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Article

The Associations between the Quantity and Quality of Urban Green Spaces and Health: Enlightenment from the Case of Hangzhou, China

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Abstract: China is experiencing rapid urbanization. The focus on health issues has shifted from the treatment of diseases to passive or active prevention. Diseases caused by the deterioration of the urban environment, such as cardiovascular disease, diabetes, obesity and other chronic diseases and mental illness, have gradually become the main threat to public health. Studies have confirmed that urban green spaces (UGS) can help residents relieve mental stress, improve mood, reduce mental fatigue and restore attention, which has a positive effect on people's physical and mental health. In this study, the relationship between the quantity and quality factors of UGS and the physical and mental health of urban residents in Xihu District of Hangzhou is examined, and on this basis, UGS design strategies are proposed to promote the physical and mental health of residents. This study is of great significance for the future construction of UGS that are beneficial to the health of residents and the promotion of a healthy China and healthy city construction.

Keywords: urban green space; health benefit; multivariate regression analysis; physical activity

1. Introduction

With the rapid development of industrialization and urbanization, high-density and high-intensity urban construction has led to the continuous reduction of UGS, and the relationship between city inhabitants and the natural environment has become increasingly distant, which has led to a series of public health problems, such as cardiovascular disease, diabetes, obesity and other chronic diseases as well as mental diseases. Statistical data show that in 2010, 30.6% of adults in China were overweight, of which 12.0% were obese. The uneven distribution and insufficient supply of UGS and people's excessive reliance on transportation are several important reasons for the lack of physical activity (PA). In 2010, the World Health Organization (WHO) identified insufficient PA as the fourth leading risk factor for global mortality. In 2005, a WHO report stated that 31.5% of the loss of healthy lives worldwide was caused by mental health issues. A 2013 study estimated that over 30 million people in China suffer from varying degrees of depression. Therefore, it is crucial to prevent or alleviate chronic diseases, promote PA, and alleviate mental stress through UGS.

Policy documents continuously promote the construction of a healthy China and healthy cities. In October 2016, China issued the "Outline of the Healthy China 2030 Plan", proposing to integrate the concept of health into the entire process of urban planning, construction, and governance. In January 2017, the State Council issued "The 13th Five-Year Plan for Hygienism and Health", which proposes a transformation in urban development from disease-treatment centered to health centered. In July 2019, the State Council issued the "Opinions of the State Council on Implementing the Healthy China Action", which proposed that the key to health issues should shift from traditional "cure" methods to passive or proactive "prevention" and "intervention" methods, clarify the construction of healthy cities, and implement healthy environment promotion actions. The National Health Commission (NHC) released the "Report on the Nutrition and Chronic Disease Status of Chinese Residents" in 2020, which pointed out that the PA level of Chinese residents is generally insufficient

(for example, the frequent PA rate of residents aged 20-69 is only 18.7%), and insufficient PA has become one of the factors that contributes to public health risks, which directly affects the occurrence of the following two public health problems: (1) the problem of overweight and obesity continues to be prominent and (2) the incidence rate of chronic diseases is on the rise, and the death rate of chronic diseases is high. In 2021, the NHC issued the "Guidelines for Physical Activity of the Chinese People", proposing the minimum level of PA standards that are beneficial to physical health for different age groups in China. As a public product with positive health effects provided by the government, utilizing UGS to actively intervene in public health is of great significance for the construction of healthy China and healthy cities.

Numerous studies have confirmed that UGS contribute to human health. The four mainstream theories are stress relief theory [1], attention restoration theory, restorative environment theory, and therapeutic landscapes [2,3]. These theories explain the role of natural or artificial environmental landscapes in the physical and mental health of the public from different perspectives. Research shows that natural landscapes can help relieve mental stress and play a positive role in people's physical and mental health recovery [4]. The natural environment is widely favored by people and can easily evoke a sense of joy and familiarity. People do not need to focus on the natural environment to appreciate it. Therefore, the natural environment has a positive effect on people's recovery from mental fatigue. The environment can help people better recover from psychological fatigue and negative emotions associated with stress [5]. Due to the special resonance that humans have with the natural environment, the natural environment has a higher restorative effect than the urban architectural environment [6,7]. The appreciation of plants and the imagination of natural scenery can help alleviate stress and eliminate anxious emotions, which is beneficial for physical and mental health.

On this basis, the internal relations between UGS and public health have been studied. In terms of the internal relations between the quantity of UGS and public health, studies have shown that the presence of more UGS in the community is associated with better health in children [8,9]. Accessibility (distance/proximity) [10] is also an important factor affecting the use of UGS and has an important impact on people's health. Increasing accessibility to UGS (i.e., by reducing the distance between residents and UGS) can effectively increase UGS use, which positively impacts residents' health [11]. The effective service area of UGS (available green space rate) also plays an important role in residents' health. Increasing the spatial coverage of UGS can effectively improve residents' evaluation of their own health and reduce obesity and mental health problems such as anxiety and stress [12]. In terms of the internal relations between the quality of UGS and public health, the quality of UGS is related to well-being [13], general health status [14] and mental health [15]. High-quality UGS can improve the frequency and duration of PA [16]. A larger UGS can promote residents' PA, so residents can obtain more health benefits [17]. UGS with more activity facilities are more likely to promote PA and improve residents' health [18]. Natural environmental quality factors (plant species and quantity, vegetation coverage area, waterscape, etc.) in UGS play a major role in alleviating mental stress.

Research has confirmed that UGS are an important public resource for promoting people's physical and mental health, but there is still much space to fill in the current research on the health benefits of UGS. In terms of the impact of the quantity of UGS on public health, further exploration is needed to determine to what extent the two are associated and which indicators are most significantly associated. In terms of the impact of UGS quality on public health, further analysis is needed to determine which UGS quality indicators have a positive correlation and the most significant correlation with public health benefits. In addition, discussions on thresholds are currently rare in the literature. Most of the existing studies have been conducted in developed countries, and there are few studies on this topic conducted in China. Chinese cities typically have a different type of city structure than cities in developed countries, with a higher population density and fewer UGS. Therefore, recommendations for cities in developed countries may not necessarily be valid for Chinese cities. Conducting such research in developing countries can make a positive contribution to establishing a global framework for the use of UGS [19]. Therefore, this study uses Hangzhou, China

as the research area to explore the above issues. The correlation between the health benefits of UGS and their quantity and quality factors was analyzed. We studied the quantity and quality factors that have a practical impact on the selected use and health benefits of UGS, explored thresholds, and proposed UGS design strategies to promote residents' physical and mental health. This research provides theoretical and methodological guidance for the construction of UGS to promote residents' physical and mental health.

2. Materials and Methods

2.1. Study Area

The data used in this research were collected from Xihu District, Hangzhou, China (**Figure 1**). Hangzhou is a metropolitan city with a population of 12.376 million, located in the north of the southeast coast of China, northern Zhejiang Province. The city has a typical subtropical monsoon climate that is warm and humid, with obvious alternation of four seasons, sufficient light and abundant rainfall. The average annual rainfall is 1546 mm. Xihu District is located in the west of the main city zone of Hangzhou, covering an area of 312.43 square kilometers. According to China's "Classification Standards for UGS" (CJJ/T85-2017) and based on the classification standards for UGS in the "UGS System Planning of Hangzhou (2002-2020)" (**Table 1**), combined with field investigations, all existing good and valuable UGS in Xihu District were selected for research, including 24 community-level UGS, 1 district-level UGS (Tanshan Park) and 4 municipal-level UGS (Xixi National Wetland Park, West Lake Scenic Area, Hangzhou Chengxi Leisure Park, and Hangzhou Dinosaur Dream Park) (**Figure 2**).

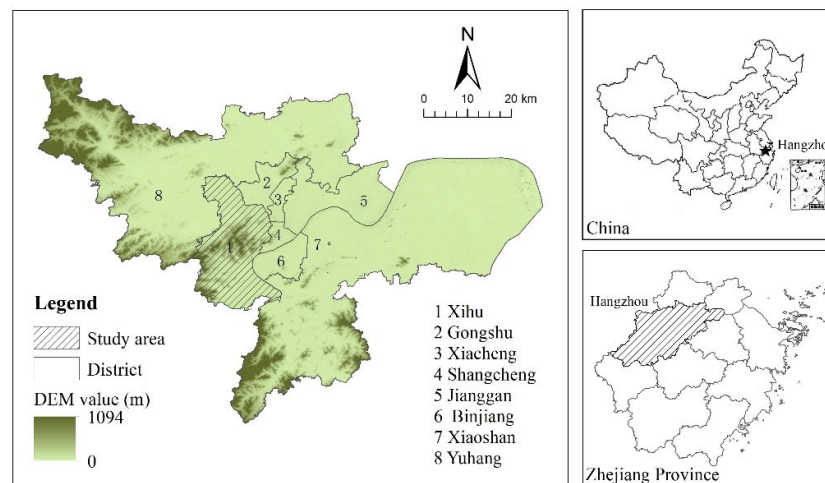


Figure 1. Study area.

Table 1. Hangzhou UGS division standard.

UGS level	Area (10000 square meters)	Service radius (meters)	notes
Municipal level UGS	>10	3000	
District level UGS	2~20	1500	
Urban section level UGS	5~10	1500	Within the urban cluster
Community level UGS	2~5	1000	
Residential quarter level UGS	≥0.4	1000	

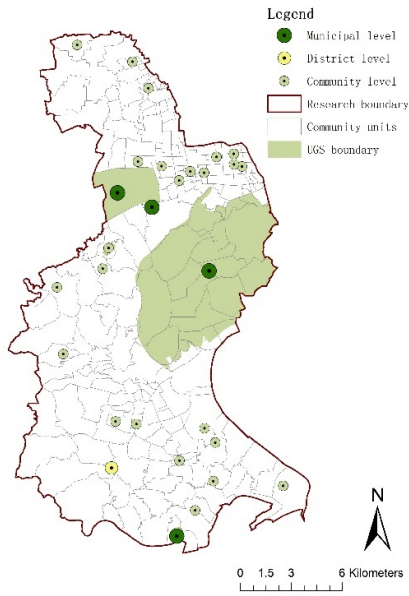


Figure 2. Distribution of UGS in Xihu District.

2.2. Data Collection Questionnaire

The questionnaire was distributed between September and December 2019. The survey time included working days and rest days. The respondents (except children) were randomly selected to ensure the validity of the sample data. A total of 1086 questionnaires were distributed to 29 UGS in Xihu District (including 653 community-level UGS and 433 district- and municipal-level UGS); a total of 974 valid questionnaires were collected (including 600 community-level UGS and 374 district- and municipal-level UGS), and the effective rate of the questionnaire was 89.6%. The questionnaire included the basic information of the respondents, the use of UGS, health benefits, and the quality and quantity factors that affect their choice to use UGS.

3. Methods

3.1. Evaluation Method of Health Benefits of UGS

3.1.1. Selection of Evaluating Indicators

The theoretical and case research results of scholars on the relationship between UGS and public health are analyzed, and the selection criteria of evaluation indicators are diverse. The improvement of self-reported health (SRH) [12,16,20] and body mass index (BMI) [21,22]; the reduction in the number of the obesity rate, the recovery of negative emotions, loneliness, and feelings of loss; the increase of social support [23–25]; and other health indicators are used to evaluate the health benefits obtained by UGS use.

Based on the relevant research results, according to the principles of comprehensiveness, hierarchy, distinction and logic of indicator selection, the health benefits obtained by the public using UGS are divided into two categories: overall health and subdividing health. Among them, SRH was used to evaluate overall health. Second, according to the definition of health by the World Health Organization (WHO) ('health refers to the good state of physical, psychological and social adaptation, not just the absence of disease or weakness') and referring to the criteria for dividing health in relevant studies (the impact of green space on residents' health mainly focuses on three aspects: physical, mental and social health), this research further divides health into physical health, mental health and social health. Finally, considering the availability of data, this research identified indicators to evaluate the health benefits obtained by the public using UGS (Table 2).

Table 2. Evaluation indicators for UGS health benefits.

Categories	Evaluation indicators	Indicators subdivision
Overall health	SRH	--
	Physical health	Reduce obesity Reduce the risk of common diseases Reduce the risk of chronic diseases
Subdividing health	Mental health	Eliminate mental fatigue Relieve psychological pressure Concentrate mind Improve mood
	Social health	Eliminate feelings of loss Reduce loneliness

3.1.2. Quantification of Indicators

(1) Overall health

The SRH of the respondents was obtained through questionnaires. The respondents were asked to rate their health on a 5-point Likert scale (1=extremely negative, 2=negative, 3=average, 4=positive, 5=extremely positive).

(2) Subdividing health

Respondents were also asked 'do you think using this UGS is beneficial to your health' and told to rate their responses on a 5-point Likert scale (1=No benefit, 2=Basically no benefit, 3=A little benefit, 4=Beneficial, 5=Very beneficial). Respondents were also asked 'What are the benefits of regular PA in UGS for your health', and the answer choices were 'to reduce obesity', 'to reduce the risk of common diseases' and other previously determined subdividing indicators of subdividing health.

3.2. The Quantity and Quality Factors Affecting the Health Benefits of UGS

3.2.1. Selection of Factors

(1) Quantity factors

Traditional quantitative indicators such as per capita UGS area, UGS service radius, and UGS coverage ratio ignore the relationship between UGS spatial distribution and accessibility. In this regard, foreign scholars used 'accessibility/distance/proximity/availability' and 'green space coverage ratio' indicators, and used buffer or network analysis tools of ArcGIS to carry out research on the relationship between UGS, PA and public health [12,26,27]. By analyzing the existing research results, two quantity factors of 'distance to UGS' and 'effective UGS service area ratio' are determined:

1) Distance to UGS:

The distance between the respondents' home and the nearest entrance to the UGS they used.

2) Effective service area ratio:

The ratio of UGS service area to research unit area. The formula is as follows: $Gr_j = G_{sj}/A_{cj}$. In the formula, Gr_j is the effective UGS service area ratio of research unit j (the area of the community where the respondents live in this research), G_{sj} is the effective UGS service area within research unit j , and A_{cj} is the area of research unit j . In addition, because people can only use one UGS at the same time, when calculating the effective UGS area in research unit j , if there is partial or complete overlap in the effective service range of two or more UGS, the overlapping part will not be repeatedly included in the effective service area of UGS in this research unit j .

(2) Quality factors

Existing research results show that the quality of UGS is closely related to their health benefits [18,26]. Based on the consultation of designers, experts and scholars and considering the availability of research data and the practical guiding value of research conclusions, 12 quality factors affecting UGS health benefits were selected from three aspects: planning quality, design quality and management and maintenance quality.

The quantity and quality factors of UGS health benefits selected in this research are shown in **Table 3**.

Table 3. The quantity and quality factors affecting the health benefits of UGS.

Categories	Factor
Quantity factors	Distance to UGS
	Effective service area ratio
	Charge
	Landscape
	Largeness
	Functional diversity
	Leisure facilities
Quality factors	Accessibility
	Pollution
	Function
	Cleanliness
	Security
	Facility maintenance
	Landscape maintenance

3.2.2. Analysis of Factors

(1) Quantity factors

1) Distance to UGS

Through the questionnaire, the information of the respondents' residence, the mode of transportation to the UGS, the length of transportation, and the calculation of the distance to UGS are obtained.

2) Effective service area ratio

First, the community where the respondents live is obtained through questionnaires. ArcGIS was used to calculate the community area. Second, based on the road network data of the study area, according to the service radius of UGS at all levels stipulated in the "UGS System Planning of Hangzhou (2002-2020)", the effective service area of UGS in Xihu District is calculated by the ArcGIS network analysis method. Finally, the calculation formula is input into ArcGIS to model and calculate the effective service area ratio of UGS.

(2) Quality factors

The score of quality factors is obtained by questionnaire. The respondents were asked to evaluate the quality factors (e.g., charge, landscape, largeness) on a 5-point Likert scale.

(3) Multivariate regression analysis

Based on the obtained data, SPSS software is used to conduct multilevel and multicategory multivariate regression analysis and finally determine the factors that have a practical impact on people's access to health benefits in the context of quantitative and qualitative UGS factors.

4. Results

4.1. Demographics

The basic information of respondents was collected (**Figure 3**). The respondents were mainly adults, of which 32.5% were 19-35 years old, 29.1% were 36-59 years old, and 34.5% were over 60 years old. Among the respondents, 50.6% were male and 49.4% were female. A total of 80.5% of the respondents were married, while 19.5% were single. On the whole, the age distribution and gender distribution of the sample respondents are relatively balanced and representative.

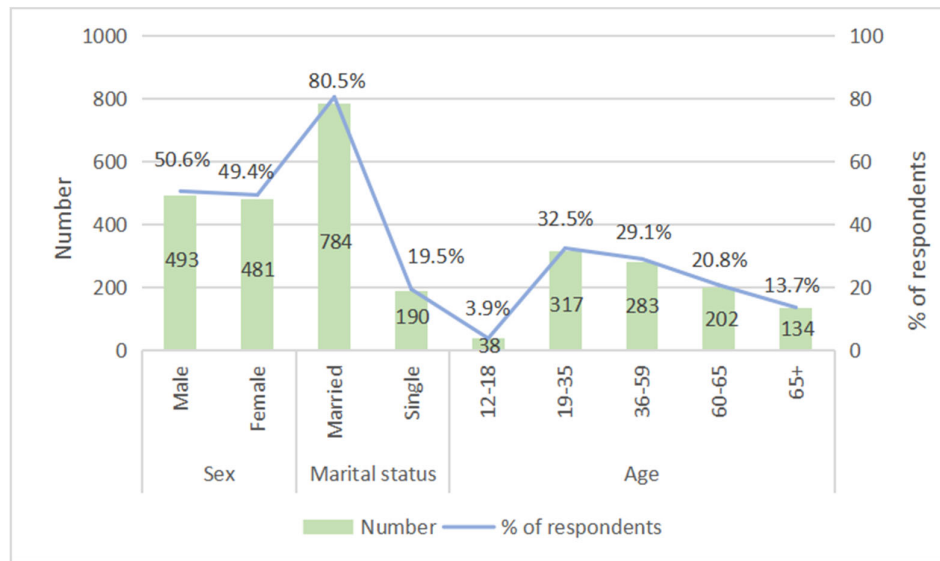


Figure 3. Basic information of respondents.

4.2. Frequency, Duration and Type of PA

In terms of the PA of UGS, the statistical results show (Figure 4) that for PA frequency and duration, respondents use community-level UGS with high frequency and high intensity, while the frequency of UGS use in district- and municipal-level parks is much lower than that of community-level UGS. However, in contrast, the duration of each use of district- and municipal-level UGS was longer than that of community-level UGS. For UGS activity types, respondents have relatively small differences in the choice of PA types in UGS at the community level, district level, and municipal level. They are more inclined to carry out recreational activities (community level accounts for 38.6%, district and municipal level accounts for 40.5%) and parent-child activities (community level accounts for 28.5%, district and municipal level accounts for 20.9%), followed by sports activities (community level accounts for 22.7%, district and municipal level accounts for 20.2%), and communication activities (community level accounts for 9%, district and municipal level accounts for 16.6%). According to the existing research results, PA will have a positive effect on people's physical, psychological and social health.

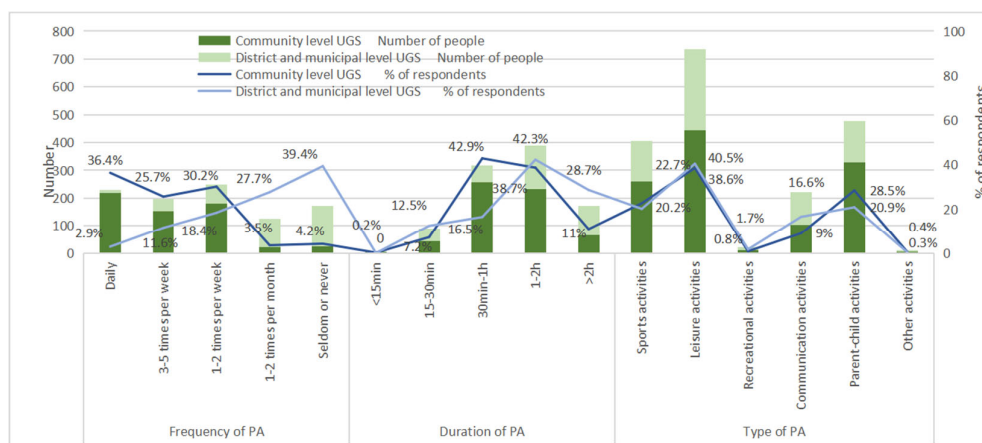


Figure 4. Frequency, duration and type of PA.

4.3. Health Benefits

In terms of health benefits (**Figure 5**), for overall health indicators, approximately 89.2% of respondents were positive about the health benefits of using UGS (respondents believed that using UGS was “beneficial” and “very beneficial” to health); 9.9% of respondents believed that using UGS had “a little benefit”. The SRH data showed that most respondents had positive evaluations of their health. For subdividing health indicators, respondents believe that the main benefits of UGS activities are mental health benefits, among which the elimination of mental fatigue is the highest. The recognition of physical health benefits is higher than that of social health benefits.

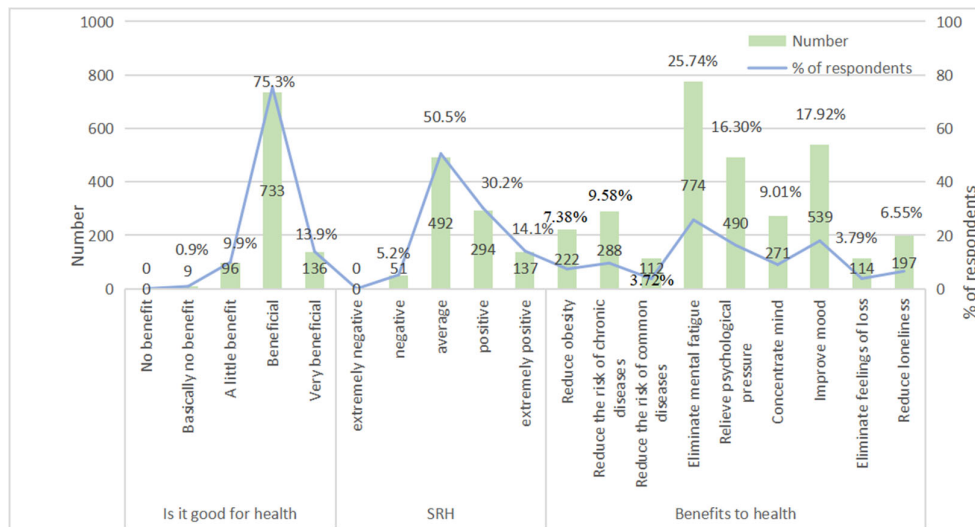


Figure 5. Health benefits.

4.4. Associations between Health Benefits and Quantity Factors of UGS

Based on the basic data obtained from the questionnaire, the distance between the respondents and UGS was calculated. The ArcGIS network analysis method was used to calculate the service scope and effective service area ratio of UGS at the community, district and municipal levels (**Figures 6 and 7**). SPSS software was used to analyze the associations between the health benefits obtained by the respondents and the quantity factors of UGS.

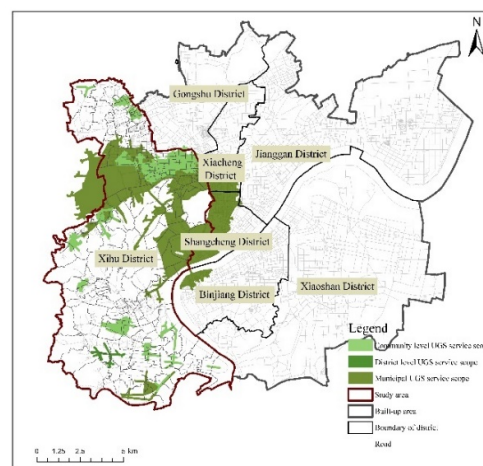


Figure 6. UGS service scope.

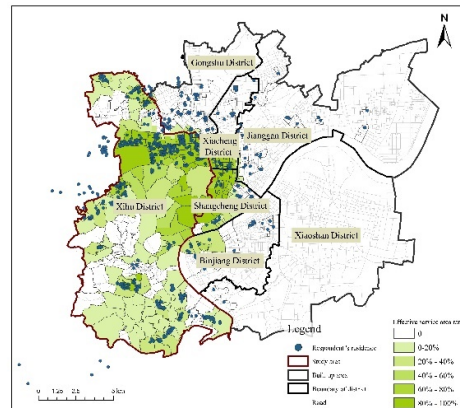


Figure 7. UGS effective service area ratio.

In terms of the associations between UGS quantity factors and overall health (Table 4), the distance to UGS was significantly negatively associated with the SRH of respondents, and the effective service area ratio was significantly positively associated with the SRH of respondents; that is, the closer the distance to an UGS and the higher the effective service area ratio of the UGS, the better the SRH of respondents.

Table 4. Summary of unstandardized multivariate regression coefficients for quantity factors of UGS and overall health indicators.

	SRH	
	β	SE
Sex(male)	-.120*	.052
Age	-.004	.036
Occupation	.034	.031
Education level	.211**	.036
Income level	.041**	.014
Marital status (married)	.397**	.077
Distance to UGS	-.064**	.016
Effective service area ratio	.180**	.059
R2	.167**	

** $p \leq .01$. * $p \leq .05$.

In terms of the associations between UGS quantity factors and subdividing health (Table 5), the distance to UGS was significantly negatively associated with physical health and mental health; that is, the shorter the distance to UGS, the greater the physical health benefits and mental health benefits obtained by the respondents. The effective service area ratio of UGS is positively associated with social health; that is, the higher the effective service area ratio of UGS is, the greater the social health benefits obtained by respondents.

Table 5. Summary of unstandardized multivariate regression coefficients for quantity factors of UGS and subdividing health indicators.

	Physical health		Mental health		Social health	
	β	SE	β	SE	β	SE
Sex(male)	.033	.067	.036	.073	.013	.047
Age	-.196**	.046	.037	.050	-.150**	.032
Occupation	-.108**	.040	-.001	.043	-.009	.028

Education level	.116*	.046	.118*	.050	.088**	.032
Income level	.024	.018	.074**	.020	-.015	.013
Marital status (married)	.077	.099	.293**	.108	.231**	.069
Distance to UGS	-.055**	.021	-.099**	.023	-.025	.015
Effective service area ratio	.065	.076	-.081	.083	.131*	.053
R ²	.044**		.152**		.111**	

**p≤.01. *p≤.05.

The associations between different UGS quantity factors and the health indicators of respondents were further analyzed. The distance to UGS is divided into five virtual variables (thresholds): 1) < 500 m (reference distance), 2) 500- < 1 km, 3) 1 km- < 1.5 km, 4) 1.5 km- < 2 km, and 5) ≥ 2 km. The effective service area ratio is divided into five virtual variables (threshold): 1) ≥ 80% (reference ratio), 2) < 80-60%, 3) < 60-40%, 4) < 40-20%, and 5) < 20-0%. We analyzed whether there is a threshold when the distance to UGS and the effective service area ratio affect the use of UGS to obtain health benefits.

The results showed that compared with the reference distance (< 500 m), the distance to UGS (1.5 km- < 2 km) and the distance to UGS (≥ 2 km) were significantly negatively associated with the SRH of the respondents (**Table 6**). Compared with the reference ratio (≥ 80%), the effective service area ratio (< 20-0%) and the effective service area ratio (< 40-20%) were significantly negatively associated with the SRH of the respondents (**Table 7**). That is, compared to respondents with the best reference distance, the SRH of respondents whose distance to UGS is greater than 1.5 km is worse; compared to respondents with the best reference ratio, respondents with an effective service area ratio of less than 40% had poor SRH.

Table 6. Summary of unstandardized multivariate regression coefficients for different distances to UGS and overall health indicators.

	SRH	
	β	SE
Sex(male)	-.106*	.053
Age	-.008	.036
Occupation	.042	.031
Education level	.215**	.036
Income level	.040**	.014
Marital status (married)	.463**	.079
Distance to UGS/500 m-1 km	-.019	.070
Distance to UGS/1 km-1.5 km	-.037	.090
Distance to UGS/1.5 km-2 km	-.537**	.108
Distance to UGS/>2 km	-.283**	.063
R ²	.171**	

**p≤.01. *p≤.05.

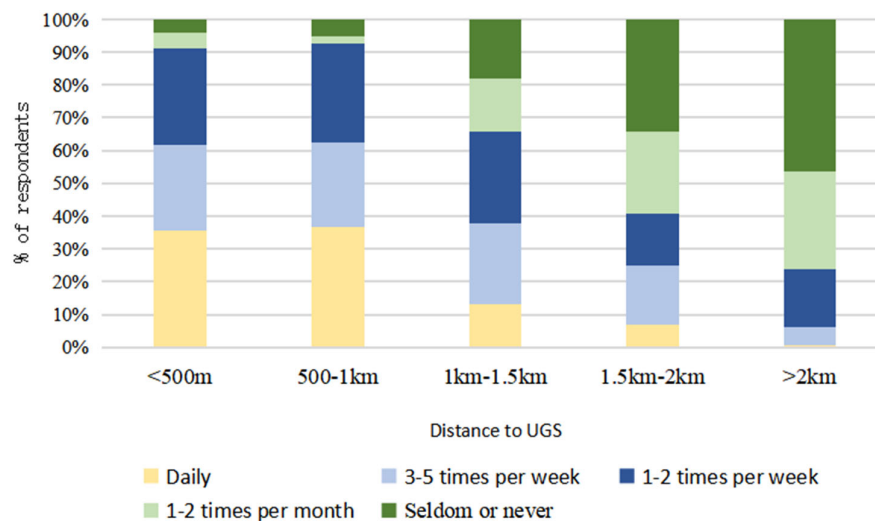
Table 7. Summary of unstandardized multivariate regression coefficients for different UGS effective service area ratios and overall health indicators.

	SRH	
	β	SE
Sex(male)	-.132*	.053
Age	-.005	.037
Occupation	.043	.032
Education level	.185**	.036
Income level	.044**	.015
Marital status (married)	.355**	.078
Effective service area ratio/<80-60%	-.090	.108
Effective service area ratio/<60-40%	-.100	.137
Effective service area ratio/<40-20%	-.158*	.080
Effective service area ratio/<20-0%	-.207**	.055
R ²	.144**	

**p≤.01. *p≤.05.

4.5. Associations between Health Benefits and Quality Factors of UGS

The associations between UGS distance and the frequency and duration of PA were analyzed (Figures 8 and 9). As the distance to UGS increases, the PA frequency decreases significantly, but the frequency of long-term PA (≥ 1 hour) in UGS increases significantly (except for the 'blank zone' between the district-level UGS and municipal-level UGS service ranges, that is, 1.5 km-2 km).

**Figure 8.** Distance to UGS versus frequency of PA, in percent of the respondents.

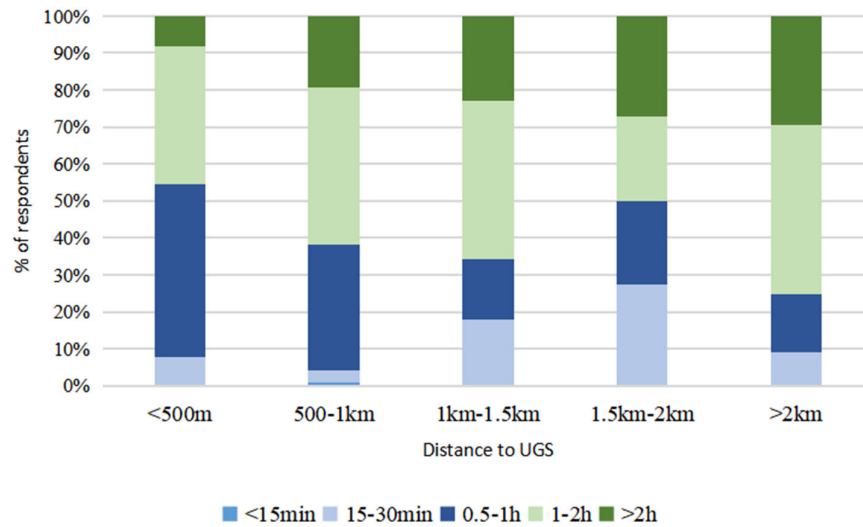


Figure 9. Distance to UGS versus duration of PA, in percent of the respondents.

The associations between UGS quality factors and the frequency and duration of PA were analyzed (Table 8). The distance to UGS and whether the UGS has costs associated with it are significantly negatively associated with the frequency of PA. Whether an UGS is accessible is significantly positively associated with the frequency of PA. No other significant associations were observed with the frequency of PA. That is, for the respondents, the closer the distance to an UGS and the better the accessibility of UGS, the greater the frequency of PA. Whether the park has costs associated with it will have a negative effect on people's choice to use UGS. The distance to UGS, rest facilities and UGS cleanliness were significantly positively associated with the duration of PA. Functional diversity was significantly negatively associated with the duration of PA. No other significant associations were observed with the duration of PA. That is, for the respondents, the farther the distance to the UGS, the more complete the rest of the UGS facilities, and the better the UGS cleanliness, then the longer the respondents' PA time in the UGS. The stronger the functional diversity in the UGS, the shorter the PA time.

Table 8. Summary of unstandardized multivariate regression coefficients for quality factors of UGS and frequency and duration of PA.

	Frequency of PA		Duration of PA	
	β	SE	β	SE
Sex(male)	-.192*	.080	-.330**	.066
Age	.308**	.056	.280**	.046
Occupation	-.016	.048	-.020	.040
Education level	-.160**	.055	.024	.045
Income level	-.071**	.022	-.040*	.018
Marital status (married)	.341**	.118	.320**	.098
Distance to UGS	-.357**	.025	.194**	.021
Charge	-.085*	.034	.015	.028
Landscape	.035	.057	-.071	.047
Largeness	-.036	.053	.045	.043
Functional diversity	.028	.053	-.112*	.048
Leisure facilities	-.005	.052	.115**	.048
Accessibility	.222**	.072	.028	.044
Pollution	.005	.058	-.040	.048
Function	-.040	.038	-.023	.031

Cleanliness	.003	.061	.101*	.050
Security	.022	.063	.025	.052
Facility maintenance	.071	.066	-.066	.054
Landscape maintenance	-.043	.067	-.028	.055
R ²		.549**		.230**

**p≤.01. *p≤.05.

The associations between quality factors of UGS, frequency and duration of PA, and overall health were analyzed (**Table 9**). The distance to UGS was significantly negatively associated with SRH. The duration of PA was significantly positively associated with SRH. No other significant associations were observed with SRH. That is, for the respondents, the closer the distance to UGS and the longer the PA time in the UGS, the better the SRH of the respondents.

Combined with the associations between quality factors of UGS and frequency and duration of PA, duration of PA was significantly positively associated with leisure facilities and cleanliness of UGS and significantly negatively associated with functional diversity. It can be concluded that the distance to UGS, leisure facilities and cleanliness of UGS have a clear positive effect on the use of UGS and the acquisition of overall health benefits, while functional diversity has a reverse effect.

Table 9. Summary of unstandardized multivariate regression coefficients for quality factors of UGS, frequency and duration of PA, and overall health.

	SRH	
	β	SE
Sex(male)	-.073	.054
Age	-.041	.038
Occupation	.047	.031
Education level	.228**	.036
Income level	-.042**	.014
Marital status (married)	-.078	.052
Distance to UGS	-.072**	.020
Frequency of PA	.042	.025
Duration of PA	.073*	.030
Charge	.000	.022
Landscape	-.017	.037
Largeness	-.019	.035
Functional diversity	.002	.035
Leisure facilities	.048	.034
Accessibility	.049	.035
Pollution	-.029	.038
Function	-.031	.025
Cleanliness	.056	.040
Security	-.001	.041
Facility maintenance	-.060	.043
Landscape maintenance	-.008	.044
R ²		.180**

**p≤.01. *p≤.05.

The associations between quality factors of UGS, frequency and duration of PA, and subdividing health were analyzed (**Table 10**). The physical health of the respondents was significantly positively associated with the frequency of PA and significantly negatively associated with the distance to UGS. The mental health of respondents was positively associated with the frequency and duration of PA and UGS cleanliness. The social health of the respondents was significantly positively associated with the frequency of PA and the size and cleanliness of UGS and significantly negatively associated with

their distance to UGS. In summary, the distance to UGS, cleanliness and size of UGS, and frequency and duration of PA have a clear positive effect on the subdividing health benefits of respondents. Combined with the relationship between UGS quality factors and the frequency and duration of PA, the frequency of PA is significantly positively associated with UGS accessibility and is significantly negatively associated with whether the UGS has costs associated with it. The duration of PA is significantly positively associated with leisure facilities and UGS cleanliness and is significantly negatively associated with functional diversity. It can be concluded that the five factors of distance to UGS, accessibility, leisure facilities, cleanliness and largeness of UGS have a clear positive effect on the use of UGS and the acquisition of subdividing health benefits, while whether the UGS has costs associated with it and functional diversity have a reverse effect.

Table 10. Summary of unstandardized multivariate regression coefficients for quality factors of UGS, frequency and duration of PA, and subdividing health.

	Physical health		Mental health		Social health	
	β	SE	β	SE	β	SE
Sex(male)	.009	.068	.058	.075	.042	.048
Age	-.153**	.049	-.021	.053	-.108**	.034
Occupation	-.106**	.040	.000	.044	-.010	.028
Education level	.128**	.046	.097	.050	.024	.035
Income level	-.018	.018	.069**	.020	-.002	.013
Marital status (married)	.040	.100	.261*	.109	.246**	.070
Distance to UGS	-.059*	.025	-.039	.028	-.060**	.018
Frequency of PA	.088**	.032	.081*	.035	.096**	.022
Duration of PA	.056	.039	.108*	.042	.026	.027
Charge	-.022	.028	-.016	.031	-.015	.020
Landscape	-.009	.048	.070	.052	-.018	.033
Largeness	.002	.044	.014	.048	.067*	.031
Functional diversity	-.016	.044	-.025	.048	.010	.031
Leisure facilities	-.012	.044	.038	.048	.028	.031
Accessibility	-.003	.045	-.007	.048	.019	.031
Pollution	.078	.048	.058	.053	.025	.034
Function	.051	.032	.024	.035	.021	.022
Cleanliness	.063	.051	.112*	.056	.073*	.036
Security	.037	.053	.081	.057	.045	.037
Facility maintenance	-.007	.055	.070	.060	.034	.038
Landscape maintenance	.016	.056	.077	.061	.040	.039
R ²	.072**		.185**		.151**	

**p \leq .01. *p \leq .05.

5. Discussion

Based on the above research results, this research proposes UGS planning and design strategies for improving residents' health benefits. In terms of quantity, first, the number and distribution density of UGS should be reasonably determined. Most of the users of community-level UGS are residents living around UGS, and most of them are elderly people who usually choose to walk to UGS. Considering the weak travel ability of elderly individuals, the service radius of UGS should be set at approximately 500 m to ensure that elderly individuals can reach UGS on foot within 10 minutes. When the distance between UGS and the residence of the respondents is greater than 1.5 km, it is significantly negatively associated with the health of the respondents. Under the condition of balanced distribution and basic indicators, the effective service radius of district-level UGS should be set at 1 km-1.5 km, and the effective service radius of municipal-level UGS should be set at approximately 2 km. Second, the spatial coverage of UGS should be reasonably determined. When the effective service area ratio of UGS is less than 40%, it is significantly negatively associated with

the SRH of respondents. Therefore, 40% of the UGS service area ratio should be guaranteed during planning. UGS at all levels should follow the principle of balanced distribution of resources. The planning should consider the function and landscape connection between UGS at all levels.

In terms of quality, we should first build an accessible path. Because the distance to UGS and accessibility have an important effect on the health benefits of residents, when planning UGS, we should not only pay attention to the requirements of quantity, scale and service radius but also pay attention to the connection between UGS and the green space system and walking system. High-quality road networks, comfortable walking routes and good accessibility can enhance residents' willingness to visit UGS and effectively extend residents' duration of PA, thereby increasing the health benefits of UGS for the public. Second, various functional spaces that support diverse activities should be created. For recreational activities, people are more inclined to use semiprivate, private dotted or planar spaces. For communication activities, an open or semi-open linear or planar space should be created. For sports activities, it is necessary to reasonably plan activity venues according to the different needs of residents, configure fitness venues of different sizes, and reasonably distinguish functional spaces for different groups of people. For parent-child activities, attention should be given to the design of children's recreational facilities and the creation of soft lawns to ensure children's play and improve safety. Finally, the health intervention of UGS should be strengthened. UGS with good accessibility, large scale, perfect leisure facilities and good cleanliness can increase the frequency of residents' visits, thus improving the health status of residents. Therefore, UGS accessibility and scale should be strengthened in UGS planning. In the design of UGS, attention should be given to the rational allocation of leisure facilities and the maintenance of cleanliness after the completion and during the operation of UGS, and active health intervention should be the focus of UGS planning and design to fully take advantage of the benefits of UGS on public health.

In the correlation analysis of UGS health benefits and their quality factors, a result that seems to violate common sense was found: the stronger the functional diversity of UGS, the shorter the PA time of respondents in UGS. Leisure activities and parent-child activities rank as the top two PA types of respondents, which need a quiet, safe and comfortable environment. UGS with strong functional diversity may have a noisy environment, resulting in respondents who prefer quieter settings not wanting to stay in them for a long time; this results in significant negative associations between UGS functional diversity and PA duration in UGS. This needs to be further verified by examples to guide the configuration of functional sites in UGS design.

There are some limitations in this research. Although this research is only devoted to exploring the relationship between the quantity and quality of UGS and public health, the results show that there is not a simple linear relationship between demographic characteristics (covariate factors, such as sex and age) and residents' health. In the future, further research can be done on the differences between different groups of people. For example, in the context of an aging society, it is unclear how to meet the needs of the elderly population in UGS system planning and how to consciously carry out age-appropriate UGS design. In the study of UGS quality and public health, this research only determines the quality influencing factors from three aspects: planning quality, design quality and management and maintenance quality, which has certain limitations. In a follow-up study, the influencing factors can be further expanded, such as increasing the influencing factors of UGS spatial perception and refining the influencing factors of UGS design, to provide a more comprehensive and detailed theoretical basis and optimization strategy for the planning and design of UGS for the purpose of improving residents' health.

6. Conclusions

Like many developing countries, China's rapid urbanization has made UGS increasingly difficult to protect. In China, most citizens do not have a private garden; therefore, UGS are the main place for citizens to engage in PA and have a positive effect on improving people's health. Protecting and maintaining UGS to meet the growing demand for leisure and recreation activities is a challenge for cities in developing countries. This research focuses on the health of citizens as the starting point

and comprehensively evaluates the relationship between the quantity and quality factors of UGS and the health benefits of citizens. The results show that the two quantity factors of distance to UGS and effective service area ratio play an important role in promoting respondents' use of UGS and health benefits, but the effect of distance to UGS is more obvious. The four quality factors of accessibility, leisure facilities, cleanliness and size have a clear positive effect on respondents' use of UGS and health benefits. UGS charges and functional diversity have a reverse effect. This research expands the value of urban and rural planning disciplines by strengthening the active intervention of UGS on residents' health and provides theoretical and methodological guidance for the future construction of UGS to promote benefits to residents' physical and mental health, which has broad application prospects.

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