Theme: 12_Healthy City Planning: Food, Physical Activity

# Does the connectivity of urban public green space promote use? An empirical study of Wuhan inner city

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**Abstract:** Improving greenness level is proved to have the potential to enhance green space use and outdoor physical activity level. However, high urbanization level and rapid densification process make green space - especially urban public green space - gradually lost and fragmented, which results in small or even no further land for public green space. Identifying such challenges, some planners and researchers suggest to connect existing urban public green space to encourage use and improve public health. Does it indeed work? Considering that, we research on the relationship between the connectivity of urban public green space and use in Wuhan inner city. In detail, we refer to the Integral Index of Connectivity in landscape ecology theory to calculate the connectivity of urban public green space by the unit of sub-district. Besides, Location Based Service (LBS) data - Tencent Yichuxing - is collected to measure the green space use of every study unit. Based on that, we make a further analysis between the two by Pearson correlation in SPSS. However, there exists in negative correlation between the connectivity of urban public green space and green space use, which is potentially due to the characteristics of public green space (such as quality and accessibility) weighing more than connectivity on promoting green space use.

**Key words:** urban pubic green space use, connectivity, LBS, Wuhan inner city

## Introduction

Regular physical activity is proved to play a key role in avoiding and relieving chronic diseases –including diabetes, obesity, cardiovascular diseases, depression, etc.– and premature death (Warburton et al. 2006, Lee et al. 2012, de Rezende et al. 2018). As the evidence that physical activity contributes to improving public health gradually becomes well-grounded, increasing authorities and governments place the emphasis on promoting physical activity. For example, variety of relevant strategies and plans are proposed in the world to enhance public physical activity level, such as the Global Action Plan on Physical Activity 2018-2030 (WHO, 2018) and Physical Activity Strategy for the WHO European Region 2016–2025 (WHO Regional Office for Europe, 2016). Particularly, most of those policies stress the importance of open space especially urban green space on enhancing physically active, because study after study has demonstrated urban green space is a significant catalyzer in encouraging physical activity. For instance, it could conduce to improve frequency, intensity and duration of outdoor physical activity (Pate et al. 2008, Schipperijn et al. 2010, Coombes et al. 2010, Han et al. 2013, Kondo et al. 2009, Dadvand et al. 2014). Besides, taking physical activity within such natural environments could benefit more than that in non-green settings (Pretty et al. 2005, Taylor and Kuo 2009, Gidlow et al. 2016).

However, the process of urbanization and densification leads to open space, especially green space constantly decreasing and fragmenting in urban area (Xu et al. 2011, Kabisch et al. 2015, Haaland and van den Bosch 2015), which means that green space use and physical activity generated by green space might be discouraged by such built environment changes. On one hand, continually shrinking urban green space cannot meet residents' growing demands due to the inadequate and scarce provision; on the other hand, the disequilibrium of urban green space distribution potentially results in its unequal accessibility and availability. Indeed, series of studies have suggested that green space use and physical activity level within it are significantly and strongly influenced by quantity, quality as well as configuration of urban green space (Schipperijn et al. 2010, Thompson et al. 2014, Richardson et al. 2013, Vujcic et al. 2019), whereas it is almost impossible to largely build new green space in the intensively compact urban area or widely revise the structure of existing urban green space system to improve public green space use and physical activity. Considering that, several researchers argue that enhancing the connectivity of actual green space by referring to the principals of landscape ecological is probably the relatively economic and efficient way to handle with the forementioned challenges (Zhang et al. 2015, Jim 2013, Oh et al. 2011).

Based on the talked above, this paper aims to explore if the solution of improving connectivity of existing urban green space would be a useful way to promote green space use. Since public green spaces are the accessible green infrastructures and free resources that can be available by all residents, therefore, we concentrate on the urban green space that is open to public in this study. In detail, the paper analyzes the correlation between the connectivity of urban public green space - calculated by applying the Integral Index of Connectivity in landscape ecology theory - and green space use through the empirical study in Wuhan inner city.

## Data and Method

### *Study area*

Wuhan, the capital of Hubei province and one of the China's megapolises, is located in the middle area of China and plays the roles of transportation hub and core of economic, technology as well as commerce trade logistics in those middle-area cities. The urbanization rate is 80.29% and approximately 647 million residents live in urban area in 2018 (Statistics Bureau of Hubei Province 2019). What's more, it is divided by Yangtze River and Han River into three parts of Hankou, Wuchang and Hanyang, which totally includes 13 districts. The scope of this study - Wuhan inner city - consists of 7 districts, namely Wuchang, Hongshan, Qingshan, Hanyang, Jiang'an, Qiaokou and Jianghan (depicted as Figure 1). Besides, each district contains several sub-districts/ *Jiedaos* (sub-district, also translated into *Jiedao*, is the lowest administrative unit in China) and 96 sub-districts are encompassed in total within the study area. In this study, we take sub-district as the basic research unit.

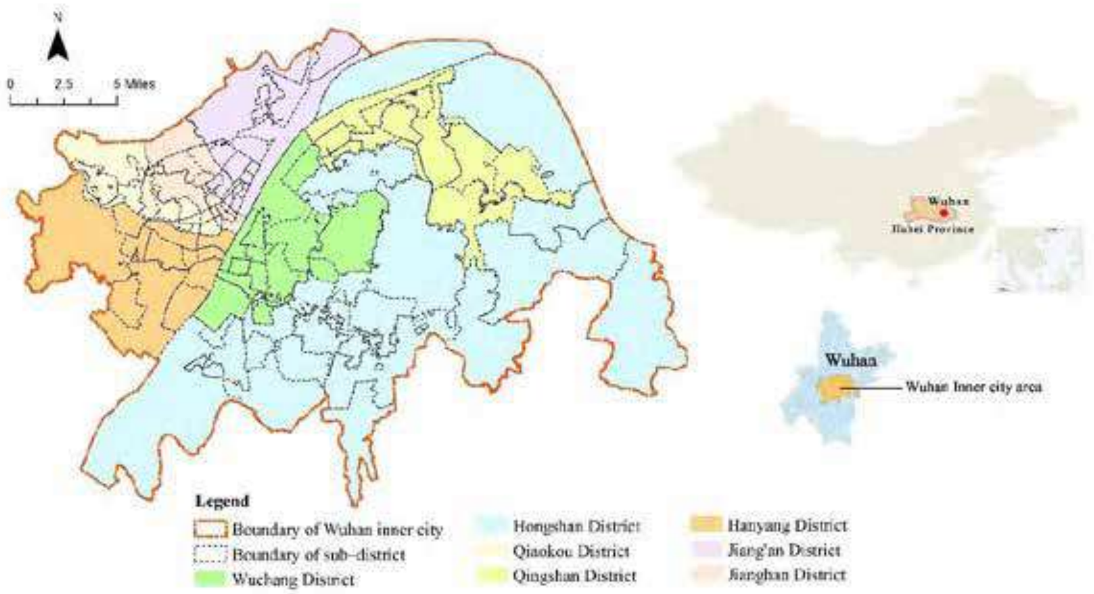


Figure 1 The location of Wuhan inner city area

***Data collection***

- Public green space

The distribution of public green space within inner city is extracted from the vector-graph of green space system provided by the official greening department in Wuhan. Public green space in this study consists of parkland (including comprehensive park, neighborhood park, theme park and pocket park), land for squares (green space proportion more than 35%), and parts of ecological green space as well as attached green space that can be accessible and used. Besides, according to the published studies, 1 hectare or more is proved to be the reasonable area for green space use especially for physical activity (Van den Bosch et al., 2016). Hence, that size is employed for the public green space selection (detailed distribution of PGS in Figure 2).

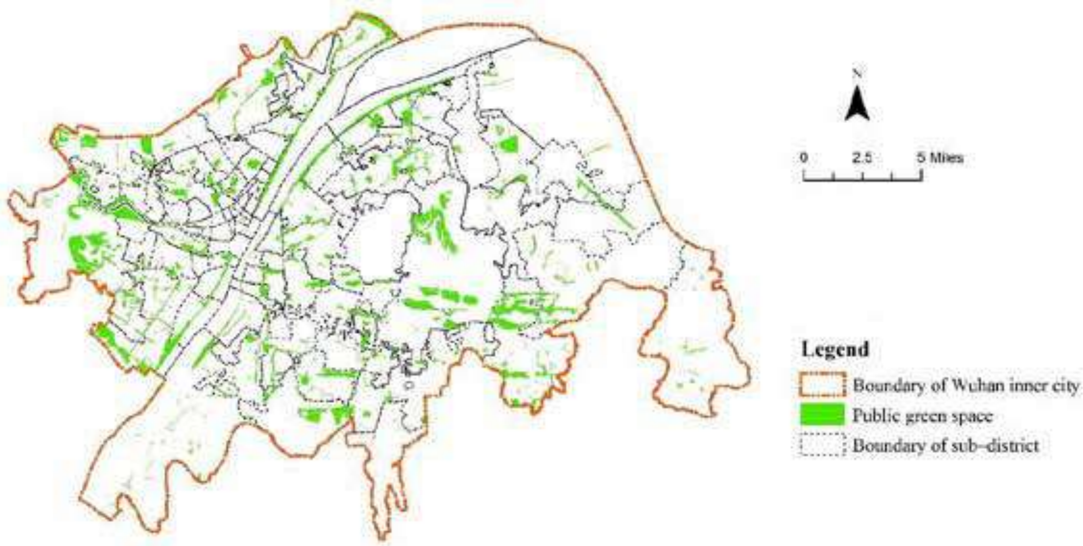


Figure 2 The distribution of public green space in Wuhan inner city

- Location Based Services data

Location Based Services (LBS) data in this paper is obtained from WeChat of Tencent company, which is the most popular social media app in China. Yichuxing is a function of WeChat to reflect population distribution by acquiring users' mobile terminal real-time position information (longitude and latitude), and the values of Yichuxing is the standardized data of actually being collected population. Therefore, it can be used to represent the relative population in a certain area. Here we apply it to calculate the relative use of public green space. Data acquisition time in this paper is a week (7 days) and the weather is non-rainy during this period. Further, it starts from 6:00 a.m. and ends at 22:00 p.m. every day with two hour-interval. In other words, there are 63 time points (9 time points/ day * 7 days) of such data acquired in total.

***Variables calculation***

- Public green space use

Public green space use of each sub-district is measured by relative population density within it. Since the values of Wechat - Yichuxing is the kind of real-time data, therefore, average relative population density of total public green space in each sub-district is calculated to reduce the impacts of data at different time points. The detailed calculation formulas are as follows:

$$P_i = \frac{\sum_{j=1}^{n} Q_{ij}}{d_i \sum_{j=1}^{n} G_{ij}} \tag{1}$$

Where $P_i$ is the relative population density of public green space in sub-district $i$, $d_i$ is the residential population density of sub-district *i* (This study takes it as a weight, when calculating the public green space use to reduce the influence of number difference of inhabitants in sub-district), $Q_{ij}$ is the average relative population within public green space *j* that belongs to sub-district $i$, $G_{ij}$ is the area of public green space *j* that belongs to sub-district *i* (in square meter), and *n* is the total numbers of public green space within sub-district *i*.

In particular,

$$Q_{j1} = \frac{\sum_{h=1}^{w} \sum_{t=1}^{m} X_{jt}}{wm} \tag{2}$$

or

$$Q_{j2} = \frac{\sum_{t=1}^{w} X_{jt}}{w} \tag{3}$$

Where $Q_{j1}$ is the average relative population of public green space *j* per day, $X_{jt}$ is the relative population within the public green space *j* at time *t*, *m* is the total time points per day (here is 9), *w* is the total days, and $Q_{j2}$ is the average relative population of public green space *j* at time *t*. It is worth to note that for formulas (2), when w is respectively equal to 7, 5 and 2, $Q_{j1}$ represents the average relative population of public green space j per day of a week (7 days), weekdays (5 days), and weekends (2 days) separately; for formulas (3), *w* is assigned as 7, which means that $Q_{j2}$ measures the average relative population of public green space *j* at time *t* during a week. In order to explore if the time makes a difference in the impacts of public green space connectivity on green space use, we correspondingly calculate the relative population density of public green space in each sub-district at 9 time points as well as per day (separately based on a week, weekdays and weekends).

- The connectivity of public green space

The connectivity of public green space in each sub-district is measured by the Integral Index of Connectivity in landscape ecology theory, which has been developed maturely in ecology, and some researchers have applied it to study the connectivity of urban green space (Shi and Xu 2011, Mu et al. 2017). By referring to the relevant publications (Pascual-Hortal and Saura 2006, Saura and Pascual-Hortal 2007), the formula applied in our study is as follows:

$$\mathrm{IIC} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{a_i \cdot a_j}{1+nl_{ij}}}{A_L^2} \quad (4)$$

Where *IIC* is the integral index of connectivity (ranging from 0 to 1), $a_i$ and $a_j$ respectively represent the areas of urban green space *i* and *j* (in square meter), $nl_{ij}$ means the link numbers between public green space *i* and *j* (based on the topological distance), and $A_L$ is the area of individual sub-district (in square meter).

Based on the analysis of distance (edge-to-edge Euclidean distances) between two arbitrary public green spaces in each sub-district by Arcgis extension, then we calculate the *IIC* in Conefor 2.6. It is worth to note that, considering on the issue focused on in this study is that the influence of public green space connectivity on its use, therefore, public green spaces within what distances can be taken into analysis is significant. According to the human's walking speed and the distance affecting users to access to public green space (Almanza et al. 2012, Kondo et al. 2009, McMorris et al. 2015, Catherine et al. 2013, Cohen-Cline et al. 2015), we separately take 500 m and 1000 m as the thresholds to decide which public green spaces are considered when calculating *IIC*.

***Analysis method***

Before correlation analysis, the process of data standardization (z-score) and descriptive statistics analysis (mainly inspecting outliers) is applied first to reduce the analysis error. Then the relationship between the connectivity of public green space and its use is analyzed by Pearson Correlation Analysis in SPSS 22. As mentioned above, we divide the average relative public green space use into two types by the unit of o'clock and day. In detail, the former includes 9 time points and the latter concerns 3 kinds of daily average. All of them are applied to test whether or not they correlate with *IIC* of public green space that is calculated based on 500 m and 1000 m respectively.

**Results**

Since there are some sub-districts that do not have the public green space meeting the requirements of area being more than 1 ha. What’s more, even if some sub-districts satisfy that standard, either the number of public green spaces within them is no more than 2 or the distance between the public green spaces within them is more than 1000 m. In a word, after neglecting those unfit sub-districts, there are 74 ones are taken into *IIC* calculation. Based on that, another two sub-districts are deleted due to the outliers, thus, only 72 units are left to be analyzed at last. According to the calculation results of *IIC*, we find that the connectivity of public green spaces within each sub-district is relatively low no matter it is based on the 500 m or 1000 m. For 500 m, the threshold of *IIC* is between 0.195 and 0 while for 1000 m, the one is from 0.202 to 0 (shown as Figure 3 and Figure 4).

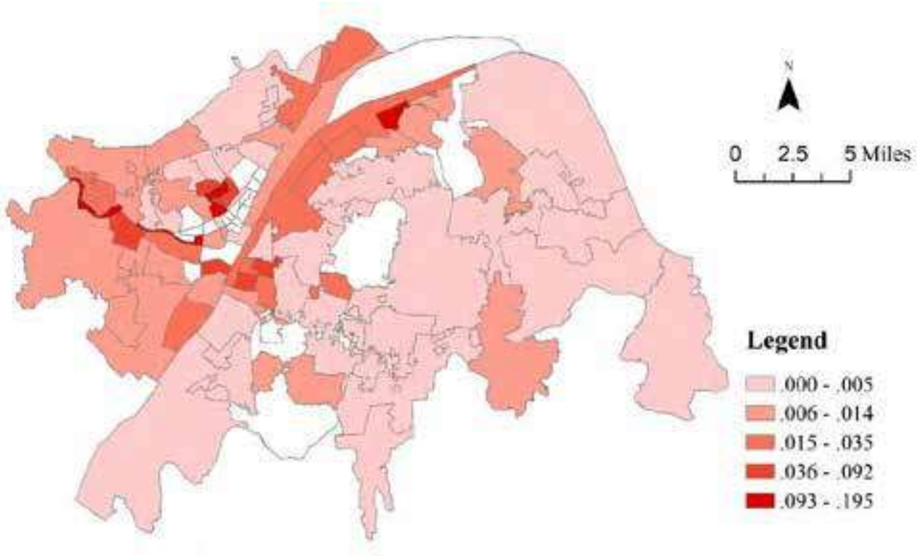


Figure 3 The connectivity distribution of public green space (distance threshold: 500 m)

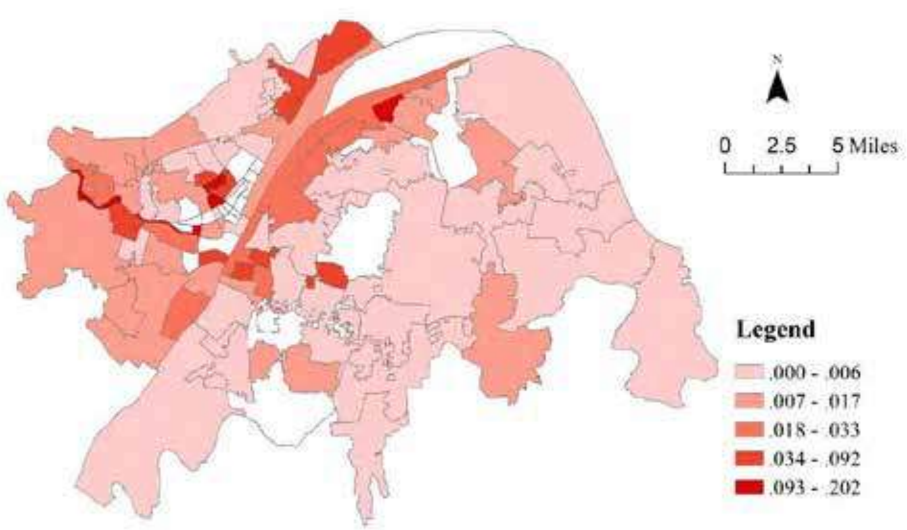


Figure 4 The connectivity distribution of public green space (distance threshold: 1000 m)

Depicted as Figure 3 and Figure 4, it is obvious that relatively high connectivity of public green space is almost in the small-scale sub-districts which locates in the old town of Wuhan, especially in the center of old urban areas, whereas low connectivity mainly lies in the large-scale sub-district, especially near the peripheral of the inner city.

Intriguingly, after visualizing the calculation results of green space use in different time, the sub-districts with high public green space use are not accompanied with high connectivity of public green spaces simultaneously. On the contrary, most high green space use distributes in low *IIC* areas, which are relatively new and near the periphery of inner city. Considering the words length of the paper, two types of public green space are selected to illustrate the detailed distribution (presented as Figure 5 and Figure 6).

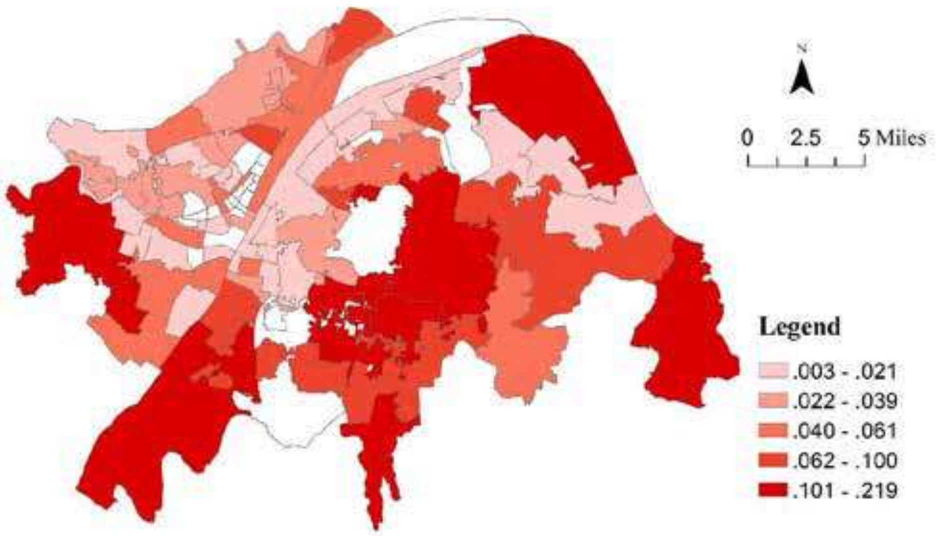


Figure 5 The distribution of public green space use (during weekends)

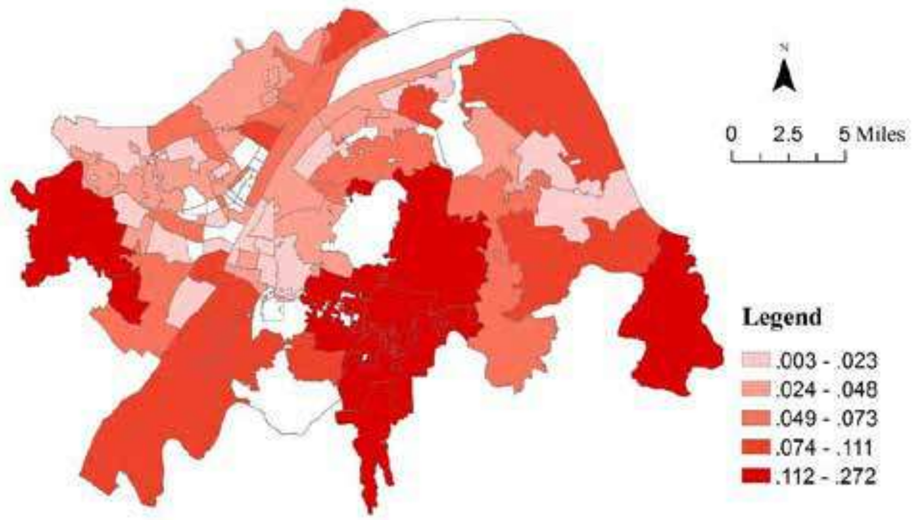


Figure 6 The distribution of public green space use (on 20 o'clock)

The results of correlation analysis are shown as Table 1 and Table 2. Different from what we expect is that the *IIC* of public green space is negatively related with green space use no matter is statistically significant or not. From the perspective of distance threshold impact, the Pearson Correlations are almost same in both ranges. In other words, as long as the distance between two public green spaces is no more than 1000 m, the generated *IIC* might not make an apparent difference in the role of green space use. While when taking time into considering, there exists several variations in that relationship. In detail, *IIC* has a statistically significant correlation （within a 95% confidence interval） with the average public green space use during weekends and a week as well as on different time points (namely, 6 o'clock, 10 o'clock, 18 o'clock, 20 o'clock and 22 o'clock). That is to say such relationship is likely to be influenced by the characteristics of residents' daily behaviors.

**Table 1 The correlations between relative public green space use (daily average) and IIC**

| Correlations | | | | | | |
|---|---|---|---|---|---|---|
| **Relative public green space use (daily average)** | **500 m_IIC** | | | **1000 m_IIC** | | |
| | **Pearson Correlation** | **Sig. (2-tailed)** | **N** | **Pearson Correlation** | **Sig. (2-tailed)** | **N** |
| Weekdays (5 days) | -.231 | .050 | 72 | -.230 | .052 | 72 |
| Weekends (2 days) | -.266* | .024 | 72 | -.268* | .023 | 72 |
| A week (7 days) | -.246* | .037 | 72 | -.246* | .038 | 72 |
| *. Correlation is significant at the 0.05 level (2-tailed). | | | | | | |

**Table 2 The correlations between relative public green space use (o'clock average) and IIC**

| Correlations | | | | | | |
|---|---|---|---|---|---|---|
| **Relative public green space use (o'clock average)** | **500 m_IIC** | | | **1000 m_IIC** | | |
| | **Pearson Correlation** | **Sig. (2-tailed)** | **N** | **Pearson Correlation** | **Sig. (2-tailed)** | **N** |
| 6 o'clock | -.237* | .045 | 72 | -.239* | .043 | 72 |
| 8 o'clock | -.177 | .137 | 72 | -.177 | .136 | 72 |
| 10 o'clock | -.235* | .047 | 72 | -.232* | .049 | 72 |
| 12 o'clock | -.186 | .118 | 72 | -.184 | .123 | 72 |
| 14 o'clock | -.215 | .070 | 72 | -.217 | .067 | 72 |
| 16 o'clock | -.207 | .081 | 72 | -.206 | .082 | 72 |
| 18 o'clock | -.243* | .039 | 72 | -.244* | .039 | 72 |
| 20 o'clock | -.264* | .025 | 72 | -.264* | .025 | 72 |
| 22 o'clock | -.286* | .015 | 72 | -.284* | .015 | 72 |
| *. Correlation is significant at the 0.05 level (2-tailed). | | | | | | |

**Discussion**

As mentioned above, the measurement of public green space use is based on the data of Yichuxing, which is obtained from WeChat users. Additionally, more than 90% of them, according to the Wechat Data Report in 2018, are less than 55 years old (WeChat Team, 2019). Public green space use (deriving from that data) during work and school hours or weekdays, therefore, might differ obviously from that during off-work and after-school hours or weekends, which indirectly mirrors the user group of public green space from single (mainly the elderly, during work and school hours or weekdays) to relatively diverse (during off-work and after-school hours or weekends). Moreover, series of studies have proved that various groups prefer and require different characteristics of green space, and take different types and levels of physical activity in it (Cohen, 2015, Mytton, 2012, Douglas, 2017). For example, Kaczynski et al. (2009) find that the area of neighborhood parks within 1000 m of individual's home could contribute to improving the level of physical activity for women as well as the younger (between 18 and 34 years old) and elder (more than 55 years old) groups. Similarly, Leslie et al. (2010) conclude that when local parks are safe, attractive and well-maintained, groups with high socioeconomic status have more park use and recreational walking. That is to way, the influences of public green space characteristics on use may vary with the user groups changing. Hence, off-work and after-school hours as well as weekends makes a difference on the correlations between *IIC* and public green space use likely due to the variation of user groups at different time.

Seemingly, the negative correlation generated in this study is unreasonable and opposite to the expectation that enhancing connectivity contributes to promoting green space use. After all, some scholars suggest that high connectedness among urban green spaces is good for the movement of both wild animals and human as well as public health (Tian et al. 2017, Selim and Demir, 2019, Zhang et al. 2015). However, it is worth to note that there is a basic difference of such movement between wild animals and human beings, which is that the former originally lives in the nature environment (that is a way of green space use per se) without need of considering the accessibility of those green spaces (Moving from one patch of green space to another is oriented by survival need for them), whereas people have to access to those nature places first if they want to use them and the activities happening within or inter green spaces are decided by many factors, such as the recreational demands and green space quality. That is to say good connectivity among green spaces is significant for biodiversity protection but not necessarily encouraging green space use for human beings.

Indeed, according to the analyzed results in this study, high connectivity- that represents good accessibility between green spaces but not equals to being accessed easily from other places (like the residence, school and workplace)- locates in the old town where the quality of green space within it is poorer than elsewhere in Wuhan inner city, while high green space use primarily exists in the areas with relatively good accessibility. What's more, in the light of the characteristic evaluation of health-oriented green space in Wuhan inner city (Dong and Liu 2018), the distribution of green space use in this paper is roughly corresponding to the locations with good greenness, quality and accessibility. That indirectly reflects the characteristics of green space (including quality, accessibility, etc.) are more likely to play a significant role in promoting use than its connectivity, which aligns with the confirmed conclusion that quantity, quality and accessibility of urban green space (especially quality and accessibility) should be emphasized to improve green space use (Haaland and van den Bosch 2015, WHO, 2016). Therefore, the negative coefficient of the Pearson Correlation Analysis in this paper does not accordingly mean the higher connectivity discourages green space use. On the contrary, such results can be considered as the old town existing poor characteristics that weighs more in the role of hindering green space use than the promoting role of connectivity. However, attention should be payed when applying it, because this underlying factor is inferred from the qualitative comparison with the conclusions previous research. Quantitative analysis will be necessary in the future to improving its credibility.

## Conclusion

In order to explore if improving the connectivity of public green space contributes to promoting green space use, we apply Pearson Correlation Analysis to test the relationship between them, whereas the analysis results are opposite to what we expect. Negative correlation is found between the connectivity of public green space and green space use whatever the time and distance threshold is. Moreover, this relationship differs in statistics significance with the variation of user groups of public green space at different time. Instead of superficially explaining the results as simple promotion-inhibition relationship between two variables, the paper identifies the underlying factor influencing the correlation between connectivity and green space use. That is the characteristics of urban green space (including quality, accessibility, etc.) playing more significant role in improving green space use than connectivity. Hence, putting more emphasis on the quality and accessibility of the existing public green space is potentially the useful way to promote its use when there is no large space left to build new public green space in the intensively compact cities.

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