IMPACTS OF NEIGHBORHOOD BUILT ENVIRONMENT FACTORS ON SENIOR CITIZENS' PHYSICAL ACTIVITY LEVEL IN WUHAN, CHINA

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1 ABSTRACT

The impact of built environment on the well-being of senior citizens has received increased research attention in recent years. In light of the fact that senior citizens often rely on open spaces within their neighborhoods for physical activity, many studies have been conducted on ways to improve outdoor environments to benefit physical and mental health for seniors.However, the impacts of specific built environment factors on senior citizens' physical activity level have yet to be fully investigated in a quantitative way. This study examined associations between the neighborhood environment factors and physical activity level of senior citizens in a large city in China; specifically durations of physical for 655 senior citizens from 16 residential neighborhoods were studied through questionnaires conducted in Wuhan, China. Neighborhood built environment attributes were classified into four categories: physical activity facilities, neighborhood open space characteristics, residential density, and surrounding built environment characteristics. A multivariable linear regression model was developed to examine the association. The results indicated that hard-surface exercise ground area ratio, floor area ratio, residential household density, and nearby public open space accessibility, correlated to higher level of senior citizens' physical activity, while other attributes of the built environment, including aesthetics, green area ratio, light condition of hard-surface exercise ground area, are not. In addition, differences between male and female residents were observed: Generally, the influence of built environment factors on female seniors were more significant than that on males and nearby public open space accessibility was only significantly correlated to female participants' physical activity (t=-3.864 , P=0.005), but not related to male's. This research contributes to the existing studies of impacts of neighborhood built environment on levels of physical activity. The findings can assist urban planners and landscape architects to create better senior-friendly residential neighborhood design guidelines.

1.1 Keywords

neighborhood built environment, physical activity, senior citizens, environment characteristics

2 BACKGROUND

Well-being of senior citizens has been receiving increasing research interest in China because of the rapidly aging Chinese population. In 2015, the number of Chinese age 65 and older was 144.34 million, and this number is expected to rise over 300 million by 2050. Therefore, it is important to research ways to improve built environment attributes that promote the well-being of senior citizens. Physical activity is essential for seniors in preventing diabetes, obesity, cardiovascular disease and stroke. Many studies have shown mounting evidence indicating that physical activity can extend years of independent living and improve the quality of life for older people. A recently focus in this area is correlating built environmental factors with levels of physical activity. The reasoning behind the trend is that senior citizens tend to highly rely upon the open spaces and facilities in their local residential neighborhoods for outdoor activity and thus are particularly vulnerable to the obstacles of built environment (King et al, 2000; Michael et al, 2006; Sugiyama & Thompson, 2007; Clarke et al, 2013; Wang et al, 2016; Gallagher et al, 2010). In addition, built environment interventions can benefit persons of all ages in the neighborhood.

To successfully implement built environment interventions, understanding of the effects of built environment factors is critical. Most existing research focus on walking and cycling activities. A few studies develop comprehensive frameworks of built environment factors associated with people's walking and cycling behaviors. Pikora et al. (2003) developed four category of features of neighborhood environment: destinations (availability of commercial and community facilities); functional (structural characteristics of street network); aesthetics of the environment; and safety. Among Chinese researchers, Zhou et al. (2012) proposed a framework of neighborhood features associated with people's physical activity, including housing density, land-use mix, street connectivity, walking/cycling facility, neighborhood aesthetic, safety, and others. In the previous empirical studies, the most common statistical studies applied regression models. Some studies applied logistic regression models to anlayze the associaitons between levels of physical activity and built environmental attributes (Sugiyama et al., 2007; Salvador et al., 2009; Jelle et al., 2012). Other studies used linear regression models (Nagel et al., 2008). Many researchers built upon these frameworks and conducted empirical studies to investigate the correlations between neighborhood built environment factors and likelihood of senior residents' physical activity in their local neighborhoods. Several studies found that the walable access to parks and greenways positively related to senior residents' physical activity level (Shin et al., 2011; Lees et al, 2007). Hunag and her colleague (2014) found that senior residents living in neighborhood with higher residential densities were less likely to participate in daily outdoor physical activity. Ottoni et al. (2016) suggested that outdoor sitting amenities also imrpoved the likelihood of seniors' physical activity. These research outcomes all provided insights for how neighborhood built environment influence senior residents' physical activities.

There remains two major gaps in the existing research. First, most exisiting studies have focused on planning-oriented factors at neighborhood scale (such as street connectivity and land-use mix) while few have considered design-oriented factors at smaller scale of open spaces (such as exercise-supporting facilities availability, or playground area per capital within a given neighborhood). However, the impacts of these factors on seniors' physical activity may vary at different scales. So there is a need to examine the effects of neighborhood built environment factors on both macro and micro scales to reach a clearer understanding of relationships between environmental factors on physical activities of senior people. Second, measures applied in existing studies were mostly quantitative; few studies have taken the morphological characteristics of the neighborhood environmental factors at smaller scales into consideration. Quantitative measures only reflect total neighborhood built environment features; these can be inaccuarte in reflecting to what extent the residents actually utilize the neighborhood spaces. Morphological characteristic, for example, layout pattern of the green space or other design features on the neighborhood, may also influence residents' activities. Take green coverage ratio as an example, it is a quantifiable measure reflecting the amount of green space provided to the residents in the neighborhood. But neighborhoods with the same green coverage ratio may largely differ in terms of green space layouts, such as the centralized public green space layout, or linear green space along neighborhood pathways, or scattered small green spaces. These layouts influence seniors' daily usage because the green spaces with different forms support different kinds of physical activities. Thus, measures limited to quantities of green space, without considering morphological characteristics, may lead to misleading associations between built environmental factors and senior physical activity.

In addition, although current official Neighborhood Planning and Design Guidelines in China provide basic quantitative standards of neighborhood design (such as floor area ratio and green space ratio), as

well as some general suggestions on neighrbohood green space and hard-surface ground design based on nromative practice, there is little guidance on how specific design features (such as size or facility) can be organized in order to meet various needs of senior residents. Thorough understanding of how the behaviors of senior residents associate with neighborhood built environment can lead to more informed neighborhood design guidelines that can assist urban planners and landscape archiects with future design practice.

To address these gaps, this study investigated the effects of neighborhood built environment factors on physical activity of the senior residents with emphasis on morphological characteristic of green spaces at smaller scales. Multiple linear regression analysis allows for quantitatively assessment of correlations between neighborhood built environment features and seniors' physical activity levels. Explorations into the disparities among the correlations in the sample neighborhoods reveal how neighborhood built environment impacts senior resident's physical activity behavior and to what extent. The results provide community designers and policy makers with decision supports on future built environment intervention for physical activity promotion purpose in the context of Chinese metropolitan areas. This study also contributes to the existing environment-behavior literature in theoretical frameworks measuring environmental factors for seniors' physical activities at the neighborhood scales.

3 METHODOLOGY AND DATA

3.1 Study Design and Study Neighborhoods

The study collected data of physical activities of senior residents with the aim to explore if the levels of their physical activities were associated with neighborhood built environment factors and to what extent. This study selected 16 sample neighborhoods from Wuhan metropolitan area (see Table 1). Wuhan Is the largest city in central China with a population of 10 million. The climate and socio-economic characteristics of Wuhan are representative of the situation of a large number of Chinese large metropolitans.

As previous research showed that individual socio-economic status also largely impacts people's physical activity behavio, sample neighborhoods in this study were selected within a range of general socio-economic status in order to minimize the random bias from individual socio-economic characteristics differences. The criteria included: construction period from 2000 to 2014; housing price from 10000 RMB/m^2 to 14000 RMB/m^2. All measurements of the criteria were conducted in September 2016.

Table 1. General socio-economic characteristics of the 16 selected neighborhoods.

Number	Name	construction period	May,2016 housing price (RMB/ m^2)	green area ratio(%)	District	Acreage(m^2)
1	Dongfang Huacheng	2005	12347	49%	Hankou	142000
2	Baoli Huadu	2009	11192	35%	Wuchang Hongshan	148000
3	Baoli Huayuan	2006	12191	42.37%	Wuchang Hongshan	137600
4	Meilin Qingcheng	2007	12589	37%	Wuchang Xudong	170000
5	Mingdu Huayuan	2006	10210	50%	Wuchang Hongshan	146000
6	Dahua Nanhu Gongyuan Shijia Section 2	2013	11760	28%	Wuchang Hongshan	176000
7	Aijia Guoji Huacheng	2010	11173	40%	Wuchang Qingshan	192000
8	Dushi Jingdian	2008	12312	44%	Wuchang Xudong	112000
9	Binhu Mingdi	2006	10075	43%	Wuchang Hongshan	52000

10	Nanguo Mingzhu Section 1	2005	11000	40%	Hanyang	183000
11	Nanguo Mingzhu Section 2	2005	11000	40%	Hanyang	124000
12	Jinqiao Gangwan	2007	10726	37%	Hanyang	75000
13	Tairan Nanhu Meiguiwan	2014	12209	35%	Wuchang Hongshan	245000
14	Huajin Huayuan	2000	11173	37%	Wuchang Hongshan	189500
15	Dahua Nanhu Gongyuan Shijia Section 3	2013	13554	35%	Wuchang Hongshan	179800
16	HanKou Chuntian	2007	12203	40%	Hankou	153000

3.2 Neighborhood Built Environment Factors

We selected the factors in this analysis, as well as their measurements, based on review of the relative literature published in the last ten years that: (1) chose senior residents as the focus group; (2) applied empirical approaches with clear illustration on sample sizes, study units, built environment factors, data analysis models. Based on the literature review, the independent variables in this study consisted of seven neighborhood built environment characteristics in four categories, as shown in Table 2. Among these variables, most of them were calculated using a GIS platform, including neighborhood floor area ratio, green area ratio, hard-surface exercise ground area ratio, and nearby public open space accessibility. The areas of green area and hard-surface exercise ground in each study neighborhood were calculated based on high-resolution satellite image derived from city planning department of Wuhan. Nearby public open space accessibility variable was defined as the distance from study neighborhoods to the closest urban public space (park, city square, etc.) in the nearby urban district, calculated with the Network Analysis tool in ArcGIS10 software. Data of facility-related variables, including street light and exercise facility condition, were collected by neighborhood observation. Neighborhood aesthetics quality variable was determined by neighborhood questionnaire survey that covered randomly selected neighborhood residents of different genders and ages, whose attitude toward the aesthetic quality of the neighborhood was evaluated with a seven-point Likert scale; and the average points from all participants represented the measurement of neighborhood aesthetics quality of the given neighborhood. All study neighborhoods were also classified based on morphological characteristics of the neighborhoods public spaces into the following two categories: (1) Centralized public space; (2) Decentralized public spaces (See Figure 1 & 2). Centralized public space refers to the condition that the given neighborhood has only one compact green space within it; while decentralized means these public spaces are in a state of dispersed distribution.

All data of neighborhood built environment characteristics were derived from September to October 2016.

Table 2. Built Environment Characteristics of the 16 neighborhoods.

Name of neighbor-hoods	Weekly average physical activity duration (h)	Aesth-etics	Nearby public open space accessi-bility (km)	hard-surfa-ce exerci-se ground area ratio	green area ratio	Reside-ntial house-hold density (Set / ha)	Light density of hard-surface exercise ground area (/ m^2)	Neighb-orhood floor area ratio
Tairan Nanhu Meiguiwan	6.500	5.100	0.880	0.042	0.350	142.857	0.007	1.700
Nanguo Mingzhu2	6.570	6.070	0.980	0.032	0.400	96.532	0.005	1.500

Nanguo Mingzhu1	6.670	5.750	1.415	0.043	0.400	81.967	0.005	1.300
Meilin Qingcheng	7.160	5.356	1.530	0.035	0.370	162.353	0.004	1.700
Dushi Jingdian	8.220	5.420	0.570	0.061	0.449	128.840	0.004	2.080
HanKou Chuntian	8.340	5.480	0.860	0.041	0.408	128.366	0.011	1.880
Dongfang Huacheng	9.700	4.880	0.520	0.036	0.490	153.803	0.011	1.560
Jinqiao Gangwan	9.810	5.250	1.090	0.034	0.370	266.667	0.001	2.200
Baoli Huayuan	10.610	5.640	0.810	0.044	0.424	194.404	0.010	2.200
Huajin Huayuan	11.230	5.510	0.840	0.055	0.335	165.013	0.005	1.798
Mingdu Huayuan	11.650	5.550	0.870	0.059	0.500	133.014	0.007	1.050
Dahua Nanhu Gongyuan Shijia2	11.970	5.620	0.250	0.059	0.280	143.182	0.006	1.730
Aijia Guoji Huacheng	12.180	5.240	0.700	0.113	0.347	249.271	0.004	2.723
Binhu Mingdi	12.560	5.580	0.550	0.077	0.430	195.167	0.008	2.200
Baoli Huadu	12.630	5.790	0.510	0.064	0.350	337.838	0.006	2.930
Dahua Nanhu Gongyuan Shijia3	12.880	5.880	0.590	0.083	0.350	139.878	0.011	1.600

Figure1 Centralized public space map

Figure2 Decentralized public space map.

3.3 Population and Physical Activities

The survey was conducted concurrently in study neighborhoods from September 2016 to October 2016 when the climate was suitable for outdoor physical activity in Wuhan. The survey occurred during two-time spans (from 7 a.m. to 10 a.m., and from 16 p.m. to 21 p.m.) on both weekdays and weekends with good weather during the previous week. The target population in this study was defined as senior residents (age > 55) living in the study neighborhoods. Their individual-level data included age, education, and gender. The education levels of the participants were classified into the following categories: Junior middle school or below, High school, college or higher. Age was grouped into seven categories as follows: (55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85 and above). A total of 665 senior residents were reached and 655 effective responses were collected. The final sample consists of 270 male and 385 female with a mean age of 68.63. All 16 neighborhoods were represented in the sample: the number of participants per neighborhood ranged from 31 to 45, with an average of 40.94.

The overall socio-demographic characteristics of the participants were summarized in Table 3.

Table 3. Overall Socio-demographic Characteristics of the Participants.

Individual level	Categores	Number	Proportion（%）	Weekly average physical activity duration (h)
Gender	Male	270	41.20	9.89
	Female	385	58.80	9.54
Education	Junior middle school and below	254	43.70	9.34
	High school	214	36.80	10.69
	College or higher	113	19.50	11.09
	Lack of data	74	11.30	
Age	55-59	76	11.60	10.27
	60-64	235	35.90	10.71
	65-69	166	25.30	9.84
	70-74	69	10.50	9.20
	75-79	60	9.20	8.09
	80-84	39	6.00	9.67
	85 and above	10	1.50	5.30
Total		655		9.89

Questions related to physical activity were adopted from the International Physical Activity Questionnaire (IPAQ) to collect information on estimated physical activities of the seniors. Participants were asked to report the hours and minutes they had participated in physical activities in the previous 7 days. The form of the physical activity in the questionnaire intentionally excluded housing working and utilitarian commuting but focusing on recreational physical activity as recommended by previous research (Chaix et al, 2014). The average value of total physical activity duration in the previous week of all participants in one neighborhood was defined as the dependent variable in this study.

3.4 Statistical Analysis

Statistical analysis was conducted in SPSS 19.0. First, one-way ANOVA analyses were used to examine the associations between participants individual characteristics and the levels of physical activities. Then a multivariable linear regression model was conducted to examine the relationships between neighborhood built environment factors and the levels of physical activities of the senior residents living in the neighborhoods. In addition, male and female participants were examined jointly and separately to explore the potential differences in the effects of neighborhood built environment factors. Last, Pearson Correlation Coefficient was applied separately to examine the differences between neighborhoods with centralized public space and ones with decentralized public space.

4 RESULTS

74.50 percent of the senior residents in these study reported participating in physical activities at least 1 hour in the previous week. And 10.38 percent of the senior residents participated physical activity over 2.5 hours during that span, which was the recommended minimal exercise time per week for adults according to WHO (WHO, 2008). The mean physical activity duration within the survey week was 9.89h.

One-way ANOVA analyses showed that participants' individual characteristics were significantly associated with their physical activity behaviors (See Table 4). Men spent more time than women taking exercise within the week. Physical activity duration decreased with age, as expected. In addition, participants with higher education (college or higher degree) were more likely to participate in daily physical activity.

Table 4. One-way ANOVA analyses results.

Dependent variable: Weekly average physical activity duration			
Individual Characteristics	P	Whether have significant correlation	N
Age	.007**	√	655
Gender	.064	×	655
Education	.011*	√	581

Notes：*P ＜ .05, **P＜ .01

The multivariable linear regression model indicated that four of the seven neighborhood built environment characteristics in this study were significantly associated with senior residents' physical activity duration, including hard-surface exercise ground area ratio, floor area ratio, residential household density, nearby public open space accessibility (See Table 5a). Higher hard-surface exercise ground area ratio was strongly associated with more time spent on physical activity (t=3.429，P=0.009), which was not surprising considering the context that hard-surface exercise ground was primary space for senior residents' physical activity. In addition, senior residents living in neighborhoods with lower floor area ratio were more likely to participate in physical activities (t=4.744，P=0.001). While higher residential household density (t=-2.677，P=0.028) of the neighborhoods were positively associated with likelihood of physical activities of the senior residents. In addition, distance from neighborhoods to the closest public open space was also found significantly associated with durations of physical activities of senior residents (t=-2.330，P=0.048), which was similar to previous research. Senior residents were less likely to spend time on physical activity with the increase of distance from the neighborhood entrances to surrounding public open spaces. This finding suggested that although built environment within the neighborhood boundary was hypothesized to directly influence seniors' physical activity behavior, the availability of surrounding public spaces also played a significant role, which was consistent with previous research. Other variables, including aesthetics, green area ratio, light density of hard-surface exercise ground area were not found to be significantly associated with dependent variables.

In addition, differences between male and female residents were observed. Three of the same neighborhood built environment characteristics were found significantly associated with the male and females' physical activity duration, but those had a more significant impact on females, including hard-surface exercise ground area ratio, floor area ratio and residential household density. Nearby public open space accessibility was significantly associated with female participants' physical activity (t=-3.864 , P=0.005) but had nothing to do with male (See Table 5a).

The Pearson Correlation Coefficient indicated that different categories of neighborhood had different environment characteristics associated with the time spent on physical activity. A positive correlation was found between aesthetics (r=0.737 , P=0.023), nearby public open space accessibility (r=-0.678 , P=0.045), hard-surface exercise ground area ratio (r=0.704 , P=0.034) and time spent on physical activity in the neighborhood type of centralized public space. Hard-surface exercise ground area ratio (r=0.798 , P=0.032), floor area ratio (r=0.782 , P=0.038) and residential household density (r=0.929 , P=0.003) of decentralized public space' neighborhoods were all found correlated with participants' physical activities duration (See Table 5b).

Table 5 Multivariable linear regression and Pearson Correlation Coefficient analysis results.

a. multivariable linear regression analysis

Independent variables	Total		Male		Female	
	t	P	t	P	t	P
Aesthetics	1.364	.210	1.511	.169	1.576	.154
Nearby public open space accessibility	-2.330	.048*	-.132	.898	-3.864	.005**
hard-surface exercise ground area ratio	3.429	.009**	3.401	.009**	2.477	.038*
green area ratio	-.098	.924	.307	.766	-.522	.616
Residential household density	4.127	.003**	2.695	.027*	4.744	.001**
Light density of hard-surface exercise ground area	1.054	.322	.904	.393	.901	.394
Floor area ratio	-2.946	.019*	-2.462	.039*	-2.677	.028*
R Square	.884		.735		.918	
Adjusted R Square	.783		.503		.847	
P	.003**		.064		.001**	
Dependent variable	Weekly average physical activity duration		Weekly average physical activity duration of male		Weekly average physical activity duration of female	

b. Pearson Correlation Coefficient

variables	Centralized public space	Decentralized public space

	Pearson Correlation	Significant (bilateral)	Pearson Correlation	Significant (bilateral)
Aesthetics	.737	.023*	-0.645	0.117
Nearby public open space accessibility	-.678	.045*	-.634	.126
hard-surface exercise ground area ratio	.704	.034*	.798	.032*
green area ratio	-.043	.913	-.376	.406
Residential household density	.242	.530	.929	.003**
Light density of hard-surface exercise ground area	.284	.459	.039	.933
Floor area ratio	.180	.644	.782	.038*
N	9		7	
Related variable：Weekly average physical activity duration				

Note: *P＜ .05, **P＜.01

5 DISCUSSION AND CONCLUSION

This study confirmed the hypothesis that the likelihood that senior residents participated in physical activity was associated with the built environment features of the neighborhoods where they lived in Chinese urban context. Overall, higher hard-surface exercise ground ratio and residential household density, decreasing floor area ratio and distance to the closest public open space in surrounding urban district, were positively related to the time senior residents spend on physical activity. Additionally, there were also some noticeable differences in built environment factors between male and female seniors. Generally, the influences of built environment factors on female seniors were more significant than that on males. Surrounding public open space availability variable was only significantly associated with physical activity time of female seniors.

One main lesson from this study was that both of the public open spaces within the neighborhoods and in surrounding urban districts were significantly related to the levels of physical activities of seniors; while the hard-surface exercise ground was the most important one among a variety of amenities of the neighborhoods. The potential reasoning might be that the primary forms of physical activities of Chinese seniors were generally in groups, which required relatively large hard-surface open spaces. This rationale could also explained why the levels of physical activities of females, who tended to participate in group exercise more actively, were even more significantly correlated with the availability of closest public open spaces than that of males. This result indicated that hard-surface exercise ground improvement could be the one of efficient approach of built environment interventions that encouraged seniors' physical activities. Therefore mandatory requirement on a minimal percentage of hard-surface open spaces in the neighborhood can be a valuable addition in the current neighborhood design guidelines in order to encourage senior residents to reach sufficient duration of physical activities.

This study also found that senior residents living in neighborhoods with high residential household density, especially the females, were more likely to participate in physical activities, indicating that seniors residents participated in physical activity in groups and thus could be influenced by other seniors who lived close. This finding highlighted further consideration on potential spatial autocorrelation effects of seniors' physical activity pattern. As a result, it is vital for future studies to include the spatial autocorrelation effects in the theoretical framework and further examine how exactly seniors' physical activity tendency would impact each other, in order to better clarify the impacts of the various interventions on both built environment aspect as well social activity encouragement.

This study also lead to some enlightening evidence that how morphological characteristics of neighborhood open space could also impact on seniors' physical activity. One interesting finding was that the seniors living in neighborhoods with centralized public spaces were more likely influenced by the accessibility to nearby public open space, while ones living in neighborhoods with decentralized public

spaces not so much. This result could suggest that in neighborhoods with centralized public spaces, seniors who did not live close to the neighborhood public space might have to turn to nearby available public spaces as substitution, while ones lived in neighborhoods with decentralized public spaces had better access to the open spaces that scattered in the neighborhood so they were less likely to rely on open spaces outside the neighborhood. This finding suggested that for the neighborhood that did not have any public open space within walking distance, designers should consider decentralized layout as the preferred pattern because it would allow residents to access public spaces easily and thus promote their level of physical activity. Another finding related to morphological characteristic was that the aesthetics of the open spaces showed significance only in neighborhoods with centralized public spaces, indicating that designer who worked on these type of neighborhood should pay more attention to improving open space environment in order to maximize its effect on the tendency of seniors' physical activities.

Another lesson from findings in this study was expectation regarding facilities-based interventions should be modest: One unexpected finding of this study was none of the facilities, including lighting and exercise facilities, turned to be significantly associated with duration of physical activity, which indicated that the primary form of physical activity that senior residents participated did not rely on facilities.

To conclude, this research confirmed that neighborhood built environment were significantly related to the durations of physical activities of senior residents and suggested a variety of built environment interventions that could increase the likelihood of physical activities among seniors. The results could be conducive to the decision-making process of neighborhood design and also help further facilitate detailed improvements of future neighborhood planning and design guidelines to support senior residents' well-being in the context of rapid-aging Chinese metropolitan areas.

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