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Effects of urban green spaces on residents' well-being

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Abstract Beijing is undergoing continuous urbanization, and considering the individual availability of urban green spaces is essential for alleviating the ecological problems created by this urbanization, especially in relation to improving residents' well-being. To prove this effect, this article analyzed the social, mental, and physical well-being of current Beijing residents to determine their level of satisfaction, then applied the seemingly unrelated regression model to study how Beijing's urban green spaces impact this well-being. The result showed that the higher the degree of resident participation with green spaces, the higher their well-being. Such participation includes actions like the frequency at which residents visit a park or green space. A significant inverted U-shaped effect was found between residents' well-being and their distance from a park or public green space, indicating that residents with the highest well-being live between 1 and 5 km away, and residents with the lowest well-being live over 10 km away. Further, age, education, career status, marital status, years of residence in Beijing, residential area, and average income per month also have a significant impact on residents' well-being. This study shows that green spaces can have a very positive effect on people's welfare and provides support for their further promotion.

Keywords Urban land use · Utilization · Well-being · Urban planning

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1 Introduction

With the acceleration of the urbanization process in Beijing, the demand for urban land is increasing; as a result, a considerable amount of pressure has been placed on expanding green spaces, which fulfill an ecological function for the public. At the end of 2015, the resident population of Beijing was 21.75 million and the resident urbanization rate was 86.5% (Beijing Municipal Bureau of Statistics 2016). These figures show that there is a large demand in the city for urban green spaces and its related ecosystem services (e.g., provisioning services, regulating services, and cultural services). However, industrialization, urbanization, and increases in the resident population exacerbate urban environmental problems. In 2016, the number of days during which Beijing's air quality failed to meet a safe standard amounted to 167; further, current levels of NO2, PM10, and PM2.5 all surpass national standards, particularly the annual average concentration of PM2.5, which is currently in excess of 109% of the national standard and has reached 73 μg/m^3 (Beijing Municipal Environment Protection Bureau 2017). Since the material and cultural needs of Beijing residents can be considered as having been met, the demand that Beijing's environmental issues be addressed is increasing, as the present environmental conditions are far from satisfactory. Air pollution and environmental disasters have a negative influence on residents' well-being (Ferreira et al. 2013); smog is particularly damaging in this regard, as it brings serious health problems and huge social health costs (Cao and Han 2015). Data show that in 2014–2016, the average annual dust-retention rate of Beijing's garden greening initiative was approximately 9800 tons, of which fine dust accounted for 100 tons and coarse particulate matter approximately 1200 tons; the remaining dust equated to approximately 8500 tons, which is equal to an extra 15 days of second-level air quality (Tie and Lun 2017). In order to continue to address this problem, the Beijing municipal government has increased the construction of green landscaping.

The total size of urban green spaces has increased annually, reaching 82,122 ha, which is equal to more than the area of 10,000 football fields, and in the future, more land will be allocated for the construction of urban green spaces. In addition, the per capita park area of Beijing has reached 16.1 m^2, the urban green spaces coverage rate (ratio of total area of green space in cities to total land area in cities) has reached 48.1%, the forest greening rate is 59.3%, and the forest coverage rate is 42.3%. As these rates continue to increase, the living environment further improves. The Beijing Municipal Bureau of Landscape and Forestry is responsible for the construction of urban green spaces. The Beijing Municipal Government pays close attention to the construction of green spaces, and efforts to expand the green space in Beijing have become the focus of their work. In 2016, the total amount of funds dedicated to landscape and forestry has reached 16 billion yuan[1] (Beijing Municipal Bureau of Landscape and Forestry 2017). Urban green spaces include city and country parks, botanical gardens, zoos, cemeteries, small gardens, and street and square green spaces. In this study, we mainly considered city and country parks and community or square green spaces.

The theory that urban green spaces have positive influence on residents' well-being has been widely advanced by scholars (Ekkel and Vries 2016). Direct benefits include the creation of areas in which residents can perform recreational and physical exercise and locations where nature and the public can meet; this can not only enhance

[1] USD1 = CNY6.67.

the general health of the public but can also increase happiness. Additionally, indirect benefits include mitigating noise and urban heat island effects, improving air quality, and reducing crime rates (Ae et al. 2010; Owen and Phillips 2016; Gidlöf and Öhrström 2007; Ambrey 2012). A specific study on this topic was conducted by Krekel et al. (2016), who investigated the effect the use of urban land had on residential well-being in major German cities. Their results showed that the closer city parks and green spaces to residents, the higher the residents' well-being; further, this positive effect was more significant in relation to the elderly. Bertram and Rehdanz (2015) observed that the amount of and distance to urban green spaces had a significant, inverted U-shaped effect on well-being. Similarly, Ambrey and Fleming (2012) found a positive and nonlinear relationship between the percentage of public green space in residents' local areas and their self-reported well-being. Specifically, they found that single-parent families, low levels of education, and high buildings cause residents to gain a higher level of well-being from public green spaces. Urban green spaces not only have a significant effect on residents' well-being, but also have a significantly positive impact on the public's physical and mental health. Through empirical research, White and Depledge (2013) found those living closer to urban green spaces such as parks, suffer less mental distress. When Richardson and Mitchell (2010) investigated the physical condition of British residents, they found that men living in green spaces suffered less from cardiovascular and respiratory disease than those who did not live in a green space, but no significant associations were found for women; this proves that green spaces can provide a buffer against the negative health impacts of stressful life events (Dzhambov and Dimitrova 2014). Larson et al. (2016) examined the influence of parks on comprehensive measurements for subjective well-being at the city level and found that park quantity, park quality, and accessibility were positively associated with well-being. In another branch of related study, scholars used the life satisfaction method to measure the value of urban green spaces; one such study found that residents' willingness to pay for green spaces decreased as the amount of available green spaces increased (Tsurumi and Managi 2015). Among the influencing factors of public welfare satisfaction, individual characteristics and location characteristics are significant. Xu et al. (2014) found that monthly income, working conditions, household type, and satisfaction with community services, along with other factors, have a significant impact on the public's well-being. Furthermore, the degree of fear in the public also plays an important role in their well-being; if the public is insecure, concerned, or fears the surrounding living environment, the green space does not generate any welfare effects (Fleming et al. 2016).

In summary, urban green spaces have important ecological service value, which has a significant effect on public health and well-being. Although the government has increased investment in the construction of such spaces, suitable areas for urban green spaces are limited as a result of accelerating urbanization; therefore, the correct methods for using existing landscaping space so that residents' cognition and well-being are improved constitute an important question. Considering the above, on the one hand, this study employs an empirical test to discuss the impact of the use of green spaces on residents' well-being, which includes physical, mental, and social well-being. On the other hand, we will also analyze factors that can influence residents' well-being, such as their individual characteristics and location conditions, in order to determine a more specific method of improving urban construction in Beijing in such a way that citizens' welfare is benefitted.

2 Materials and methods

2.1 Data collection

Data collection for this study was performed in November 2016. The survey was conducted using a structured questionnaire focusing on demographic characteristics, demand, attitude, cognition and satisfaction toward green spaces, green spaces utilization and accessibility, and individual well-being. The design of the questionnaire followed the survey technical manual, and technical guide of German Socio-Economic Panel (SOEP) and China Health and Retirement Longitudinal Study (CHARLS) (Wagner et al. 2007; Zhao et al. 2015). Surveys were conducted by 24 trained social researchers, who were social science masters, and undergraduate students who had some research experience. We selected parks, public green spaces, and communities in Haidian, Chaoyang, Dongcheng, Xicheng, Miyun, and Yanqing Districts for study. To ensure the reliability and credibility of the questionnaire, our team was trained in questionnaire techniques and methods before beginning their investigations. During the process, the respondents completed questionnaire sheets, and our investigators assisted by explaining any questions with which the respondents had difficulty. The investigators also helped elderly people who were unable to finish the sheets by themselves. It took approximately 20–30 min to complete one questionnaire. Before the interview, we told participants they would receive a gift after the survey in order to encourage them to participate; once they had finished, the respondents received thank-you gifts like spring water or soft drinks.

Next, samples were selected using multistage and cluster sampling. Firstly, considering the differences between urban green spaces and urbanization in the urban and suburban areas of Beijing, we chose four districts in urban areas and two in suburban areas, and we selected representative sites in each district. Beijing has a total of 16 municipal districts. Among them, Haidian, Chaoyang, Dongcheng, Xicheng, Shijingshan, and Fengtai are the main cities. We refer to these as the six urban districts; the other districts are known as suburban districts. In the urban districts, Haidian, Chaoyang, Dongcheng, and Xicheng are located close to the city center. Their level of economic development and population density are among the top four. Fengtai and Shijingshan are located far away from the city center and are not sufficiently represented in the urban districts. We chose more urban than suburban districts for this study because Beijing's urban green spaces are constructed in urban areas and most citizens live in these locations.

A total of 1002 residents were randomly selected from the study areas. The questionnaire collection was completed in 3 days, with four investigators in each district forming an investigation team. Considering the large population of Beijing, the survey anticipated the receipt of approximately 1000 completed questionnaires, given the difficulty of each district survey (number of citizens, transport accessibility). Therefore, we asked each investigation team to complete a total of at least 150 questionnaires, comprising not more than 200 responses, to ensure that the number of samples in each county does not differ significantly. The specific distribution of the number of questionnaires is shown in Table 1; however, a crosscheck was performed with each questionnaire in order to guarantee the quality of the data. If the questionnaire was not at least 80% complete or if it was filled out randomly, we treated it as an invalid questionnaire and eliminated it. Accordingly, 927 questionnaires (91.6% of the total) were used in the final, valid sample.

A formal household survey was conducted using a structured questionnaire containing questions related to the basic situation of the respondents (e.g., gender, age, education,

Table 1 Questionnaire distribution

	Miyun district	Yanqing district	Chaoyang district	Haidian district	Xicheng district	Dongcheng district	Number of observations
Park	69	58	60	63	52	50	352
Square green space	60	57	50	55	58	52	330
Community green space	57	50	53	50	57	51	318
Number of observations	186	165	163	168	167	153	1002

living area, and income), as well as their cognition of urban green spaces development and environment improvement, utilization and participation in activities in urban green spaces, current well-being, satisfaction with urban green spaces, evaluation of the development of Beijing landscaping, and any efforts they have made to improve the ecological environment. Specifically, we used three indicators to represent residents' well-being: physical, mental, and social welfare; these indicators were selected based on research conducted by Krekel et al. (2016), Bertram and Rehdanz (2015), Welsch and Kühling (2009), and Puhakka et al. (2016). Lastly, the indicators for each respondent were determined using a five-point single-item Likert scale that featured the following questions: "How satisfied are you with your current social interpersonal relationships," "How satisfied are you with your current mental health?" and "How satisfied are you with your current physical health?" We hypothesized that indicators of the frequency of going to public green spaces and the distance to green spaces would emerge as significant explanatory variables in models predicting well-being.

2.2 Research method

2.2.1 Model building

As this study examines the impact of urban green spaces on residents' well-being, the dependent variable is residents' well-being, comprising of social, mental, and physical well-being. Additionally, the degree of urban green spaces utilization is the main variable, while individual and geographical characteristics are the main control variables. Hence, we can build the equations as follows:

$$Y_{1i} = \beta_0 + \beta_1 PG_{1i} + \beta_2 X_{1i} + \varepsilon_i \tag{1}$$

$$Y_{2i} = \beta_0 + \beta_2 PG_{2i} + \beta_2 X_{2i} + \mu_i \tag{2}$$

$$Y_{3i} = \beta_0 + \beta_1 PG_{3i} + \beta_2 X_{3i} + \gamma_i \tag{3}$$

In Eqs. (1), (2), and (3), Y_{1i}, Y_{2i}, and Y_{3i} show the residents' satisfaction in terms of social, mental, and physical well-being, PG_{1i}, PG_{2i}, and PG_{3i} represent the degree of urban green space utilization in the variable vector group, which includes frequency of going to city parks per month, frequency of going to country parks per month, frequency of going to community or square green spaces per week, the cost of potted green plants per year, and the distance to the nearest public green space. X_{1i}, X_{2i}, and X_{2i} are the individual characteristics of the variable vector group, which includes age, gender, education, occupation, marital status, living period in Beijing, housing type, living area, average household income, etc. The value of these variables is shown in Table 2. β_0, β_1, and β_2 are the coefficient vectors, and ε_i, μ_i, and γ_i are the random disturbance terms.

2.2.2 Estimation method

Residents' perception of their current life status can be evaluated by determining three aspects: social interpersonal satisfaction, physical health satisfaction, and mental health satisfaction. These three aspects combined were used as the dependent variable. Although the explanatory variables may differ, a resident's unobservable factors can concurrently influence their social, mental, and physical well-being, so the random disturbance terms are related. Thus, we have combined the three equations to estimate the efficiency of the

Table 2 Descriptive statistics concerning the respondents' characteristics

Variables	Definition	Mean	SD
Social well-being	1 "very dissatisfied" to 5 "very satisfied"	3.596	1.120
Mental well-being	1 "very dissatisfied" to 5 "very satisfied"	3.660	1.104
Physical well-being	1 "very dissatisfied" to 5 "very satisfied"	3.498	1.142
Gender	1 if "male," 0 if "female"	0.455	0.504
Age			
Under 30 years old	1 if "age Under 30 years old," 0 else	0.429	0.495
30–44 years old	1 if "30–44 years old," 0 else	0.287	0.452
45–64 years old	1 if "45–64 years old," 0 else	0.145	0.353
Above 65 years old	1 if "Above 65 years old," 0 else	0.139	0.346
Education			
High school or college and below	1 if "High school or college and below," 0 else	0.630	0.483
Bachelor degree	1 if "Bachelor degree," 0 else	0.308	0.462
Master's degree and above	1 if "Master's degree and above," 0 else	0.063	0.242
Occupation			
Full-time employed	1 if "full-time employed," 0 else	0.581	0.493
Part-time employed	1 if "part-time employed," 0 else	0.132	0.338
Retired	1 if "retired," 0 else	0.125	0.331
Unemployed	1 if "unemployed," 0 else	0.162	0.369
Student	1 if "Student," 0 else	0.002	0.046
Marital status			
Married	1 if "married," 0 else	0.455	0.498
Unmarried	1 if "Unmarried," 0 else	0.002	0.046
Divorced	1 if "divorced," 0 else	0.001	0.033
Living period in Beijing			
1–5 years	1 if "Living period in Beijing is about 1–5 years," 0 else	0.276	0.447
5–10 years	1 if "Living period in Beijing is about 5–10 years," 0 else	0.093	0.291
10–15 years	1 if "Living period in Beijing is about 10–15 years," 0 else	0.114	0.317
Above 15 years	1 if "Living period in Beijing is above 15 years," 0 else	0.517	0.500
Housing type	1 if "own a house," 0 if "rent a house"	0.837	0.370
Living area	1 if "urban," 0 if "suburban"	0.713	0.452
Average household income (yuan)			
Below 5000	1 if "average household income below 5000," 0 else	0.253	0.435
5001–10,000	1 if "average household income between 5001–10,000," 0 else	0.299	0.458
10,001–15,000	1 if "average household income between 10,001–15,000," 0 else	0.320	0.466
Above 15,000	1 if "average household income above 15,000," 0 else	0.128	0.335

evaluation. Notably, the three explanatory variables are discrete, so there is a measurement deviation if we use the ordinary least squares (OLS) model. In such a situation, we would generally use the ordered logit model, but some problems would remain, such as discrete

models for ordinal variables, which are not easily applicable to the seemingly unrelated regressions estimation (SURE), and the bias resulting from this measurement error has been found to be negligible (Ferrer-i-Carbonell and Frijters 2004), if the result of the ordered logit model is similar to that of the OLS (Ferreira and Moro 2010). If we use the ordered logit model to estimate the parameters of the three model equations separately, the estimation of the model parameters is not valid since we neglect the linear correlation between random errors (Song et al. 2016). Hence, to improve the efficiency of the estimates, we employed the SURE model to estimate the parameters of the three model equations and determine whether there is a significant relationship between urban green spaces and residents' well-being, as well as the intensity of any such relationship. However, joint estimation in a multi-equation system has some limitations. If the error of one equation is large, the system estimates that the error of this equation will be incorporated into other equations, contaminating the whole system. In a sense, choosing a single equation estimate or system estimate is also a trade-off between "effectiveness" and "robustness" (Chen 2014).

3 Results

3.1 Sample characterization

The descriptive statistics for the characteristics are shown in Table 2. According to the table, the scores for mental well-being are the highest, followed by social well-being, while the scores for physical well-being are the lowest. The proportion of men and women in the sample population are almost equal, with slightly more women than men; more than 90% had a bachelor's degree or below (specifically, 30.8% of the respondents had a bachelor's degree, 63% had finished high school or college and below, and the others had a master's degree or a doctorate); full-time employed and part-time employed were in the majority in terms of employment status; married people constituted the largest group with regard to marital status. In relation to residential status, over 70% of the respondents had lived in Beijing for over 5 years; over 80% of the housing types were self-housing; and the residents mainly lived in urban areas, with only approximately three percent living in the suburbs. Further, a large proportion of residents earned over 5000 yuan per month, with most incomes concentrated between 5000 and 15,000 yuan. In 2016, the annual per capita disposable income of urban residents in Beijing was 57,275 yuan; the middle and high-income groups had a monthly income of 5000 yuan and above. Residents in Beijing who use the green spaces mostly belong to the middle and rich classes.

Residents' utilization of urban green spaces and their accessibility are shown in Fig. 1. Overall, the ratio of public use of and participation with urban green spaces' use is very high; the frequency per month at which the majority of the public visits city or the country parks is more than six times; the frequency of community or square green space visits per week is three or more. This is because our respondents were mainly chosen in the parks or public green spaces that have a high visitation rate among urban green spaces; most of the parks we chose are free for citizens to visit. Furthermore, respondents over 50 years old make up a large proportion of those who like to go to urban green spaces to exercise or for recreation. Besides, it can be seen that the public spent a lot of money on the purchase of potted green plants, with most of the respondents spending over 300 yuan per year in this

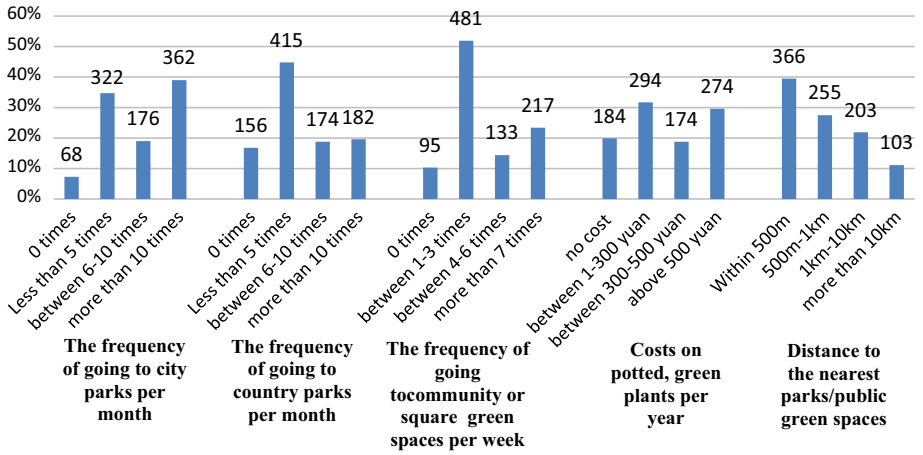

Fig. 1 Residents' utilization and accessibility of urban green spaces

regard. The distance from home to the nearest parks/public green spaces is mainly within 1 km.

3.2 The influence of urban spaces on residents' well-being

The influence of urban green spaces on residents' well-being is shown in Table 3. Through this, we can see that individual characteristics and the participation and utilization of urban green spaces have different influences on residents' well-being.

With regard to individual characteristics (see Table 4 in Appendix), age is shown to be a variable that has a significant impact on residents' well-being. Compared to people under 30 years of age, people of 45–64 are significantly more satisfied with their social and mental well-being; people over 65 years old are also significantly more satisfied with their social well-being and mental well-being, but are less satisfied with their physical well-being. The higher the level of education, the higher the residents' social well-being, but education does not create a significant change in mental or physical well-being. Current professional status is also an important factor. Compared to those who have a full-time occupation, those working part-time or who are unemployed have significantly negative social well-being. Further, part-time workers and the unemployed also have negative mental well-being, retired people have lower physical well-being, and students have significantly higher physical well-being. Marriage was also found to have a significant impact; compared to married individuals, divorcees have negative social, mental, and physical well-being. Compared with people who have lived in Beijing for 5 years, those living in Beijing for over a decade showed positive social and mental well-being. Compared to those renting, those who owned their own houses had significantly positive social and mental well-being, while living in the four districts in the urban area was found to have a negative impact on residents' physical health. Although the level of green spaces construction in urban areas is higher than that of suburban districts, the environmental conditions are significantly worse, which significantly affects physical well-being. Further, the effect of income on residents' well-being is significant; the higher the income level, the higher the social, mental, and physical well-being.

Table 3 The SURE result of the impact of urban green spaces' utilization and accessibility on residents' well-being

Well-being	Social well-being	Mental well-being	Physical well-being
Number of visits to city parks per month; 0	Reference	Reference	Reference
6–10	0.1314	0.2648*	0.2752*
	0.1535	0.1595	0.1603
Over 10	0.3460*	0.3362*	0.3111*
	0.1798	0.1857	0.1767
Number of visits to community or square green spaces per week; 0	Reference	Reference	Reference
1–3	0.2676*	0.2621*	0.2442*
	0.1425	0.1472	0.1401
4–6	0.2906*	0.288*	0.3247**
	0.167	0.1724	0.1641
Over 7	0.2005	0.3034*	0.4151**
	0.176	0.1817	0.1729
Distance to the nearest park/public green space; within 1000 m		Reference	Reference
1–5 km		0.2615***	0.2293**
		0.0948	0.093
5–10 km		−0.1101	−0.0819
		0.1019	0.0999
Over 10 km		−0.2808**	−0.2408*
		0.1315	0.1383
Money spent on potted green plants per year		Reference	Reference
1–300 yuan		0.2610**	0.2858**
		0.1154	0.1132
300–500 yuan		0.2592**	0.2802**
		0.1308	0.1282

Table 3 (continued)

Well-being	Social well-being	Mental well-being	Physical well-being
Over 500 yuan		0.2674**	0.3238***
		0.1293	0.1268
Obs	942	942	942
RMSE	1.0606	1.095	1.0735
R^2	0.1028	0.0883	0.0589
χ^2	107.88	91.19	59.01

***, **, and * denote significance at the 1, 5, and 10% levels, respectively

Regarding the participation in and utilization of urban green spaces, the degree of public participation in urban green spaces was found to have a significantly positive impact on residents' well-being. To be more specific, people who visit city parks over six times per month are more satisfied with their mental and physical well-being. The reason for this is that the use of parks or public green spaces for recreation makes people feel happy and relaxed and provides people with a space to exercise. Concurrently, social interaction is increased in such places, the emotions of relatives and friends are improved, family cohesion is increased, and social welfare is enhanced. Purchasing potted green plants was found to have a significant positive impact on the residents' physical and mental well-being.

Additionally, the distance from the nearest park or public green spaces has a significant impact on well-being, but this relationship between distance and well-being is not linear, instead it shows a significant inverted U-shaped effect. Compared to people who live within 1 km of a park or public green space, people who live at a distance of 1–5 km have significantly higher mental well-being and better health, and those at a distance >10 km have negative mental and physical well-being. On the one hand, the closer green spaces are to the home address, the higher the degree of participation, including using the space for rest, exercise, etc. This increases public participation with the gardens. On the other hand, the ecological role of green spaces in improving the surrounding environment, alleviating the city heat island effect, and reducing dust is unparalleled. However, people living <1 km away tend to experience negative effects of park or public green space construction; for example, increases in visitors affect surrounding residents' daily life and cause traffic congestion, creating great inconvenience; hence, the satisfaction of people who live close to the park is not very high. People who live at a distance of between 1 and 5 km can not only enjoy the ecological function of green spaces, but can also effectively avoid the negative effects of its establishment; however, people who live at a distance of more than 10 km cannot easily enjoy the ecological services of green spaces. Finally, the more people spend on potted green plants, the greater the increase in their mental health and physical well-being. With regard to social well-being, income and education are more important influencing factors than urban green space utilization. For mental well-being, urban green space utilization and age are most crucial. For physical well-being, income and urban green spaces utilization are the top two critical factors, more important than the other factors, such as age, education, and employment.

Due to space limitations, we only reported significant result; the results of the effect of respondents' characteristics on well-being are shown in "Appendix" section.

4 Discussion and conclusion

The construction of urban green spaces can have a significant impact on residents' well-being, but the impact is not linear; people who live between 1 and 5 km from such areas have the highest level of well-being, while those at a distance of over 10 km have the lowest. The higher the frequency of participation with the space, the higher the well-being, which shows that regularly visiting a city park or public green space has a significantly positive impact on welfare, especially in terms of physical and mental well-being. Purchasing potted green plants also has a significantly positive impact on residents' physical and mental well-being. Further, individual characteristics are important factors; age, education, occupation status, marital status, years living in Beijing, residential area, and

average income per month have a significant impact on the residents' well-being; however, the impact of gender is not significant.

The results of this study further verify that public green spaces have significant positive effects on human well-being (White and Depledge 2013; Kabisch et al. 2015; Fleming et al. 2016); the inverted U-shape relationship between distance to green spaces and well-being, which corresponds to Bertram and Rehdanz (2015), particularly demonstrates these effects. In addition, higher income is associated with greater well-being, and education, occupation status, marital status have significant effects on well-being, further supporting the existing research (Kahneman et al. 2004; Ambrey and Fleming 2012; Xu et al. 2014). Findings specific to this study are as follows: we can improve our well-being by taking an active part in urban green space utilization by increasing the frequency of our visits to green spaces and by buying potted green plants four our home or workplace. We also found that residents who live in urban areas experience a more negative effect on well-being than those living in suburban districts.

However, this research has some limitations. Because the respondents were mainly chosen from urban green spaces, these people have a high ratio of public use of and participation with urban green spaces. They are more keen to be close to nature and to enjoy nature compared to general citizens. The conclusions cannot represent the general citizenry in Beijing. In order to get a general conclusion about the relationship between urban green spaces and human well-being, it would be more effective to adopt a combination of web and face interviews, which can get a more representative sample of the total citizens. Our exploratory study revealed significant associations between public green spaces and subjective well-being, but regarding the idea that the specific use of public green space is conducive to the improvement in well-being, this study did not conduct in-depth discussion; for example, does the reason for its use (e.g., exercise, landscape appreciation, or environmental education) influence human well-being. Furthermore, because the urban ecosystem has many types, like urban wetlands, urban forests, and urban ancient and rare trees, it is meaningful to discuss the relationship between these urban ecosystem types and well-being in the future. In addition, there is abundant literature highlighting the benefits of natural spaces on emotional well-being (Huynh et al. 2013; Wells and Evans 2003). Emotional health considers how one expresses or is aware of their emotional state(s). Positive emotional well-being is fundamentally important for the general health status; it is associated with many favorable health outcomes (Ward et al. 2016). Moreover, emotional state emerges as a large gap that predicts the perception of current life (Brooks et al. 2015). However, in this study, we did not consider emotional well-being.

From the above, it can be seen that urbanization has a negative impact on residents' well-being, as it brings a large increase in population, increasing demand for urban land space and causing increasingly prominent environmental problems. Under these circumstances, it becomes clear that urban green spaces are essential and important for enhancing residents' well-being. Urban green spaces provide a unique form of social gathering space in congested cities, parks and other natural settings; these spaces facilitate social interactions and collaboration (Zelenski et al. 2015) and contribute to a sense of community or neighborhood attachment (Kuo et al. 1998). In addition, urban green spaces are perfect places for recreation, reflection, and cognitive growth; parks can supply urban residents with a sense of satisfaction and goal fulfillment that fosters a sense of purpose (Russell et al. 2013).

When constructing urban green spaces, it is necessary to consider the further use of existing landscaping resources in order to enhance residents' well-being, since existing space is increasingly scarce. This study shows that the higher the degree of public use of

green spaces, the higher the residents well-being and satisfaction; therefore, the government should encourage the public to participate in green spaces use by reducing the price of park tickets and opening more public green spaces, while also pursuing other measures to attract the public. Concurrently, the government must strengthen the legalization of landscaping, as this will promote the further development of Beijing's landscaping-management system, and continuously enhance the functions and levels of urban green spaces. Urban landscaping is not only a welfare project for the public, but also reflects a city's image; however, we cannot increase investment in landscaping without considering some important questions, such as traffic conditions and maintenance costs. In other words, urban green spaces construction should also consider local conditions and avoid exacerbating urban challenges.

Beijing has a high population density, with serious environmental pollution, a lack of biodiversity, and other issues; coupling this with busy lives and a high cost of living means that many people in the city live in a sub-health state (Zhou et al. 2015). Hence, the improvement in residents' well-being cannot be delayed. For the public, participating in the use of green spaces to enhance their own welfare is important but, occasionally, factors such as living busy lives, living a long distance away, and smog will dispel enthusiasm. From a regional point of view, respondents living in urban areas had well-being that was significantly lower than the suburban residents, especially with regard to physical well-being. Although the urban districts have better access to medical facilities and a large investment in landscaping and green spaces, daily challenges are also more prominent, especially haze pollution, traffic congestion, housing tension and other issues. In this instance, it is necessary to further increase green space in urban districts and also to highlight the suburban districts' green space construction (Bell et al. 2008; Krekel et al. 2016). By improving the ecological environment of suburban districts to further encourage the urban population to move to or visit suburban areas, thus alleviating the problem of urban development. Finally, the public should be aware of the effect of city public green spaces on subjective well-being to enhance the significance of their role in increasing the use of public green space, in public green space as child education, and as important places for physical exercise and recreation.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

Appendix: The SURE result regarding the impact of residents' characteristics on well-being

See Table 4.

Table 4 The SURE result about residents characteristics on well-being

Well-being	Social well-being	Mental well-being	Physical well-being
Under 30 years old	Reference	Reference	Reference
45–64 years old	0.2633**	0.2546*	−0.0772
	0.1456	0.1503	0.1474
Over 65 years old	0.2850*	0.3246**	−0.2949*
	0.1555	0.1605	0.1574
High school or college and below	Reference	Reference	Reference
Bachelor's degree	0.1744**	0.0841	−0.059
	0.0842	0.0885	0.0867
Master's degree and above	0.1842***	0.1004	−0.0953
	0.0556	0.0635	0.0603
Full-time employment	Reference	Reference	Reference
Part-time employment	−0.2916***	−0.2052*	−0.0651
	0.1102	0.1138	0.1115
Retired	−0.0005	−0.071	−0.2509*
	0.14	0.1445	0.1417
Unemployed	−0.2930**	−0.2683**	−0.085
	0.1249	0.1289	0.1264
Student	0.0319	0.0525	0.1963*
	0.1209	0.1248	0.1124
Married	Reference	Reference	Reference
Unmarried	−0.2005***	−0.1710**	−0.1777***
	0.07	0.0749	0.0647
Living in Beijing for	Reference	Reference	Reference
5–10 years	0.2206	0.2500*	−0.0375
10–15 years	0.1418	0.1464	0.1436
Over 15 years	0.3144***	0.1867*	−0.0477
	0.1049	0.1083	0.1062
Housing type; 1 if "own a house," 0 if else	0.2266**	0.2509**	0.0489
	0.1093	0.1128	0.1106
Living area; 1 if "urban," 0 if "suburban"	−0.1136	−0.0758	−0.2181**
	0.0909	0.0928	0.0898
Average household income below 5000	Reference	Reference	Reference
5001–10,000	0.2493**	0.2526**	0.1920*
	0.0979	0.1011	0.103
10,001–15,000	0.1993**	0.1704*	0.2317**
	0.0997	0.1029	0.1049
Over 15,000	0.3888***	0.2931**	0.4243***
	0.13	0.1342	0.1368
Obs	942	942	942
RMSE	1.0606	1.095	1.0735
R^2	0.1028	0.0883	0.0589
χ^2	107.88	91.19	59.01

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