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ORIGINAL ARTICLE

A Canonical Correlation Analysis Study on the Association Between Neighborhood Green Space and Residents' Mental Health

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Abstract Based on survey data conducted in Guangzhou in 2021, this study employs canonical correlation analysis (CCA) to evaluate the relationship between neighborhood green space, residents' green space use behavior, and their mental health. The results show that compared with the objectively measured accessibility, residents' subjective perceived accessibility of neighborhood green space plays a greater role in promoting green space use behavior and mental health. Meanwhile, the plant diversity, safety, and the number of recreational facilities in a green space can promote the frequency of green space use, improve residents' mental health status and reduce their perceived stress. Although perceived accessibility is more related to green space use behavior than green space quality indicators, green space safety and recreational facilities have many more benefits on mental health than perceived accessibility. In addition, residents' green space use behavior, especially green space visit frequency, can promote mental health and reduce perceived stress.

Keywords Neighborhood green space · Accessibility · Quality · Mental health · Canonical correlation analysis

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Introduction

As informatization progresses and transforms modern lifestyles, people worldwide, especially in cities, are under increasing stress, and their mental health is facing severe challenges [1, 2]. Green space plays an essential role in urban sustainability and public health. Studies have substantiated the positive effect of green space on air quality, biodiversity, and reducing heat island effects [3–5]. The potential association between green space and mental health has recently become an important issue. Green space exposure positively impacts social interaction, enhances attachment to place, and restores attention [6–8], thereby improving positive changes in mood and relieving mental stress [9–11].

Neighborhood green space provides outdoor recreational spaces for residents' activities and social interaction in their daily lives. Green space in neighborhoods has been confirmed as a critical element for promoting residents' mental well-being [12]. However, with the acceleration of urbanization, increased residential densities are gradually depriving residents of access to green space and its mental health benefits [13]. Against the background of a high-density urban environment and its limited spatial resources, the increasing demand for high-quality green space near neighborhoods has also inspired extensive research on what characteristics of green space can more effectively improve mental health [14–16]. Studies have contributed to understanding the relationship between green space accessibility and residents' mental well-being, and have revealed

accessible green space is associated with better mental status and less stress [17–20]. However, less attention has been paid to the relationship between perceived and objectively measured green space accessibility and mental health. Proximity to green space is associated with the frequency and duration of green space exposure, which is associated with mental health [13, 21]. Green space quality, like biological diversity, safety, and cleanliness, has also been found to be related to residents' green space use behavior and mental health. In addition, the concepts of mental health and stress are composed of multiple dimensions [22, 23]. However, it is unclear in existing studies what the relationship is between green space accessibility, green space quality, and particular dimensions of mental health or stress.

To address these issues above, this study employs canonical correlation analysis (CCA) to explore the association between the accessibility and quality of neighborhood green space and residents' mental health. Based on the above background, this paper, using 2021 questionnaire survey data from Guangzhou, China, investigates the following two questions: Firstly, are there differences in the effects of perceived and objective green space accessibility on residents' green space use behavior and mental health? Secondly, which green space quality indicators promote residents' green space visiting and mental health? The findings of this study will help to insightfully recognize the relationship between green space, green space use behavior, and public health and provide scientific guidance for optimizing the urban green space system and building green, livable, and healthy neighborhoods.

The remainder of the paper is organized as follows. The literature on green space accessibility, quality, use behavior, and mental health is briefly reviewed in the "Literature Review" section. The "Methodology" section introduces the study data and methods used in the analysis. The "Results" section presents the results of the CCA, while the "Discussion" section discusses the CCA estimation results. The "Conclusions" section summarizes the key findings.

Literature Review

Green Space Accessibility and Mental Health

Although many researchers have suggested a positive association between green space accessibility and mental health [24–27], mixed results were observed, especially the objective accessibility measured by green space proximity [12, 20, 28, 29]. For instance, according to Noordzij et al. [29], proximity to green space is associated with higher mental health levels. Yet, there was no evidence for relationships between green space accessibility and mental health in these samples during follow-up.

As highlighted by previous studies, the perceived accessibility of green space is not necessarily equal to the actual level [30]. Differences in transportation modes for green space visiting, travel ability, and familiarity with their neighborhood shape the diverse range of daily activities of residents in the same neighborhood. Research has pointed out the strength of perceived dimensions in measuring green space accessibility and the health effects of green space [13]. They emphasized the importance of perceived green space or vegetation affecting residents' health [31]. However, studies seldom compare the different effects of perceived and objective green space accessibility on residents' mental health.

The Quality of Green Space and Mental Health

Green space quality reflects the potential attractiveness of the green space to provide services to the surrounding residents. In addition to accessibility, the quality characteristics of green space have been proven to be key predictors of mental health [32]. Higher quality green space is associated with better social cohesion, perceived restorativeness, and mental health [33–36]. According to previous studies, green space quality generally includes surrounding architecture, activity facilities, amenities, aesthetics and attractiveness, safety, and biological diversity [37, 38]. Some studies have emphasized that the presence of specific facilities is associated with increased physical activity in children and adolescents [39, 40]. The green space aesthetic has been recognized as an essential aspect of improving public health and well-being [41, 42]. Uncivilized behavior and insecurity can lead to a rejection of green space and thus a reduction in use [43, 44]. Additionally, many studies have confirmed that green space naturalness and biodiversity positively impact the restoration potential and mental health benefits [14, 36, 45–48]. These studies explored the impact of one or several aspects of green space quality on residents' green space use behavior and

health or well-being. However, the concept of green space "quality" is composite and multidimensional [49, 50] and each of these dimensions may have a different impact on residents' green space use and mental health. Therefore, to guide green space planning and design more microcosmically, it is significant to comprehensively identify and compare the direction and strength of associations between multiple quality characteristics and residents' green space use behavior and mental health.

Green Space Use Behavior and Mental Health

Previous epidemiological studies have focused on the relationship between green space exposure and mental health, and in recent years, scholars have considered residents' actual green space use behavior [8]. Studies have constructed research frameworks that include green space characteristics, residents' green space use behavior, and mental health and found potential associations between them [13, 21, 51, 52]. It has been suggested that visiting green space helps to improve mental health by relaxing and calming people and relieving anxiety, tension, depression, and fatigue [53–56].

The frequency and duration of green space visiting are the most fundamental variables in relevant research on green space use behavior and public health [57]. Evidence has been revealed in previous studies that people who spend more time in green space tend to report higher scores on mental health [58, 59]. Frequent visits to green space are negatively associated with a mental disorder [60]. However, findings also vary on whether the frequency and duration of green space visiting contribute to mental health and its different aspects [33, 57, 61–63]. It is worth examining how and to what extent the frequency and duration of green space visits affect residents' mental health.

Methodology

Study Data

This study is based on survey data on green space and health in seven districts of Guangzhou, China. The formal survey was conducted from January 2021 to February 2021 after a pre-survey in December 2020 during which we revised and refined the questionnaire design based on the feedback. The respondents were permanent residents over 16 years old living in these districts. To ensure the randomness of the sample space and the balance of the socio-economic characteristics of the respondents, the survey was conducted by a combination of online and offline methods. A total of 1391 questionnaires were collected, of which 1265 were valid (effective rate 90.94%), distributed in 560 neighborhoods (Fig. 1). Table 1 presents the socio-economic characteristics of the sample population.

Measures of Residents' Mental Health and Perceived Stress

The Mental Health Inventory-5 (MHI-5) and Perceived Stress Scale-4 (PSS-4) items were used to measure residents' mental health status and perceived stress levels, respectively. The MHI-5, deriving from the MHI-38 [64], was developed to measure overall emotion [23]. It included five questions to report the frequency of symptoms during the previous month: how much of the time have you (1) "been a very nervous person?",

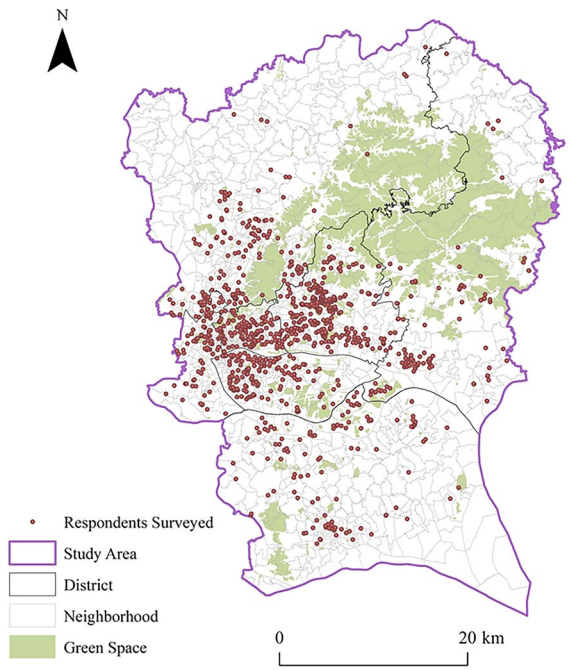


Fig. 1 Spatial distribution of survey respondents

Table 1 Socio-economic characteristics of the sample population

Variable	Level	*N*	Percent (%)
Gender	Male	561	44.35
	Female	704	55.65
Age	16–24	349	27.59
	25–34	498	39.37
	35–49	253	20.00
	50–64	125	9.88
	≥ 65	40	3.16
Any child under 16	No	803	63.48
	Yes	462	36.52
Education level	Junior middle school and below	121	9.57
	Senior high school	196	15.49
	Junior college	174	13.76
	Bachelor's degree	471	37.23
	Master's degree or above	303	23.95
Work status	Employed	844	66.72
	Unemployed	325	25.69
	Retired	96	7.59
Car ownership	No	610	48.22
	Yes	655	51.78
Household monthly income per capita	≤ 2999 RMB	113	8.93
	3000–3999 RMB	135	10.67
	4000–5999 RMB	265	20.95
	6000–7999 RMB	203	16.05
	8000–9999 RMB	139	10.99
	10,000–14,999 RMB	204	16.13
	≥ 15,000 RMB	206	16.28

(2) "felt so down in the dumps that nothing could cheer you up?", (3) "felt downhearted and blue?", (4) "felt calm and peaceful?", and (5) "been a happy person?". PSS-4 was used to assess psychological stress, including the following items: in the last month, how often have you (1) "felt that you were unable to control the important things in your life?", (2) "felt confident about your ability to handle your personal problems?", (3) "felt that things were going your way?", and (4) "felt difficulties were piling up so high that you could not overcome them?" [22]. The responses to MHI-5 and PSS-4 were made on a 5-point Likert scale, ranging from never to always/very often, which were scaled from 1 to 5. We conducted reliability tests on the results of the MHI-5 and PSS-4 (reverse-scoring the first three questions of MHI-5 and the first two questions of PSS-4 in reliability tests), and the Cronbach's α coefficients (0.843 and 0.712, respectively) showed adequate internal consistency.

Accessibility of Neighborhood Green Space

Objective accessibility and perceived accessibility of neighborhood green space were both explored. The green space data was obtained from OpenStreetMap 2020. The Neighborhood Green Accessibility Index (NGAI) was constructed based on the area and residents' travel distance to nearby green space within 20 min of walking from the residence. The NGAI is calculated as:

$$NGAI_i = \sum_j M_j D_{ij}^{-b} \quad (1)$$

where $NGAI_i$ is the neighborhood green accessibility index of sample i; M_j is the area of green space j that is within 20-min walking distance of this sample; D_{ij} is the actual walking travel distance from the residence of sample i to the edge of green space j; and b is the friction of distance, which describes as

the distance between the sample's residence and the green space increases, the possibility for the sample to access the green space decreases. The value of the friction of distance is usually 1 or 2. In this study, its value was set as 1.

We also considered the perceived accessibility of neighborhood green space to compare the impact of subjective and objective green space accessibility. Data on the perceived accessibility of neighborhood green space were obtained through the questionnaire (Table 2). The responses were made on a 5-point Likert scale, ranging from "very inconvenient" to "very convenient" on a scale from 1 to 5.

The Quality of the Green Space

Based on previous studies on green space quality related to residents' behavior or mental health, the vegetation diversity, animal diversity, cleanliness, safety, aesthetics, and recreation facilities of green space were used to characterize green space quality (Table 2) through a questionnaire survey. These indicators were evaluated and scored with a 5-point Likert scale. The higher the score, the higher the quality of the green space in this regard. For example, plant diversity was rated from 1 to 5 on a scale from "very homogeneous" to "very rich".

Green Space Use Behavior

The visit frequency and duration were two major dimensions to reflect residents' use behavior of neighborhood green space in this study, which were obtained by the survey through the following levels. The green space visit frequency: hardly ever or several times a year, once or twice a month, once a week, several times a week, and daily or almost daily, scored by 1 to 5, respectively. The green space visit duration: <15 min, 15–30 min, 0.5–1 h, 1–2 h, and >2 h, scored by 1 to 5, respectively.

Canonical Correlation Analysis

Canonical correlation analysis (CCA) is a statistical method to identify and measure the linear relationship between two datasets of multidimensional variables [65]. Although CCA has been widely used in social sciences, the method has been seldom applied to green space and health studies [55]. Based on the dimensionality reduction technique to linearly transform the two groups of variables, CCA can extract the linear combination with the greatest correlation to reflect the correlation between the two groups of multidimensional variables [66].

For a given two sets of variables, $\boldsymbol{X}=[x_1,x_2,x_3\ldots x_p]$ and $\boldsymbol{Y}=[y_1,y_2,y_3\ldots y_q]$, CCA searches for the linear combination of them and obtains the coefficients of

Table 2 Indicators of neighborhood green space

Dimension	Measurement	Indicator	Index/ questionnaire questions
Accessibility	Geographic Information System	Objective accessibility	Neighborhood Green Accessibility Index
	Questionnaire survey	Perceived accessibility	"How convenient to reach, access, and visit are the green spaces near your neighborhood?"
Green space quality	Questionnaire survey	Plant diversity	"How about the plant diversity (plant color, species, etc.) of green spaces near your neighborhood?"
		Animal diversity	"How about the animal diversity (birds, butterflies, etc.) of green spaces near your neighborhood?"
		Cleanliness	"How clean and maintained is the green space near your neighborhood?"
		Safety	"How safe is the green space near your neighborhood?"
		Aesthetics	"How beautiful is the green space near your neighborhood?"
		Recreation facilities	"How many recreational facilities (sports field, park bench, toilets, park trash can, etc.) are in the green spaces near your neighborhood?"

the linear combination, a_{k1}, a_{k2}, a_{k3}, …, a_{kp} and b_{k1}, b_{k2}, b_{k3}, …, b_{kq}. It generates a pair of canonical variates, U_k and V_k, to maximize the correlation between the projections of the variables on the canonical variates [67]. The linear combinations of two sets of variables can be defined as follows:

$$U_k = a_{k1}x_1 + a_{k2}x_2 + \cdots + a_{kp}x_p \tag{2}$$

$$V_k = b_{k1}y_1 + b_{k2}y_2 + \cdots + b_{kq}y_q \tag{3}$$

where U_k and V_k are the kth pair of canonical variates generated from $\boldsymbol{X}$ and $\boldsymbol{Y}$, respectively, and a_{kp} and b_{kq} are the canonical coefficients. We report and analyze the standardized a_{kp} and b_{kq} generated from CCA estimation so as to compare the contributions of variables more intuitively and more easily. The standardization method used here is the Z-score method.

The specific algorithm flow of CCA is as follows. In the first step, the first pair of canonical variates (U_1, V_1) is formed as the linear combination with the greatest correlation. Thereafter, the linear combination uncorrelated with the first pair of canonical variates is selected among the remaining linear combinations of variables, while ensuring that the canonical correlation coefficient is the largest. This process continues until all correlations between the two sets of variables are extracted, n pairs of canonical variates combinations are obtained, and $n \leq \min(p, q)$ [66]. The likelihood-ratio method was used to test whether the canonical correlation coefficient between U_k and V_k was significantly different from 0. In this paper, we only analyze the estimation results of the first pair of canonical variates combinations because the canonical correlation between them is the greatest. The canonical correlation coefficient (r_1) between U_1 and V_1 can be calculated as follows [68]:

$$r_1 = \frac{C\hat{o}v(U_1, V_1)}{\sqrt{V\hat{a}r(U_1)V\hat{a}r(V_1)}} \tag{4}$$

To explore the relationship between neighborhood green space, residents' green space use behavior, and mental health (including perceived stress), we construct and estimate 5 canonical correlation models: Model 1 "neighborhood green space–residents' green space use behavior," Model 2 "residents' green space use behavior–residents' mental health (MHI-5)," Model 3 "residents' green space use behavior–residents' perceived stress (PSS-4)," Model 4 "neighborhood green space–residents' mental health (MHI-5)," and Model 5 "neighborhood green space–residents' perceived stress (PSS-4)"(Fig. 2).

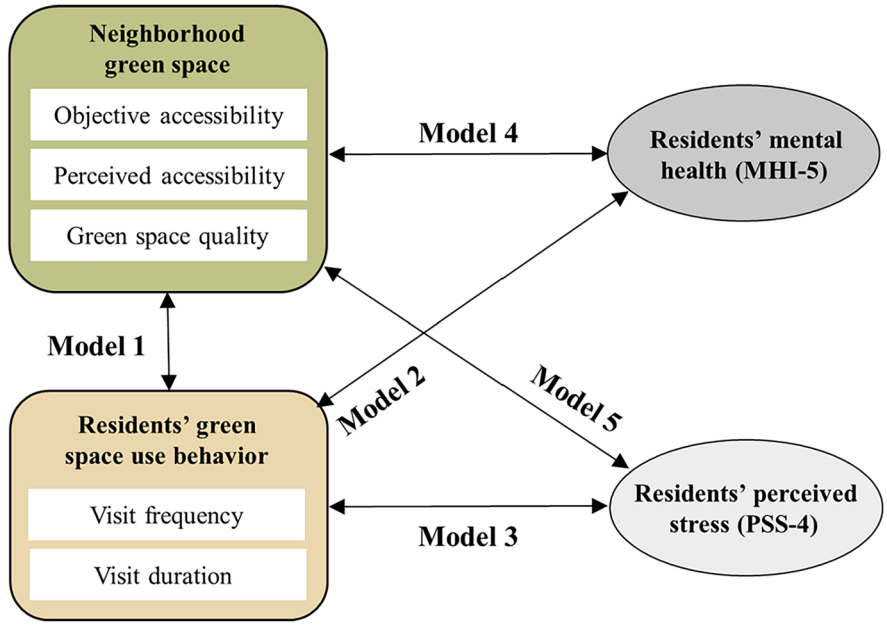
Results

The Association Between Neighborhood Green Space and Residents' Green Space Use Behavior

Figure 3 presents the result of Model 1 and the correlation between neighborhood green space and residents' green space use behavior. The canonical correlation coefficient (r_1) of the first pair of canonical variates is 0.392 and statistically significant ($P < 0.001$) (Table 3). If the variables in the two groups are the same color (red vs blue), it indicates a positive correlation between them. Otherwise, they are negatively correlated. The gradation of color represents the weight of the variable to the canonical variate.

It can be seen from the results in Fig. 3 that the main contribution variables of neighborhood green space (U_1) are perceived accessibility, plant diversity, safety, and recreational facilities, and their standardized coefficients are 0.606, 0.370, 0.277, and 0.218, respectively. The main contributing factor to residents' green space use behavior (V_1) is green space visit frequency (standardized coefficient 1.036). This shows that residents' perceived accessibility, plant diversity, safety, and recreational facilities of neighborhood green space have the greatest correlation with residents' green space use behavior, especially green space visit frequency. Although animal diversity is positively correlated with the frequency of green space visits, its contribution is much less than plant diversity (the standardization coefficient is only 0.013).

Compared with the frequency of green space visits, the above neighborhood green space variables correlate opposite with green space visit duration. This is probably because, in many cases, residents' length of green space visits is negatively correlated with the frequency of green space visits. People usually tend to stay shorter in the green space where they can access it easily or visit frequently, and



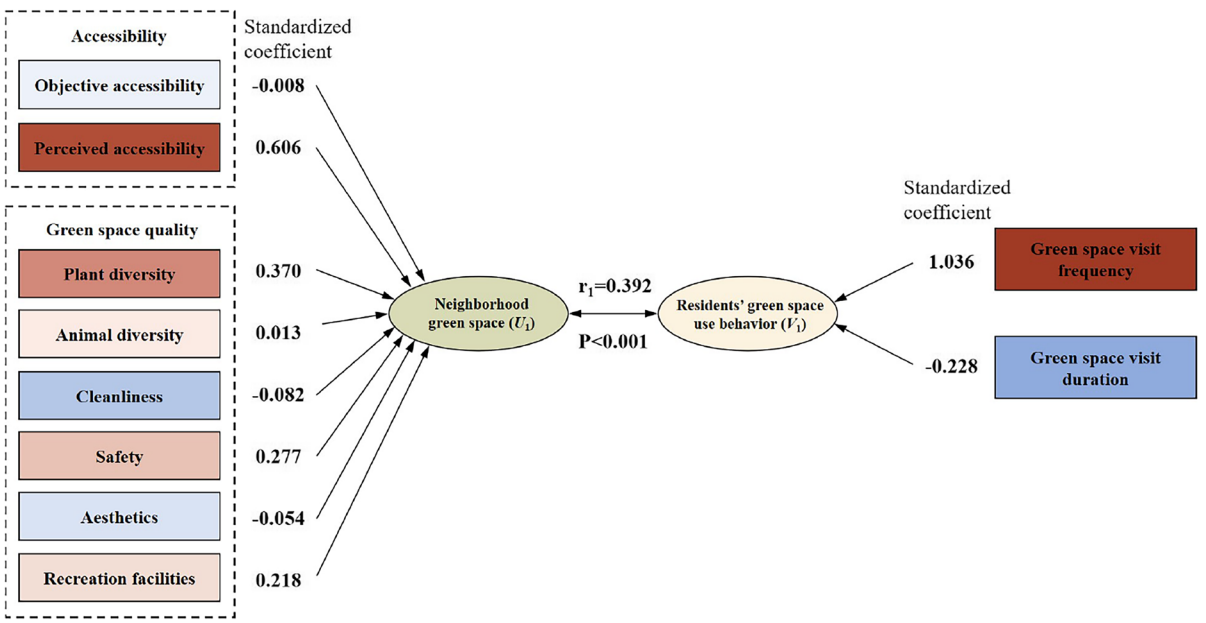


Fig. 2 Framework diagram of canonical correlation models construction

Fig. 3 Canonical correlation model of neighborhood green space and residents' green space use behavior (Model 1)

conversely, in the green space that is hard to access or they visit less, they are more likely to stay longer. Specifically, the objective accessibility, cleanliness, and aesthetics of the green space are positively correlated with the green space visit duration. However, the objective accessibility of the green space only has a tiny effect on residents' green space use behavior because of its small, standardized coefficient (-0.008), which is the smallest of all the green space variables we consider.

Table 3 The results of the first pair of canonical variates in five canonical correlation models

X–*Y*	Canonical correlation coefficient (r_1)	Eigenvalue	Wilks statistic	*F*-value	DF	Sig. of r_1
Neighborhood green space–Residents' green space use behavior	0.392	0.181	0.8154	16.856	16	< 0.001
Residents' green space use behavior–Residents' mental health (MIH-5)	0.331	0.123	0.8876	15.461	10	< 0.001
Residents' green space use behavior–Residents' perceived stress (PSS-4)	0.312	0.108	0.9013	16.782	8	< 0.001
Neighborhood green space–Residents' mental health (MIH-5)	0.250	0.066	0.9204	2.622	40	< 0.001
Neighborhood green space–Residents' perceived stress (PSS-4)	0.233	0.057	0.9356	2.631	32	< 0.001

The Association Between Residents' Green Space Use Behavior and Mental Health

In Model 2 and Model 3, we explored the correlation of residents' green space use behavior with mental health (MHI-5) and perceived stress (PSS-4). The results (Table 3) show that the canonical correlation coefficients of the first pair of canonical variates combinations are 0.331 and 0.312, respectively, and both are statistically significant ($P < 0.001$).

On the whole, residents' green space use behavior is beneficial to promoting residents' mental health status and reducing perceived stress levels. Both the green space visit frequency and green space visit duration play a positive role, although the former's impact is greater. Specifically, residents who visit green spaces more frequently and stay longer can feel happy, calm, and peaceful and can alleviate their down, blue and nervous emotions. Meanwhile, they are more likely to feel in control of their own lives and tend to be less bothered by stress (Fig. 4).

The Association Between Neighborhood Green Space and Mental Health

The associations between neighborhood green space and residents' mental health (MHI-5) and perceived stress (PSS-4) are analyzed, whose canonical correlation coefficient for the first pair of canonical variates combinations are 0.250 ($P < 0.001$) (Model 4) and 0.233 ($P < 0.001$) (Model 5), respectively (Fig. 5).

Comparing the results of these two models, we can derive from the standardized coefficient that the perceived accessibility of neighborhood green space plays a greater role in both mental health status and perceived stress level than objective accessibility. Moreover, the perceived accessibility and the objective accessibility of the green space play different roles in mental health, having an impact in different directions. Residents' subjective perception of the accessibility of neighborhood green space can make them feel happier, calmer, and more peaceful. It can also improve their confidence in handling personal problems and life satisfaction.

In terms of green space quality indicators, the safety of green space, the recreational facilities, cleanliness, and plant diversity have a positive impact on residents' mental health (MHI-5) and perceived stress (PSS-4), especially in increasing happiness, calmness and peace, and improving confidence to handle personal problems and difficulties. However, the aesthetics and animal diversity of the green space are positively correlated with downcast mood, nervous emotion, and depression, as well as feeling a lot of difficulties and being unable to overcome them. In other words, these two quality indicators may have adverse effects on residents' mental health status and perceived stress levels. From the above, different green space quality characteristics play different roles in residents' mental health status and perceived stress levels.

Discussion

Previous studies on perceived and objective green space accessibility also confirm that perceived accessibility is more effective in promoting physical

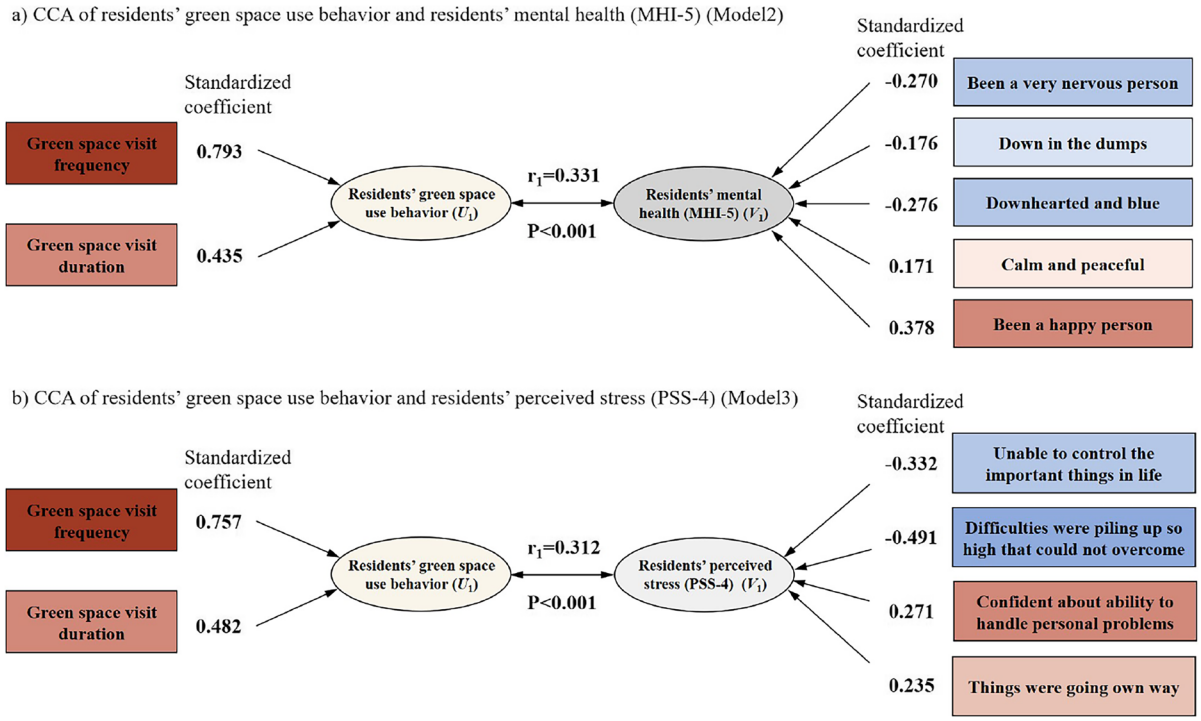


Fig. 4 Canonical correlation models of residents' green space use behavior-mental health (**a**) and residents' green space use behavior-perceived stress (**b**)

activity and public health than objective accessibility [69]. Perceived accessibility is a combination of physical proximity and the transportation mode for visiting, neighborhood safety, and perceived convenience [70, 71]. Among all the neighborhoods, we observed those neighborhoods with large gaps between objective and perceived green space accessibility. It was found that neighborhoods with more developed transport infrastructure and built environments tend to have better perceived green space accessibility than objective green space accessibility. The possible explanations are, on the one hand, that developed transportation facilities promote various and convenient travel modes; on the other hand, the walkable environment may shorten residents' perceived time to access the green space. Residents living near a larger green space are more likely to have lower perceived accessibility than objective accessibility to green space than those living near a small green space. This may be because that large area of green space usually has multiple entrances or access points, and the residence may be much closer to the location of the green space entrances than to the nearest green space edge as measured objectively. The residence may be far away from the green space entrance than the nearest green space edge measured objectively. In addition, some large parks, especially parks with entrance fees or forest parks, are not preferred by residents for their daily activities, so residents are likely to ignore the closest but less accessible green spaces when making subjective evaluations of green space accessibility and instead evaluate the green spaces that are accessible routinely. This shows that green space close to the scale of residents' daily activities plays a vital role in perceived accessibility. These results also suggest that, while it is difficult to improve the spatial accessibility of green spaces, it is also effective to promote the visiting frequency if the perceived accessibility of green spaces can be improved by increasing and highlighting green space entrances, optimizing the walking environment and public transportation infrastructure near green spaces, and creating a safe neighborhood.

In terms of the green space plant and animal diversity, previous studies have shown that biodiversity positively affects resident green space use,

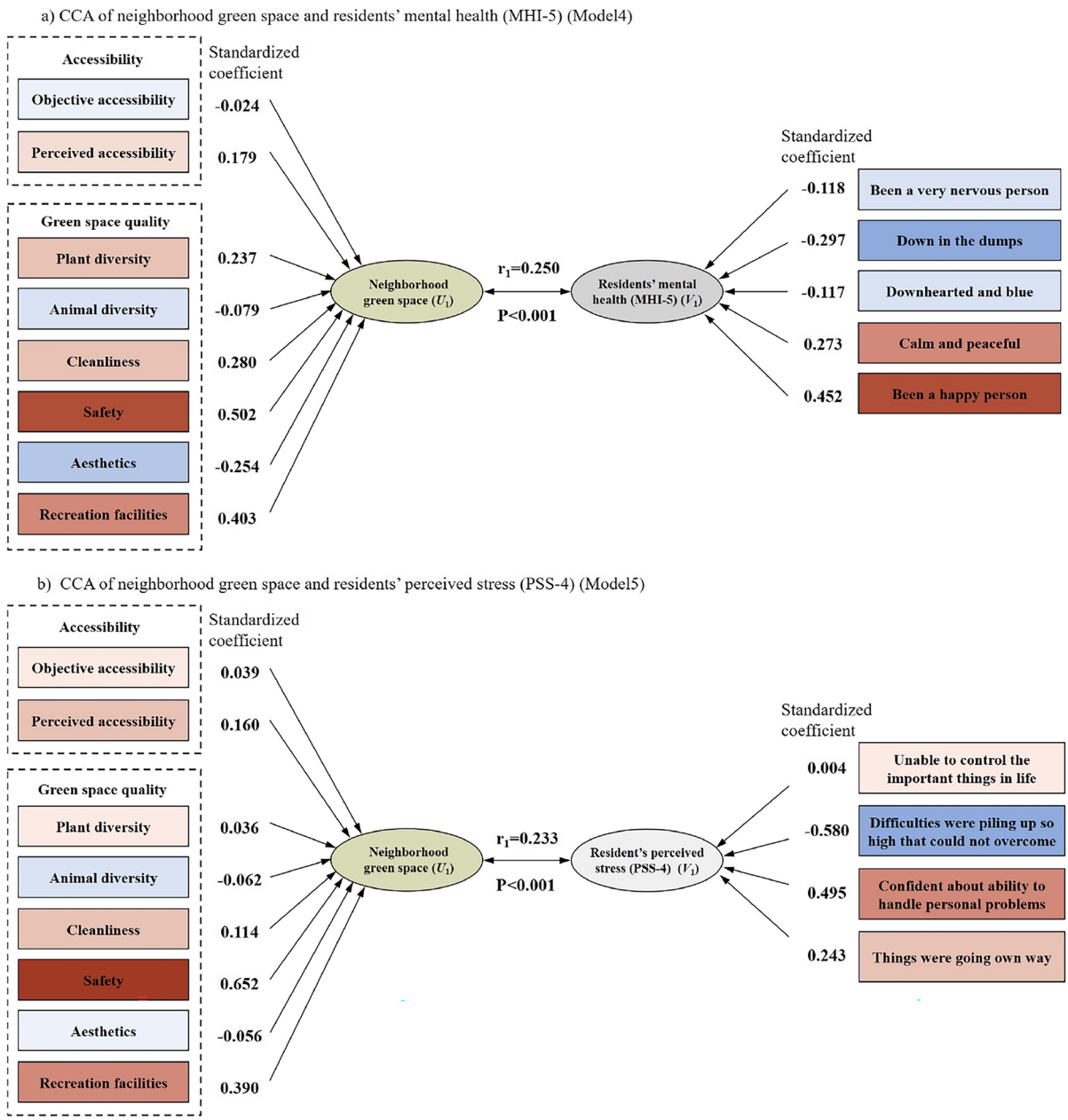


Fig. 5 Canonical correlation models of neighborhood green space-mental health (**a**) and neighborhood green space-perceived stress (**b**)

restoration of attention capability, and mental well-being [45, 47, 48, 72]. However, this study showed that plant diversity was a positive contributing factor to the frequency of green space visits and mental health. Conversely, animal diversity was negatively associated with green space visit duration and the mental health of residents. This finding is consistent with the research of Wang et al. [73], where mental well-being was found not to be influenced by animals such as fish and birds. Some studies have also shown that some animals (pigeons, bats, and squirrels) may negatively affect green space visiting because they are associated with the accumulation of garbage and the spread of infectious diseases, which advances the

understanding of our case [55, 74]. We found that there were generally more insects and birds, especially mosquitoes, in the green spaces considered diverse in animals, and therefore respondents tended to stay for shorter periods.

In addition, green space safety and recreational facilities are also key factors influencing residents' green space use behavior and mental health. In terms of safety, uncivilized behavior and insecurity can lead to the rejection of green space and consequently reduce its use [43, 44, 75] and cause anxiety. Our results demonstrated that the green space recreational facilities have a positive association with green space visit frequency and residents' mental health, consistent with previous studies [39, 40]. Abundant recreational facilities provide more diverse recreational activities and space, creating interaction opportunities among residents of different ages and interests and contributing to neighborhood social cohesion and mental health [55, 76]. Regarding the aesthetics of green spaces, previous studies have shown that aesthetics contribute to promoting quality of life and mental health [77]. However, in this case, when examining a combination of multiple green space accessibility and quality characteristics, the role of aesthetics was weaker and negatively correlated with mental health. Respondents perceived aesthetics of green spaces may be more related to their aesthetic standards and preferences than other green space quality characteristics. The negative association between green space aesthetics and mental health may be explained by these unmeasured social and environmental factors, which influence mental health.

Perceived accessibility of green space was more strongly correlated with green space use behavior. In contrast, green space quality was more strongly correlated with mental health. We found that most dimensions of green space quality were positively correlated with green space use and mental health. Previous studies pointed out that compared with green space availability, quality may be a more critical factor in promoting leisure time physical activity, social cohesion, and restorative experience [78, 79]. Policymakers and managers must evaluate green space quality and maintain high-quality green space regularly to maximize their mental health benefits instead of only considering green space abundance and accessibility.

Also, we found that both residents' green space visit frequency and duration positively improved mental health and reduced perceived stress, with the former being more significant. Therefore, making people aware of the health benefits of green spaces and encouraging residents to visit green spaces frequently may be a necessary means of promoting residents' mental health and reducing perceived stress. On the other hand, given the perceived and objective accessibility and different quality characteristics of green spaces that contribute to residents' green space visit frequency and duration, the potential mediating role of residents' green space use behavior in the effects of green space on residents' mental health and perceived stress can be further examined in future studies.

Conclusions

This study investigates the relationship between neighborhood green space, residents' green space use behavior, and mental health with the use of CCA and a green space and health survey data in Guangzhou, China. The main findings are as follows. The perceived accessibility of neighborhood green space has a stronger association with residents' green space use behavior and mental health than the objective accessibility. In addition, the safety, recreational facilities, cleanliness, and plant diversity of green spaces play a positive role in promoting residents' mental health and reducing psychological stress. Compared with green space quality characteristics, the green space perceived accessibility is more related to residents' green space use behavior. However, some green quality indicators, such as safety and recreational facilities, have greater benefits in improving residents' mental health than perceived accessibility. These conclusions indicate that land use and transport planning and community design should consider not only where to build new green spaces but also how to improve the subjective perception of accessibility of green spaces among residents. Improvement of the neighborhood walking environment, like improving the safety of sidewalks, the landscape quality and aesthetics of the street, and adding more street trees and shade, may be a potent measure to facilitate more green space visits and thus improve public health. Moreover, the safety of green spaces, the number of recreational facilities, the cleanliness, and the diversity of plants also play a positive role in the mental health of residents. Therefore, the landscape design of

green spaces should pay more attention to these key factors, so that the health effect of green spaces can be maximized.

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