in Turkey: Is closing green spaces for use a solution? *Urban For. Urban Green.* **2021**, *64*, 127295. [CrossRef]

83. Coleman, J. *Foundations of Social Theory*; Harvard University Press: Cambridge, UK, 1990.

84. Sampson, R.J.; Raudenbush, S.W.; Earls, F. Neighborhoods and violent crime: A multilevel study of collective efficacy. *Science* **1997**, *277*, 918–924. [CrossRef]

85. Gaither, C.J.; Aragón, A.; Madden, M.; Alford, S.; Wynn, A.; Emery, M. "Black folks do forage": Examining wild food gathering in Southeast Atlanta Communities. *Urban For. Urban Green.* **2020**, *56*, 126860. [CrossRef]

86. Raina, V.; Krishnamurthy, S. Natural language processing. In *Building an Effective Data Science Practice*; Springer: Berlin/Heidelberg, Germany, 2022; pp. 63–73.

87. Chopra, A.; Prashar, A.; Sain, C. Natural language processing. *Int. J. Technol. Enhanc. Emerg. Eng. Res.* **2013**, *1*, 131–134.

88. Bagozzi, R.P.; Yi, Y. Specification, evaluation, and interpretation of structural equation models. *J. Acad. Mark. Sci.* **2012**, *40*, 8–34. [CrossRef]

89. Rogerson, P.A. *Statistical Methods for Geography: A Student's Guide*; Sage: Newcastle, UK, 2019.

90. Byrne, B.M. *Structural Equation Modeling with Mplus: Basic Concepts, Applications, and Programming*; Routledge: London, UK, 2013.

91. Schermelleh-Engel, K.; Moosbrugger, H.; Müller, H. Evaluating the fit of structural equation models: Tests of significance and descriptive goodness-of-fit measures. *Methods Psychol. Res. Online* **2003**, *8*, 23–74.

92. Haukoos, J.S.; Lewis, R.J. Advanced statistics: Bootstrapping confidence intervals for statistics with "difficult" distributions. *Acad. Emerg. Med.* **2005**, *12*, 360–365. [CrossRef]
93. Kelley, K. The Effects of Nonnormal Distributions on Confidence Intervals Around the Standardized Mean Difference: Bootstrap and Parametric Confidence Intervals. *Educ. Psychol. Meas.* **2005**, *65*, 51–69. [CrossRef]
94. Brown, T.A. *Confirmatory Factor Analysis for Applied Research*; Guilford Publications: New York, NY, USA, 2015.
95. Hu, L.-T.; Bentler, P.M. Fit indices in covariance structure modeling: Sensitivity to underparameterized model misspecification. *Psychol. Methods* **1998**, *3*, 424. [CrossRef]
96. Curran, P.J.; West, S.G.; Finch, J.F. The robustness of test statistics to nonnormality and specification error in confirmatory factor analysis. *Psychol. Methods* **1996**, *1*, 16. [CrossRef]
97. Hu, L.-T.; Bentler, P.M.; Kano, Y. Can test statistics in covariance structure analysis be trusted? *Psychol. Bull.* **1992**, *112*, 351. [CrossRef]
98. West, S.G.; Finch, J.F.; Curran, P.J. Structural equation models with nonnormal variables: Problems and remedies. In *Structural Equation Modeling: Concepts, Issues, and Applications*; Hoyle, R.H., Ed.; Sage Publications, Inc.: New York, NY, USA, 1995; pp. 56–75.
99. Hayes, A.F. *Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-Based Approach*; Guilford Publications: New York, NY, USA, 2017.
100. Zhao, X.; Lynch, J.G., Jr.; Chen, Q. Reconsidering Baron and Kenny: Myths and truths about mediation analysis. *J. Consum. Res.* **2010**, *37*, 197–206. [CrossRef]
101. Burnham, K.P.; Anderson, D.R. Multimodel inference: Understanding AIC and BIC in model selection. *Sociol. Methods Res.* **2004**, *33*, 261–304. [CrossRef]
102. Elkaseh, A.M.; Wong, K.W.; Fung, C.C. Perceived ease of use and perceived usefulness of social media for e-learning in Libyan higher education: A structural equation modeling analysis. *Int. J. Inf. Educ. Technol.* **2016**, *6*, 192. [CrossRef]
103. Kim, N.E.; Han, S.S.; Yoo, K.H.; Yun, E.K. The impact of user's perceived ability on online health information acceptance. *Telemed. E-Health* **2012**, *18*, 703–708. [CrossRef] [PubMed]
104. Zhou, H.; Li, L. The impact of supply chain practices and quality management on firm performance: Evidence from China's small and medium manufacturing enterprises. *Int. J. Prod. Econ.* **2020**, *230*, 107816. [CrossRef]
105. Olsson, U.H.; Foss, T.; Troye, S.V.; Howell, R.D. The Performance of ML, GLS, and WLS Estimation in Structural Equation Modeling Under Conditions of Misspecification and Nonnormality. *Struct. Equ. Modeling A Multidiscip. J.* **2000**, *7*, 557–595. [CrossRef]
106. Shanahan, D.F.; Bush, R.; Gaston, K.J.; Lin, B.B.; Dean, J.; Barber, E.; Fuller, R.A. Health benefits from nature experiences depend on dose. *Sci. Rep.* **2016**, *6*, 28551. [CrossRef] [PubMed]
107. Zhu, J.; Xu, C. Sina microblog sentiment in Beijing city parks as measure of demand for urban green space during the COVID-19. *Urban For. Urban Green.* **2021**, *58*, 126913. [CrossRef]
108. Baoxin, Z.; Wei, Z. A study on the temporal and spatial characteristics of children's outdoor activities in big cities—A case study of Shanghai. *City Plan.* **2018**, *42*, 87–96. (In Chinese)
109. Ekkel, E.D.; de Vries, S. Nearby green space and human health: Evaluating accessibility metrics. *Landsc. Urban Plan.* **2017**, *157*, 214–220. [CrossRef]
110. Coombes, E.; Jones, A.P.; Hillsdon, M. The relationship of physical activity and overweight to objectively measured green space accessibility and use. *Soc. Sci. Med.* **2010**, *70*, 816–822. [CrossRef]
111. Kroeger, T.; Escobedo, F.J.; Hernandez, J.L.; Varela, S.; Delphin, S.; Fisher, J.R.; Waldron, J. Reforestation as a novel abatement and compliance measure for ground-level ozone. *Proc. Natl. Acad. Sci. USA* **2014**, *111*, E4204–E4213. [CrossRef]
112. Van Renterghem, T.; Forssén, J.; Attenborough, K.; Jean, P.; Defrance, J.; Hornikx, M.; Kang, J. Using natural means to reduce surface transport noise during propagation outdoors. *Appl. Acoust.* **2015**, *92*, 86–101. [CrossRef]
113. Xuejin, W.; Juxin, Z. Planning and construction of livable city green space. *Resour. Environ. Yangtze River Basin* **2011**, *20*, 5. (In Chinese)
114. Li, G.; Xiong, J.; Xu, M.; Dong, L. Comprehensive study on the noise reduction ability and the visual effect on the edge of green space of Beijing urban park. *J. Beijing For. Univ.* **2017**, *39*, 12. (In Chinese) [CrossRef]
115. Miao, Y.; Chen, Z.; Chen, Y.; Du, G. Resistance to and absorbency of gaseous for 38 young landscaping plants in Zhejiang Province. *J. Zhejiang For. Coll.* **2008**, *25*, 765–771. (In Chinese) [CrossRef]
116. Pan, W.; Zhang, W.; Zhang, F.; Liu, J.; Duan, J.; Chen, J. Decontamination ability of sulfur dioxide and nitrogen dioxide for 38 young landscaping plants in Guangzhou city. *Ecol. Environ. Sci.* **2012**, *21*, 7. [CrossRef]
117. Zhang, D.; Chu, G.; Yu, Q.; Liu, S.; Lu, Y.; Hu, X.; Xue, k.; Kong, G. Decontamination Ability of Garden Plants to Absorb Sulfur Dioxide and Fluoride. *J. Trop. Subtrop. Bot.* **2003**, *11*, 336–340. (In Chinese)
118. Maas, J.; van Dillen, S.M.E.; Verheij, R.A.; Groenewegen, P.P. Social contacts as a possible mechanism behind the relation between green space and health. *Health Place* **2009**, *15*, 586–595. [CrossRef]
119. Kawachi, I.; Kennedy, B.P.; Glass, R. Social capital and self-rated health: A contextual analysis. *Am. J. Public Health* **1999**, *89*, 1187–1193. [CrossRef]
120. Molnar, B.E.; Gortmaker, S.L.; Bull, F.C.; Buka, S.L. Unsafe to play? Neighborhood disorder and lack of safety predict reduced physical activity among urban children and adolescents. *Am. J. Health Promot.* **2004**, *18*, 378–386. [CrossRef]

121. Abel, T.; McQueen, D. *The COVID-19 Pandemic Calls for Spatial Distancing and Social Closeness: Not for Social Distancing!* Springer: Berlin/Heidelberg, Germany, 2020; Volume 65, p. 231.
122. Chen, X.; Zou, Y.; Gao, H. Role of neighborhood social support in stress coping and psychological wellbeing during the COVID-19 pandemic: Evidence from Hubei, China. *Health Place* **2021**, *69*, 102532. [CrossRef]
123. Feng, Z. New urban immigrants have a "home" only when they have neighbors. *Times Mail* **2020**, *7*, 22–24. (In Chinese)
124. Helbich, M.; Yao, Y.; Liu, Y.; Zhang, J.; Liu, P.; Wang, R. Using deep learning to examine street view green and blue spaces and their associations with geriatric depression in Beijing, China. *Environ. Int.* **2019**, *126*, 107–117. [CrossRef]