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Enclosed by Walls, Embraced by Trees: Effects of Indoor Residential Crowding and Outdoor Green Space on Mental Health

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Abstract

Despite growing interest in how the urban built environment influences mental health, few studies have examined them across indoor-outdoor domains and subgroups. Using survey data from Beijing, we find that both residential crowding (indoor) and neighborhood green space (outdoor) are linked to depression risk. Specifically, residential crowding mainly affects local residents, while green space mainly affects migrants, with these effects varying by gender and family structure. The findings highlight that built environment inequality leads to health disparities, and planning strategies promoting mental health should address both indoor and outdoor factors and be tailored to the needs of specific vulnerable groups.

Keywords: housing; inequality; migrants; park; well-being.

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Introduction

Mental health is an important aspect of an individual's well-being and is included in the United Nations Sustainable Development Goals (United Nations 2015). Unfortunately, the increasing prevalence of mental health issues is a growing concern. For instance, the World Health Organization (2017) reported that over 300 million individuals, approximately 4% of the global population, experienced depression to some extent in 2015. Similarly, in China, the most recent nationwide survey to date (2013–2015) reported a 6.8% prevalence rate of depressive disorders, with the rate in big cities being higher than in small cities (Huang et al. 2019; Yang et al. 2018). The prevalence of depression leads not only to a lower quality of life but also to other physical health issues and imposes financial burdens on the public health sector. Recent studies have shown that medical costs related to mental health issues total an estimated 1.1% of China's national GDP, with indirect costs, such as productivity loss, likely being even higher (Gupta et al. 2016; Xu et al. 2016). These facts underscore the need to improve mental health both globally and within Chinese cities.

The urban built environment plays an important role in shaping mental health (Botchwey et al. 2014). Based on the stress process model, the built environment—indoor or outdoor—can act as a source of chronic stressors (e.g., overcrowding, noise, lack of green space), which in turn elevate the risk of mental health problems such as depression and anxiety (Pearlin et al. 1981). The built environment may affect mental health directly by decreasing a person's sense of control over their space or indirectly by impacting their level of social engagement (Evans,

2003). An emerging body of literature has examined the relationships between diverse built environment elements and mental health outcomes, including housing quality, access to amenities, neighborhood safety, and social cohesion, as well as physical environmental features such as green space availability (Hu and Coulter 2017; Evans et al. 2000; Frank et al. 2019; Lai et al. 2024; Leslie and Cerin 2008; Liu et al. 2022; Mouratidis 2021; Yoo et al. 2022). Within this broader context, two contrasting dimensions of the built environment have received increasing attention: outdoor neighborhood conditions, particularly access to and availability of green space, and indoor residential conditions, particularly the amount of private living space – partially due to their strong relevance to planning practice. Studies consistently find that access to green space is associated with improved mental well-being (Fan et al. 2011; Lee et al. 2024; Liu et al. 2019; Qin et al. 2021; Rahman et al. 2024; Wu and Kim 2021; Yoo et al. 2022), while crowded living conditions are linked to poorer mental health across diverse urban and cultural contexts (Foye 2017; Li and Liu 2018; Ruiz-Tagle and Urria 2022). However, limited research has simultaneously considered outdoor and indoor factors and how their impacts may differ among various population groups.

In the context of Chinese cities, one primary driver of recent urban development is rural-to-urban migration (Wu and Wang 2014). The uniqueness of China's internal migration is linked to the household registration system or *hukou*; migrants to a city do not automatically receive the local *hukou*, resulting in unequal access to public services such as education, housing, and healthcare (He et al. 2010; Li and Wu 2008). Such differential access between local residents

(*hukou* holders) and migrants (non-*hukou* holders), together with different socioeconomic conditions and lifestyles, may lead to divergent housing options, activity spaces, and opportunities for social interaction (Li and Rose 2017; Ta et al. 2021). Building on this context, theoretical perspectives suggest that these disparities may shape how the built environment affects migrants and locals differently. Migrants often experience baseline disadvantages in housing, employment, and familiarity with local amenities, which heighten their sensitivity to indoor and outdoor stressors (Wu et al. 2010; Wu and Wang 2014), and they also face environmental vulnerability and psychosocial stress due to housing insecurity, social isolation, and limited access to supportive environments (Li et al. 2021). At the same time, some migrants may draw resilience from the migration process itself (Wong and Song 2008) or rely more heavily on coping through social ties, in contrast to locals who are less dependent on these buffers (Cheung 2014). Consequently, disparities in *hukou* status and associated living conditions mean that the physical indoor and outdoor built environment can have varying effects on individuals' mental health.

Using Beijing as a case study, this paper examines the effects of both indoor and outdoor built environment factors on mental well-being. Specifically, it examines the relationships between depressive symptoms and two environmental factors: indoor residential crowding and outdoor green space. Additionally, it investigates whether these effects differ between local residents and migrants, as well as other sociodemographic groups. Hence, the study contributes to the discussion on healthy cities by suggesting targeted urban planning interventions to

enhance mental well-being.

Literature Review

The relationship between the outdoor green space, indoor residential crowding and mental health is supported theoretically and empirically by the literature. This section examines relevant theoretical discussions and empirical findings that link these built environment factors (i.e., green space and residential crowding) with mental health. Additionally, it explores the differences in mental health conditions between migrants and local residents in Chinese cities.

The effects of green space and residential crowding on mental health is supported by the stress process theory, which conceptualizes the green space and residential crowding as built environment stressors, with chronic exposures to specific environmental stressors leading to a higher or lower probability of mental health problems (Pearlin and Bierman 2013; Pearlin et al. 1981). Built environment stressors can act as either positive ones that enhance mental health or negative ones that worsen it, and they can also occur at different geographical scales, from the macro city level to the meso neighborhood level and down to the micro household level, all of which contribute to people's mental health status (Sarkar et al., 2014).

One of the most well-studied built environment stressors related to mental health is outdoor green space. The mental health effects of green space can be theoretically attributed to its restorative effects (Kaplan 1995). Research suggests that humans possess an intrinsic affinity for natural environments, which can directly help reduce mental fatigue, alleviate stress, and

improve life satisfaction (Ambrey and Fleming 2014; Kaplan 1995). Contacting with green spaces can also provide indirect benefits by buffering against life stress, offering serene environments conducive to relaxation, promoting physical activity and social interaction, and thereby enhancing mental well-being as well as public health (Brown et al. 2018; Hartig et al. 2014; Jabareen 2006; Sugiyama et al. 2008; Van den Berg et al. 2010).

The mental health benefits of green space are also supported by empirical evidence. For instance, a study in Auckland, New Zealand, utilizing data from 3,149 area units, revealed a strong correlation between the prevalence of mood disorder treatments and the amount of neighborhood green space within three kilometers, suggesting that green space availability has a protective effect on mental health (Nutsford et al. 2013). Similar studies in China have also reported comparable results (Qin et al. 2021; Wu and Kim 2021). However, the availability of these beneficial green spaces can be uneven and is often influenced by socioeconomic disparities, resulting in environmental injustice that can limit the positive effects of green spaces for underserved populations. (Brown et al. 2018; Yoo et al. 2022; Wolch et al. 2014).

Besides the outdoor green space, household-level indoor built environment stressors are also related to mental health. Here, we focus on residential crowding, which is characterized by high density and limited living space. Crowded residential living space is theoretically connected with mental health conditions due to restricted personal space, increased noise, reduced privacy, and limited ability to escape unwanted social interactions (Evans 2003; Schwab et al. 1979). Additionally, prolonged social exposure to crowded living conditions can diminish control over

personal and social situations at home, intensifying these adverse effects (Baum et al. 1978). Further literature indicates that factors such as household composition and housing conditions can strengthen the adverse mental health effects of residential crowding (Li and Liu 2018; Ruiz-Tagle and Urria 2022).

Prior studies have provided empirical evidence linking crowded living conditions with worse mental health outcomes. For example, a UK study found that individuals living in overcrowded conditions experienced poorer mental well-being (Guite et al. 2006). Similar findings have been observed in Asian cities such as Hong Kong (Lai et al. 2024). It is worth noting that although per capita living space and persons per bedroom—the two most common measurements for residential crowding—are both significantly associated with mental health conditions, studies in Asian cities typically use square meters per person as a measurement, while studies in Western cities often use persons per room (Blake et al. 2007; Foye 2017). This difference may arise from higher residential density in Asian cities, where per capita space is a greater concern than in Western cities. Furthermore, the effects of residential crowding can vary among demographic groups, with female, single, and low-income residents being particularly vulnerable (Guite et al. 2006; Li and Liu 2018; Regoeczi 2008). This underscores the need for targeted initiatives to mitigate these disparities.

Although the existing literature often examines the mental health effects of indoor residential crowding and outdoor green space separately, these two factors are deeply interconnected and jointly shape individuals' daily experiences. On the one hand, indoor residential crowding (the

private sphere) and outdoor green space (the public sphere) together form a continuum of one's daily environment, cumulatively contributing to mental health (Guite et al. 2006; Sarkar et al. 2014). On the other hand, these factors are often intercorrelated, making it crucial to examine their effects jointly. Residents move continuously between indoor and outdoor environments, and stressors originating in one domain can amplify or mitigate those in the other (Evans 2003). Additionally, these factors may be linked by underlying socio-economic drivers, as households with more private indoor space often reside in greener, better-served areas. While there is growing recognition of the need to examine indoor and outdoor factors together in relation to physical health (e.g., Ma et al. 2020), integrated research on their combined effects on mental health remains limited.

For Chinese cities, one notable aspect related to mental health disparity is mass internal migration—primarily from rural areas to urban areas, as well as from smaller cities to larger cities, mainly in search of better economic opportunities (Chen 2011; Wu and Wang 2014). Migration to Beijing, for example, is largely driven by economic, educational, and family reasons, with many migrants employed in the service, construction, or manufacturing sectors, while others pursue white-collar jobs (about 30% in our study sample) (Chen 2011; Shi et al. 2024; Wu and Wang 2014). However, these migrants typically reside in larger cities only temporarily, intending to return to their hometowns in rural areas or smaller cities once they have saved sufficient funds (Du et al. 2018; He et al. 2010). Migrants in large cities often lack formal local residency status, or *hukou*, in their destination cities, creating institutional barriers to

accessing certain public services and local amenities (Wu et al. 2010; Wu and Wang 2014). Besides, obtaining a local *hukou* remains highly restrictive (Shi et al. 2024; Liu et al. 2023). Research shows that significant disparities persist in non-income dimensions of well-being, including housing conditions and access to social insurance programs, highlighting how institutional and social barriers continue to shape migrants' urban experience (Park and Wang 2010). As a result, migrants generally face poorer housing conditions, including smaller living spaces, lower housing quality, reduced access to green space, and weaker community services, compared to local residents (Chen 2011; He et al. 2010; Huang 2003; Li et al. 2018). Beyond institutional exclusion, migrants also encounter non-institutional disadvantages, such as limited activity spaces, restricted access to recreational areas, public schools, and healthcare, as well as inadequate social support (Li and Rose 2017; Li and Wu 2008; Wu and Wang 2014). These disadvantages not only undermine living conditions but also heighten environmental vulnerability and psychosocial stress (Li et al. 2021). Together with differences in socioeconomic status, these factors make migrants more likely than local residents to face physical and mental health issues—a topic that has already drawn attention in the existing literature (Chen 2011; Li and Rose 2017; Song and Smith 2021). Meanwhile, a resilience perspective highlights that migrants may cope differently from locals. Migration itself can serve as a source of meaning and adaptation (Wong & Song 2008), and migrants may benefit more strongly from social ties in buffering stress, whereas locals are less reliant on these networks (Cheung, 2014). Taken together, these factors suggest that the impacts of indoor and outdoor built environments on

mental health may differ between migrants and locals, making it important to analyze these groups separately.

Although growing research links the built environment to mental health, key knowledge gaps persist. First, most existing studies in the built environment and urban planning fields focus on either indoor or outdoor environmental factors—such as housing conditions or neighborhood greenery—without examining how multiple dimensions of the living environment, both inside and outside the home, may interact to shape mental well-being. Yet mental health is likely influenced by the combined pressures and supports found in both private and public spaces. Second, in the context of Chinese cities, the living experiences of migrants and local residents often differ significantly in both housing and neighborhood quality. However, few studies systematically compare how these differences translate into mental health outcomes across groups.

Data and Methods

Study Sample

The study sample comes from a survey conducted in Beijing, China, in July 2022.[1] The sample comprises 1,020 individuals from 40 communities (*shequ*) (Figure 1). A multi-stage stratified sampling method was employed. First, 12 out of the city's 16 districts were selected to

[1] The survey was conducted face-to-face on non-Covid-lockdown days.

reflect the distribution of inner-city and outer-city areas. From these, 40 communities were randomly chosen. These communities were selected to capture variation in both socioeconomic characteristics and built environment conditions across Beijing. Within each community, approximately 25 residents were randomly selected and stratified by age, gender, and hukou status to ensure demographic representativeness and comprehensive coverage of living conditions. All interviews were conducted in person on-site. Respondents were required to have resided in Beijing for at least six months in 2022 and to be 19 or older. The survey collected data on socio-demographics, living conditions, employment, and income. The socio-demographics of the study sample (e.g., average age of 43.9 and female share of 48.9%) are comparable with the most recent official statistics (Beijing Municipal Bureau of Statistics and NBS Survey Office in Beijing 2022). The survey has a good completion rate with no missing values. Nevertheless, we applied Cook's distance and removed 31 extreme outlier observations in our regression models, resulting in a total sample size of 989 (Cook and Weisberg 2009; Stevens 1984).

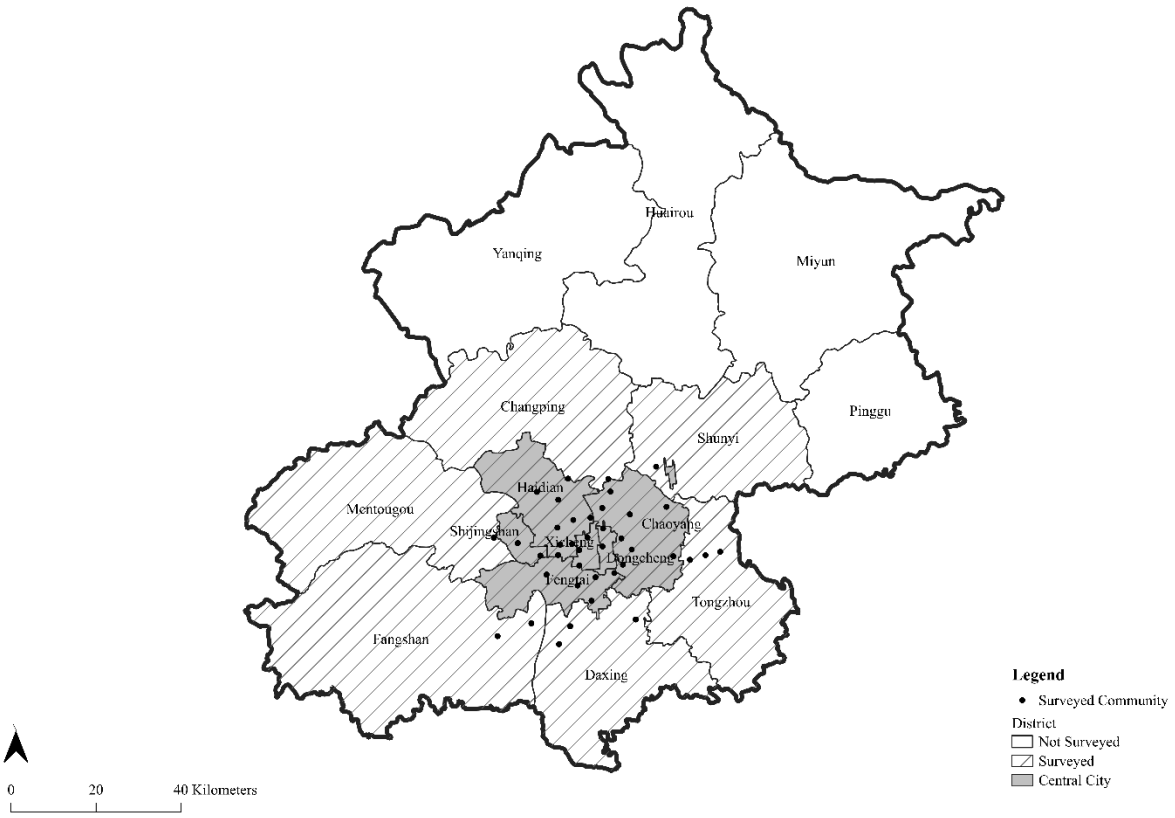

Figure 1. Locations of communities and districts surveyed in the study sample.

Depressive Symptoms

The outcome variable is whether the respondent screens positive for depressive symptoms, measured by the Chinese version of the 10-item Center for Epidemiologic Studies Depression Scale (CESD-10) (Andresen et al. 1994). Recognized for its reliability and validity, the CESD-10 is widely used for depression screening, as it has minimal indications of discriminatory bias or invariance across different geographic and cultural contexts (Björgvinsson et al. 2013; Chen and

Mui 2014). In the CESD-10 scale, each individual is surveyed about the frequency of a list of 10 feelings in the past week, and the responses are converted into a score of 0–30, with a higher score indicating greater depressive symptoms. A person with a CESD-10 score of 10 or higher is screened as positive for depressive symptoms (Andresen et al. 1994). We use this cutoff to create a binary outcome variable, which equals one if a respondent screens positive for depressive symptoms and zero otherwise. The cutoff has been widely tested and confirmed for reliability (Andresen et al. 1994; Björgvinsson et al. 2013).

Indoor Residential Crowding and Outdoor Green Space

This study focuses on two exposure variables: indoor residential crowding and outdoor green space. Indoor residential crowding is analyzed as a micro-scale variable at the household level, whereas outdoor green space is treated as a meso-scale variable at the neighborhood level.

Indoor residential crowding is quantified by calculating the average square meters per person, based on survey responses to two self-reported questions: the total square meters of living space and the household size. Average square meters per person is a widely used measure for residential crowding, particularly within the context of Chinese cities (Huang 2003; Li and Liu 2018; Li et al. 2018). The Chinese national survey sets the residential space benchmark at eight square meters per person (Li et al. 2018). Households with living areas below this benchmark are considered overcrowded, a standard lower than those in Western countries (Blake et al. 2007). In our study, 99% of the participants live in homes with an average area exceeding

eight square meters per person. Hence, we evaluate indoor residential crowding by considering square meters per person, without a fixed threshold.

Outdoor green space, the second exposure variable, is measured as the proportion of green space within a one-kilometer radius of each community center, geocoded using Baidu Maps, a widely used online mapping service. The green space data are derived from the Beijing high-resolution urban green space (UGS) product by Shi et al. (2023), with a detailed one-meter by one-meter granularity based on Google Earth imagery from 2020. These data include various vegetated areas, ranging from parks and green belts to small green patches, aligning with existing literature on green space and mental health (e.g., Ambrey and Fleming 2014; Nutsford et al. 2013; Qin et al. 2021; Richardson et al. 2013). We use a one-kilometer radius because it represents the average distance residents are willing to walk to access transportation and other amenities (Cerin et al. 2018; Lee and Moudon 2006), making it pertinent for urban planning and public health studies.

Migrant and Hukou Status

We measure migrant status in the study sample using formal residency, or *hukou* status, categorizing participants as either local residents with Beijing *hukou* or migrants without Beijing *hukou*. Prior research has shown that migrants and local residents in large cities often experience differences in living quality, lifestyles, health outcomes, and activity spaces (Ta et al. 2021; Zhou and Guo 2023). *Hukou* status is a widely used measure of migrant status because it determines

access to housing, employment, education, healthcare, and other services (Chen 2011; He et al. 2010). Migrants are generally not able to acquire local *hukou* due to strict requirements, making it difficult for them to adapt to urban environments and limiting their access to public services in the city, which can lead to adverse effects on their mental health (Cui 2020; Song and Smith 2021).

Control Variables

We adjust for a wide range of control variables that theoretically correlate with outcome and exposure variables. The socio-economic variables include age (in 2022), gender (female or male), marital status (single or married), education attainment (lower than high school; high school; university or higher), type of employment (government and management positions; professionals; construction or manufacturing; agriculture; service; and others), annual household income in 2021 (in 10k Chinese *yuan*), ownership of residential property in Beijing (yes/no), community type (condominium or commercial residential development; work-unit compound; urban village; and others), and living with family (yes/no). We also include district-fixed effects to control district-specific attributes that may influence mental health (socioeconomic conditions and stereotypes).

Statistical Modeling

To examine the effects of indoor residential crowding and outdoor green space on

depression, we propose logit regression models using the following equation:

$$Depression_i = \beta_0 + \beta_1 \times IndoorCrowd_i + \beta_2 \times OutdoorGreen_i + \beta_3 \times SocialDemo_i + \beta_4 \times District_i + \epsilon_i$$

where $Depression_i$ is a binary dependent variable with a value of one when individual i is screened positive for depressive symptoms and zero otherwise; $IndoorCrowd_i$ represents the level of indoor residential crowding measured as the square meters per person; $OutdoorGreen_i$ refers to the proportion of urban green space within a one-kilometer radius of the individual i's community center; and $SocialDemo_i$ and $District_i$ are control variables capturing the sociodemographic characteristics and district-specific fixed effects, respectively, to account for potential confounding factors. In addition, we introduced interaction terms between the level of indoor residential crowding and the proportion of urban green space to examine potential moderation effects.

Given the binary nature of the dependent variable, we adopt a binomial regression approach. To mitigate the influence of extreme outliers that skew the analysis, we employ Cook's distance method—a standard statistical measure that identifies influential data points based on their effect on the estimated regression coefficients (Cook and Weisberg 2009; Stevens 1984). All the analyses are conducted using R (Version 4.2.2).

Results

Descriptive Statistics

Table 1 shows the descriptive statistics of the study sample. As shown in Table 1, 24.9% of participants screened positive for depressive symptoms, with a slightly higher prevalence among migrants (25.7%) compared to local residents (24.3%)[2]. To date, government-led surveys or censuses have not included questions about mental health. However, the China Family Panel Studies (CFPS), a nationally representative survey conducted by the Institute of Social Science Survey at Peking University, included such questions (CESD-20) in its 2016 wave; the CFPS reported that 23.4% of adults screened positive for depression (Xu et al. 2021), making our sample results comparable to these findings. For indoor residential crowding measures, the average living space per person in our study sample is 29.6 square meters. This number is slightly lower than the city-level statistics in 2015 (31.7 square meters per person) (Beijing Municipal Bureau of Statistics and NBS Survey Office in Beijing 2016). The slight discrepancy may arise from our study focusing more on urban areas, whereas the official statistics cover both urban and suburban areas. Regarding outdoor green space, the proportion of urban green space within a one-kilometer radius of each community center is 18.0%. This number is lower than the district-level urban green space coverage rate required by China's Ministry of Housing and

[2] The prevalence of depressive symptoms reported here is higher than the national-level prevalence rate of depression disorder reported in the Introduction section (Huang et al. 2019; Yang et al. 2018), as the two are based on different measurements. Depressive disorder refers to a more severe, longer-term clinical condition, while depressive symptoms typically refer to milder forms, short-term psychological distress.

Urban-Rural Development (28%) (Ministry of Housing and Urban-Rural Development 2019). However, note that at the district level, there is normally large green space (in the form of district parks) to meet the green space requirement, while the geographical coverage of our study sample is the residential areas.

Table 1. Descriptive Statistics of the Study Sample

	Mean or %		
	All	**Local resident**	**Migrant**
Experiencing depression	24.9%	24.3%	25.7%
Square meters per person	29.551	32.022	25.803
Share of urban green space within a 1 km radius	0.180	0.178	0.182
Age in 2022 (years)	43.928	46.394	40.188
Female	48.9%	46.0%	53.4%
Beijing *hukou*	60.3%	100%	0
Being married*	78.6%	84.2%	70.0%
Education (%)			
Lower than high school	29.9%	26.0%	35.9%
High school	38.1%	42.1%	32.1%
University or higher	32.0%	31.9%	32.1%
Job type (%)			
Government and manager	25.2%	26.3%	23.4%
Professionals	16.8%	16.8%	16.8%
Service	22.8%	16.3%	32.6%
Agriculture	2.2%	3.5%	0.3%
Manufacturing/Construction	4.9%	3.7%	6.6%
Others	28.2%	33.4%	20.4%
Household income in 2021 (in 10k Chinese yuan)	19.394	19.888	18.645
Own residential property in Beijing	82.2%	95.0%	62.8%
Community Type (%)			
Condominium	68.4%	66.3%	71.5%
Work-unit compound	8.1%	8.9%	6.9%
Urban Village	9.0%	10.4%	6.9%
Others	14.6%	14.4%	14.8%
Living with family members	91.8%	98.3%	81.9%
District (%)			
Changping	4.7%	4.0%	5.6%
Chaoyang	19.8%	20.6%	18.6%
Daxing	7.5%	7.9%	6.9%
Dongcheng	5.3%	5.4%	5.1%
Fangshan	4.7%	4.0%	5.6%
Fengtai	12.8%	13.8%	11.5%
Haidian	20.3%	19.3%	21.9%
Mentougou	2.4%	2.3%	2.5%

Shijinshan	5.1%	5.4%	4.6%
Shunyi	2.5%	3.0%	1.8%
Tongzhou	7.6%	7.2%	8.1%
Xicheng	7.4%	7.0%	7.9%
Number of Observations	989	596	393

Notes: * In this study, the term "married" also includes unmarried couples who live together (i.e., cohabitating partners).

Indoor Residential Crowding, Outdoor Green Space, and Depression

Table 2 investigates the associations between household-level and neighborhood-level environmental factors and depression for the whole sample as well as for local residents versus migrants. Column (1) shows that lower living space per capita and a lower share of urban green space within a one-kilometer radius are both associated with higher risks of depression. Columns (2) and (3) show that indoor residential crowding is significant only for local residents, not for migrants, whereas outdoor green space significantly affects only migrants, not local residents. Specifically, when all other factors are held at their means, an additional 10 square meters of living space per person is associated with an approximately 4.9% decrease in the odds of depression among local residents, and the effect of indoor residential crowding is not significant for migrants. Additionally, an increase of 10 percentage points in the proportion of urban green space within a one-kilometer radius is associated with an 8.6% decrease in the risk of depression for migrants, while the effects of outdoor urban green space are not significant for local residents.

To test the potential moderation effect, we examined the interaction between indoor

residential space (square meters per person) and the proportion of urban green space within a 1 km radius. However, we did not find significant results for the interaction terms (Table 2 Columns (4)–(6)).

Table 2. Logit Regression of Depression Associated with Indoor Residential Crowding and Outdoor Green Space

	(1) All	(2) Local residents	(3) Migrants	(4) All, w/ crowding-green interaction	(5) Local residents, w/ crowding-green interaction	(6) Migrants, w/ crowding-green interaction
Square meters per person	-0.016 **	-0.029 ***	0.002	-0.035 **	-0.048 **	-0.015
	[0.008]	[0.011]	[0.012]	[0.016]	[0.023]	[0.026]
Share of urban green space within 1 km radius	-2.279 **	-1.188	-5.063 ***	-5.215 **	-4.348	-7.508 *
	[1.114]	[1.439]	[1.928]	[2.375]	[3.498]	[3.86]
Square meters per person * Share of urban green space within 1 km radius				0.107	0.110	0.097
				[0.076]	[0.111]	[0.132]
Owning a Beijing *hukou*	-0.016			-0.008		
	[0.185]			[0.185]		
Age in 2022 (years)	0.010	0.013	0.011	0.011	0.014	0.012
	[0.008]	[0.012]	[0.014]	[0.008]	[0.012]	[0.014]
Female	0.094	0.067	0.163	0.097	0.074	0.155
	[0.160]	[0.211]	[0.280]	[0.161]	[0.211]	[0.28]
Household income (in 10k *yuan*) in 2021	-0.013 **	-0.013 *	-0.018	-0.013 **	-0.013 *	-0.018
	[0.006]	[0.008]	[0.011]	[0.006]	[0.008]	[0.011]
Living with family members	0.513	-1.077	1.051 **	0.502	-1.103	1.035 *
	[0.386]	[0.786]	[0.533]	[0.386]	[0.788]	[0.534]
Married	0.011	0.202	-0.292	0.022	0.207	-0.257
	[0.243]	[0.338]	[0.393]	[0.244]	[0.339]	[0.397]
Own residential property in Beijing	-0.344	-0.003	-0.496 *	-0.342	0.008	-0.501 *
	[0.222]	[0.468]	[0.275]	[0.222]	[0.468]	[0.275]
Community Type						

Others	(Ref.)	(Ref.)	(Ref.)	(Ref.)	(Ref.)	(Ref.)
Condominium	-0.135	0.284	-0.551	-0.146	0.267	-0.559
	[0.227]	[0.324]	[0.362]	[0.228]	[0.325]	[0.363]
Work-unit compound	-0.118	0.155	-0.176	-0.141	0.121	-0.196
	[0.352]	[0.457]	[0.635]	[0.353]	[0.459]	[0.636]
Urban village	0.172	0.722	-0.736	0.139	0.683	-0.753
	[0.337]	[0.445]	[0.622]	[0.338]	[0.448]	[0.623]
Education						
Lower than high school	(Ref.)	(Ref.)	(Ref.)	(Ref.)	(Ref.)	(Ref.)
High school	0.135	-0.219	0.740 **	0.154	-0.203	0.762 **
	[0.206]	[0.272]	[0.355]	[0.207]	[0.273]	[0.357]
University or higher	0.504 *	0.508	0.649	0.533 **	0.546	0.664
	[0.269]	[0.366]	[0.442]	[0.27]	[0.368]	[0.443]
Job type						
Government and manager	(Ref.)	(Ref.)	(Ref.)	(Ref.)	(Ref.)	(Ref.)
Professionals	-0.388	-0.341	-0.675	-0.369	-0.318	-0.654
	[0.264]	[0.348]	[0.450]	[0.265]	[0.349]	[0.450]
Service	-0.149	0.030	-0.157	-0.139	0.041	-0.148
	[0.248]	[0.343]	[0.413]	[0.249]	[0.344]	[0.413]
Agriculture	-1.199	-1.083	-14.056	-1.161	-1.047	-14.057
	[0.800]	[0.840]	[882.744]	[0.799]	[0.840]	[882.744]
Manufacturing/Construction	0.319	0.371	0.405	0.339	0.377	0.414
	[0.389]	[0.555]	[0.624]	[0.391]	[0.557]	[0.626]
Others	0.189	0.197	0.218	0.194	0.206	0.223
	[0.268]	[0.358]	[0.459]	[0.269]	[0.358]	[0.460]
District-fixed effects						
Xicheng	(Ref.)	(Ref.)	(Ref.)	(Ref.)	(Ref.)	(Ref.)
Changping	-0.345	-1.016	1.026	-0.378	-1.114	1.042
	[0.526]	[0.735]	[0.833]	[0.527]	[0.744]	[0.833]
Chaoyang	-0.555 *	-1.007 **	0.077	-0.564 *	-1.028 **	0.065
	[0.317]	[0.420]	[0.520]	[0.318]	[0.423]	[0.521]

Daxing	-0.815 **	-1.046 **	-0.427	-0.817 **	-1.054 **	-0.431
	[0.379]	[0.496]	[0.646]	[0.380]	[0.499]	[0.647]
Dongcheng	-1.134 **	-1.191 **	-1.207	-1.128 **	-1.187 **	-1.233
	[0.464]	[0.577]	[0.886]	[0.465]	[0.579]	[0.888]
Fangshan	-0.042	-0.112	0.122	-0.055	-0.155	0.125
	[0.437]	[0.589]	[0.700]	[0.438]	[0.592]	[0.699]
Fengtai	-0.153	-0.400	0.292	-0.159	-0.413	0.280
	[0.317]	[0.421]	[0.526]	[0.318]	[0.423]	[0.525]
Haidian	-1.237 ***	-1.424 ***	-1.002 *	-1.257 ***	-1.461 ***	-1.015 *
	[0.354]	[0.470]	[0.575]	[0.355]	[0.473]	[0.575]
Mentougou	-0.863	-1.777 **	0.287	-0.885	-1.819 **	0.277
	[0.542]	[0.852]	[0.785]	[0.543]	[0.855]	[0.785]
Shijinshan	-0.798	-0.723	-0.847	-0.838 *	-0.795	-0.852
	[0.497]	[0.620]	[0.918]	[0.498]	[0.625]	[0.917]
Shunyi	-1.925 **	-2.440 **	-1.172	-1.918 **	-2.446 **	-1.154
	[0.793]	[1.099]	[1.222]	[0.793]	[1.100]	[1.221]
Tongzhou	-0.678 *	-0.972 **	-0.123	-0.649 *	-0.954 *	-0.092
	[0.363]	[0.496]	[0.573]	[0.365]	[0.500]	[0.574]
Constant	-0.164	0.984 *	-0.580	0.305	1.524	-0.205
	[0.597]	[1.046]	[0.967]	[0.687]	[1.189]	[1.092]
Number of Observations	989	596	393	989	596	393

Note: Logit regression with screening positive for depression (y/n) as dependent variable. "Local residents" refers to those holding a Beijing *hukou*, and "migrants" refers to those not holding a Beijing *hukou*. Standard errors are shown in brackets. *, **, and *** represent significance at the .10, .05, and .01 levels, respectively.

Effects by Gender and Marital Status

Table 3 Panel A examines gender-specific mental health effects of indoor residential crowding and outdoor green space. As identified in Table 2, per capita living space is significantly associated with depressive symptoms only for local residents; columns (2) and (3) of Table 3 show that this effect is significant only among local females. Similarly, Table 2 shows

that the share of green space is significantly related to depressive symptoms only for migrants; columns (5) and (6) of Table 3 reveal that this effect is relatively stronger for migrant males and not significant for migrant females. Additionally, Table 2 demonstrates that per capita living space is not significantly associated with depression for migrants, nor is the share of green space significantly associated with depression for local residents; Table 3, Panel A further confirms that when analyzed separately by gender, the non-significance for indoor residential crowding for migrants and for outdoor green space for locals remains unchanged.

Table 3 Panel B explores the connections among depression, indoor residential crowding, and outdoor green space by marital status. Recall that Table 2 shows that per capita living space is significantly associated with depressive symptoms only for local residents. In Table 3, columns (8) and (9) show that this living space–depression association is significant only for single locals and not for married locals. Similarly, Table 2 also shows that the share of green space is significantly related to depressive symptoms only for migrants; in Table 3, columns (11) and (12) further dissect the sample and find that this green space–depression association is slightly stronger for married migrants and not significant for single migrants. However, this difference should be interpreted with caution, as the magnitude of the coefficients for these two subgroups is similar (-4.922 vs. -4.320), and there are only 118 single migrants in the study sample. The lack of significance of the single migrant subsample may be due to the small sample size. Moreover, Table 2 indicates that indoor residential crowding is not significantly associated with depressive symptoms for migrants, and outdoor green space is not significantly associated with

depressive symptoms for local residents; Table 3 Panel B further confirms that such patterns remain consistent when analyzed separately by marital status.

Table 3. Logit Regression of Depression Associated with Indoor Residential Crowding and Outdoor Green Space: By Gender and Marital Status

Panel A – By Gender	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	Local residents, all	**Local resident, female**	**Local resident, male**	**Migrant, all**	**Migrant, female**	**Migrant, male**
Square meters per person	-0.029 ***	-0.046 **	-0.015	0.002	0.002	-0.006
	[0.011]	[0.018]	[0.015]	[0.012]	[0.021]	[0.019]
Share of urban green space within 1 km radius	-1.188	-1.915	-0.976	-5.063 ***	-3.829	-8.193 **
	[1.439]	[2.320]	[1.992]	[1.928]	[2.608]	[3.675]
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
District-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	596	274	322	393	210	183

Panel B – By Marital Status	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
	Local residents, all	**Local resident, married**	**Local resident, single**	**Migrant, all**	**Migrant, married**	**Migrant, single**
Square meters per person	-0.029 ***	-0.010	-0.303 **	0.002	0.028	-0.010
	[0.011]	[0.013]	[0.120]	[0.012]	[0.020]	[0.022]
Share of urban green space within 1 km radius	-1.188	-1.999	9.038	-5.063 ***	-4.922 **	-4.320
	[1.439]	[1.573]	[7.207]	[1.928]	[2.273]	[4.369]
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
District-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	596	502	94	393	275	118

Note: Logit regression with screening positive for depression (y/n) as dependent variable. "Local residents" refers to those holding a Beijing *hukou*, and "migrants" refers to those not holding a Beijing *hukou*. Control variables include age, gender, household income, living with family members, home ownership in Beijing, community type, education, job type, and district-fixed effects. Standard errors are shown in brackets. *, **, and *** represent significance at the .10, .05, and .01 levels, respectively.

Robustness Checks

We have conducted several sensitivity analyses to test the robustness of our findings. First, we changed the continuous living space per capita variable into a categorical variable (with cutoff values of 1 and 1.5 persons per bedroom), and the main findings still held. Second, we tested alternative buffer radii of 500 meters and 800 meters for the green space variable, replacing the original 1 km buffer. The results indicate that the main regression outcomes remain robust across different spatial definitions. Third, we deleted the outdoor green space variable for the local resident group (which is significant only for indoor living space) and deleted the indoor living space variable for the migrant group (which is significant only for outdoor green space). Removing these corresponding insignificant exposure variables did not change the main findings. Fourth, following the existing literature on the mental health effects of other built environment variables, we included additional control variables, such as building heights, commute time, physical activity levels, and life stressor variables. Adding these additional variables did not change the main results. Fifth, we estimated variance inflation factors (VIFs) and found no evidence of multicollinearity. Sixth, we ran multilevel models with the same set of outcome, exposure, and control variables, and the main results remained consistent. Lastly, we clustered the standard errors at the community level to match the level of variation of the green space variable, and the main results are largely unchanged.

Discussion

Using survey data from Beijing, we find that both indoor residential crowding and outdoor green space are significantly associated with depression risk. However, the particular factors that significantly affect mental health vary across different subgroups. Specifically, higher levels of residential crowding are associated with an increased risk of depression only for local residents, not for migrants, whereas lower neighborhood green space availability is linked to higher depression risks only for migrants, not local residents. Moreover, the connection between residential crowding and depression is more pronounced for female or single local residents, whereas the relationship between neighborhood green space and depression is stronger for male or married migrants.

The finding that a higher level of residential crowding is linked with a higher depression risk aligns with previous studies on residential crowding and psychological well-being (Ruiz-Tagle and Urria 2022; Sarkar et al. 2014). Our finding that the residential crowding–depression link is significant only for local residents, not migrants, aligns with Li and Liu (2018), who found that housing quality, rather than living space, matters for stress levels among migrants in Chinese cities. Several factors may explain this migrant–local resident discrepancy. Many migrants in Chinese cities view their accommodations as temporary and plan to return to their hometowns once they have sufficient savings (Du et al., 2018; He et al., 2010). This mindset may reduce the psychological impact of crowding, as migrants often frame current housing as a temporary sacrifice for better economic, educational, or social opportunities (Chen and Liu 2016;

Li and Rose 2017). Although migrants frequently face economic precarity, social exclusion, and institutional barriers, they are not necessarily more depressed at baseline; rather, their sense of purpose and hope for improvement can act as a psychological buffer. Prior research also suggests that migrants' stronger social cohesion, place attachment, and the support of close-knit communities may enhance resilience to crowded living conditions (Du et al. 2018; He et al. 2010; Li and Wu 2008; Yu et al. 2019). In line with this, the expectation–reality gap is critical: migrants may "suffer less" from crowding because they anticipate such conditions and accept them as part of the price for better opportunities, whereas local residents, with higher expectations of housing quality, are more likely to experience frustration.

We have also found that higher green space availability is associated with lower depression risks for migrants, consistent with previous studies highlighting the positive mental health effects of green space (Brown et al. 2018; Qin et al. 2021; Wu and Kim 2021). The mental health benefits of green space are significant only for migrants – not local residents – aligning with Yoo et al.'s (2022) study in New York City, which showed significant mental health benefits from urban green space only in socially disadvantaged neighborhoods, and with Brown et al.'s (2018) nationwide study in the US, which found greater mental health benefits from urban green space in low socioeconomic neighborhoods. In Chinese cities, one explanation is that local residents typically have more mobility options and access to a broader range of activity spaces beyond neighborhood green space, while migrants often have more limited activity spaces (Liu et al. 2020; Ta et al. 2021). Evidence also suggests that migrants in Chinese cities visit neighborhood

parks more frequently than local residents (Zhao and Wang 2018). The wider range of activity options available to local residents may dilute the mental health benefits from neighborhood green space, making these effects less pronounced.

Our subsample analysis on the residential crowding–depression association reveals that such local resident-specific effects are relatively stronger for females or singles. The gender difference aligns with previous empirical evidence in Canada indicating that females tend to experience greater mental health impacts from residential crowding (Regoeczi 2008). While women in high-density living environments are more prone to internalized stress outcomes such as depression, men tend to exhibit externalized or withdrawal behaviors (Regoeczi 2008). This suggests that the stronger depression effects observed among women may not only reflect exposure differences but also gendered coping mechanisms. Possible explanations include gender differences in affective, biological, and cognitive characteristics, as well as differences in household responsibilities, which may exacerbate stress for females in crowded living conditions (Hyde et al. 2008; Parker and Brotchie 2010). In Chinese cities, many women live in shared rental housing or multi-generational households, which can provide support but also heighten pressures related to childcare, eldercare, and household responsibilities. These added demands, combined with limited privacy in crowded housing, may help explain why women exhibit stronger associations between crowding and depression in the Beijing context. Additionally, the finding that single local residents are more affected by residential crowding is consistent with research from Hong Kong showing that single individuals are more susceptible to depression

under adverse living conditions (Cheung et al. 1998). Singles may lack the social support that married individuals often have and experience greater feelings of loneliness or isolation, making them more mentally vulnerable to crowded living conditions (Buckman et al. 2021; Cheung et al. 1998).

We also found that the neighborhood green space–depression association, seen only in migrants, is stronger for males or married migrants. The finding that male migrants are more "mentally sensitive" to neighborhood green space connects with research showing males and females have different activity patterns in the same urban green spaces. For instance, females typically visit neighborhood parks less and engage in lower levels of physical activity compared to males (Derose et al. 2018; Fontán-Vela et al. 2021). The finding that the green space–depression link might be stronger for married migrants echoes studies showing that married persons use neighborhood green spaces more frequently than singles, likely through family-related activities—as almost all (98%) married migrants in our sample live with their families (Enssle and Kabisch 2020; Schipperijn et al. 2010). Admittedly, due to data limitations, we do not have information on urban green space visit frequencies, and further research is needed to confirm these mechanisms.

Our sub-sample analyses also highlight a few subgroups that are relatively more mentally sensitive to crowded indoor living spaces or limited outdoor green spaces: namely, females and single local residents for the former, and males and married migrants for the latter. Planners and policymakers can prioritize these vulnerable subgroups to address place-based inequalities when

conducting housing subsidies and designing neighborhood public spaces (Rosen et al. 2022; Hirt and Campbell 2023). Furthermore, as discussed above, certain sub-sample differences may reflect the groups' different social settings, and tailored interventions focusing on these social differences would be helpful. For instance, community engagement programs such as community garden projects can mitigate isolation and promote social interactions, which may help alleviate the negative impact of residential crowding on singles. Additionally, the relatively lower usage of green space by females is often due to safety concerns; thus, establishing safe and accessible recreational spaces can address their greater sensitivity to environmental stressors. In sum, effective planning should not only be comprehensive and cover different spatial aspects but also consider the needs of different demographic and social groups to foster healthier urban built environments.

This study has the following limitations, many of which should motivate future research. First, we can only claim the relationships observed as associational rather than causal, due to the nature of cross-sectional data. Future longitudinal studies could help reveal the causality of how the physical environment may affect people's mental health. Second, as there are 40 communities in our study, the neighborhood green space variable only has 40 distinct values across the 989 observations, making the variation in the proportions of urban green space smaller than that of individual-level residential crowding variables. Third, the residential crowding variable is self-reported, and its reliability would be enhanced by complementing it with objectively measured variables. Fourth, our data do not include migrants' expectations or perceptions of crowding.

Future studies should examine whether these factors and the "expectation-reality gap" can affect the impact of residential crowding on mental health. Fifth, our study did not collect information on time spent in or use of green spaces, which would help provide a clearer picture of the mechanisms through which neighborhood green space affects mental health – especially across different socio-demographic groups. Sixth, the insignificance of the green space variable in the single migrant subsample should be interpreted with caution, as the coefficient's magnitude is comparable to that of the married migrants, and the model for the single migrant subsample has a small sample size. Lastly, future research may benefit from systematically examining the mental health effects of built environment factors across multiple spatial scales (household, neighborhood, city, regional, and beyond) to better capture the layered and interacting influences of factors across different geographical levels.

Conclusions

Using survey data from Beijing, China, our findings show that inequalities in the urban built environment – both indoor and outdoor – can lead to mental health disparities. However, the specific factors associated with mental health vary across groups: indoor residential crowding significantly affects only local residents, while outdoor green space availability affects only migrants. Moreover, the effects vary by gender and marital status: the crowding–depression relationship is more pronounced for female or single local residents, while the green space–depression relationship is more pronounced for male or married migrants. These findings

underscore the need for urban planning that is both comprehensive and targeted, incorporating both indoor and outdoor built environment factors and addressing the specific needs of groups more mentally sensitive to these factors. By addressing the distinct needs of local residents, migrants, and vulnerable groups, we can enhance the built environment across scales, fostering healthier and more equitable cities.

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