

# What is the impact of the built environment on leisure moderate-to-vigorous physical activity and sedentary time among the elderly: A cross-sectional study

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## Research article

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# Abstract

## Background

Although many studies have reported the association between moderate-to-vigorous physical activity (MVPA), sedentary time (ST), and the built environment (BE) among older adults, little is known about these associations in the Chinese older adult population. The purpose of this study was to investigate how various factors in the built environment of Nanjing's communities influence leisure moderate-to-vigorous physical activity and sedentary time among the elderly.

## Methods

A multilevel cross-sectional study was conducted from November 2016 to April 2017. Altogether, thirty neighborhoods were selected and 586 individuals aged 60 years or older living in the urban zone of Nanjing in Southern China were surveyed. Physical activity was measured using Actigraph GT3 Accelerometer. Built environment variables were measured using ArcGIS software. A multivariate linear regression method was used to analyze the factors influencing leisure moderate-to-vigorous physical activity and sedentary time among the elderly.

## Results

The percentage of moderate-to-vigorous physical activity of urban elderly within a 1000-m distance reached 76.12%, indicating this zone as appropriate for the study of urban elderly moderate-to-vigorous physical activity. We found that land-use mix ( $\beta=8.800$ ,  $p=0.001$ ) and distance to fitness venue ( $\beta=-5.876$ ,  $p=0.004$ ) influenced moderate-to-vigorous physical activity. Population density ( $\beta=13.998$ ,  $p=0.004$ ) and land-use mix ( $\beta=-21.62$ ,  $p=0.033$ ) use influenced sedentary time.

## Conclusions

Our findings provide support for the association between the built environment and physical activity among the Chinese elderly. Some characteristics of the built environment including land-use mix and distance to fitness venue may affect MVPA, while other characteristics including population density and land-use mix may impact ST. In formulating urban planning policies, the above factors should be taken into account to promote physical activity in older people, encouraging them to modify their sedentary lifestyle and improving their overall health.

## Background

The increasing aging of the population and resulting social and economic pressures have become a great challenge for Chinese society today and for a long time to come. Data from the 2010 National Census showed that China's population aged 60 and over represented 13.2% of the total population, with 119 million people aged 65 and over representing about 8.9% of the total population. China has 21 provinces with a predominant elderly population. China has also become the world's largest elderly

population, representing 21.04% of the total elderly population. The United Nations predicted that by 2049, China's elderly population over 60 years of age will represent 31% of the total world's population, second only to the one in Europe.

With the rapid rise of urbanization in China, the living environment for the elderly has been facing unprecedented challenges, such as high population density, serious shortage of public facilities, and limited transportation of living space, which are extremely detrimental to physical activities in the elderly. The classical social ecological theory holds that physical activity in the elderly is influenced by variables such as internal and interpersonal factors, the physical environment, and policy, and that the impact of intervention is optimal when all these factors are combined. The physical environment is defined as the surrounding living environment available to the elderly for physical activity, leading to the tenet that leisure physical activity in the elderly is influenced by interactions between the various elements of urban activity space. The elderly, who have more leisure time following retirement but often also have reduced physical function and illnesses, have become the most active people in terms of recreational physical activity. From the perspective of the activity space environment, in recent years identifying ways to promote leisure physical activity among the elderly has generated much research interest.

Regular physical activity has been reported to reduce risk of mortality [1, 2] and coronary heart disease and to prevent chronic diseases such as diabetes, obesity, and some forms of cancer [3] or cognitive impairment [4]. Despite the importance of regular physical activity in preserving health, most elderly people are insufficiently active [5]. Aging statistics show that people over the age of 60 are the fastest growing segment of the China population [6], and that most older adults have a long-term or chronic disease. Therefore, efforts to promote increased levels of physical activity among older adults have become a new objective in public health [7]. Yet, current evidence is insufficient and mainly from non-China populations [8]. Thus, environmental survey data are often complex, making the choice of an appropriate statistical analysis model the prerequisite for the correct evaluation of the relationship between the activity space environment and the leisure physical activity of the elderly. The purpose of this study was thus to investigate how various factors in the built environment of Nanjing's communities may influence leisure moderate-to-vigorous physical activity and sedentary time among the elderly.

## Methods

### Selection of participants

A multilevel cross-sectional study was conducted over 2 years (2015 and 2016) using a two-stage randomized sampling design in which the Communities and the older adults were the principal and the secondary units of parsing, respectively. NanJing's Communities, as defined by the Major's office, are not homogeneous in terms of built environment components and geographical parameters. Thus, this study used a modified notion of Community, defined as a residential area of similar urban characteristics and bounded by urban or natural limits. The neighborhood mean area in our study was 95,833 m<sup>2</sup> (median=71,372 m<sup>2</sup>, SD=82,527) with a median population of 4,821 people.

Communities were classified in Policy, Unit, Commercial, and Old-fashioned housing categories using the criteria established by the Town Council of NanJing. Power analysis was conducted based on the expected precision of the estimate to define the sample design. First, a preliminary selection of 30 communities was made. Second, a random selection of older adults who met the following criteria were considered for selection: age  $\geq 60$  years and at least 2 years of local residency. The final sample included 586 individuals aged 60 years or older distributed across 30 communities (approximately 20 older adults per community).

## Survey Questionnaire

To control for the influence of social variables such as education, income, and gender on the relationship between built environment and physical activity, subjects' educational qualifications (1= no schooling; 2 = Junior high school graduate; 3 = High school graduate; 4= College graduate); income (1= below 500 ¥; 2 = 500-1000 ¥; 3 = 1,001-2,000 ¥; 4 = 2,001-4,000 ¥; 5 = 4,000 ¥ or more) and gender (1= male; 2 = female) were included in the survey questionnaire and then entered into the analytical model as control variables. Occupations were divided according to the People's Republic of China Professional Classification, which defines four levels: the upper class (8), the middle class (66), working category (413), and lower class (1838). On the basis of the characteristics of our survey sample, occupational level was divided into the following types, effectively distinguishing between different social strata.

## Measurement of Built Environment Index

### *Determination of buffer distance*

In this study, the accelerometer data was matched with the GPS data to calculate longitude. The linear distance between the latitude and longitude of the family residence and the physical activity place was estimated. The latitude and longitude of the home address is indicated as  $A1$   $B1$  and the longitude and latitude of the activity record is indicated as  $A2$   $B2$ ). Thus,

$$D = \sqrt{(A2 * 100000 - A1 * 100000)^2 + (B2 * 100000 - B1 * 100000)^2}.$$

Altogether, 586 subjects were surveyed. Data was collected from 2,483 physical activity sites of the family. The average was 1,018 m, with a median of 367 m. The average for male subjects was 985 m, with a median of 369 m. The average for female subjects was 1032 m with a median of 364 m. The average distance to a physical activity place for each family was much higher than the median distance. The distance to the physical activity place for most urban elderlies was within the average of 1018 m. To explore the Basic Law of the distance from home to physical activity places for the urban elderly, 2,483 data were assessed according to 100 meter-intervals, and the number of groups was 20.

### *Definition of objective built environment*

Using the GIS buffer technology to measure population density, the residential density, street connectivity, total road length, land-use mix, distance to public transport, distance to recreational facilities, and distance to commercial facilities within 1000 meters were determined.

This study focuses on the built environment characteristics for residents in the areas of Nanjing Qixia District Gossip Garden Community (**fig.2**). Population density was 2,726 per km<sup>2</sup>; building density was 0.201; street connectivity was 16/km<sup>2</sup>. The total road length was 0.244 m; the land-use mix was 12; the distance to public transport stations was 235.4 m; the number of nearby public transport stations was 5; and the distance to recreational and commercial facilities was 337.6 m and 227.1 m, respectively. The results of the eight built environmental indicators were averaged and divided into 3 levels, assigned 1, 2 and 3, respectively.

### **Physical activity and sedentary time measurement**

Actigraph GT3 Accelerometer was used to measure physical activity and sedentary time in the elderly. Data on physical activity was recorded for 4 consecutive days includes two working days and two rest days. Subjects wore the device for at least 8 h a day. On the fifth day, the investigators recovered and recorded the data for the 4 full days.

The data was downloaded and analyzed using Actilife (Version 6.13.3). The accelerometer parameters included: test instrument, sampling interval, daily wear effective time, effective statistical analysis days, physical activity intensity boundary value and so on. CPM  $\geq 1952$  and CPM  $\geq 5725$  were selected as the boundary value of moderate-to-vigorous physical activity (MVPA) and VPA. Converts the acceleration count to the average daily time (light-intensity physical activity (LPA), MVPA, VPA) and calculates the average daily MVPA time (MVPA time = MPA time +VPA time).

## **Results**

### **Sample Characteristics**

Table 1 shows the characteristics of all subjects in the samples as collected through the questionnaires. Subjects in this study had a higher average sex ratio at all levels of education and income than in the general population.

### **Daily Physical Activity Among the Elderly**

A total of 586 older adults were required to wear Actigraph accelerometer, including 258 males and 328 females. As shown in Table 2, male and female participants reportedly engaged in an average of 157 and 182 minutes of LPA per day, respectively. MVPA was about 47 and 40 minutes for men and for women, respectively. Daily sedentary time was around 584 min for men and 569 minutes for women.

This study explored the effects of built environmental factors on leisure moderate-to-vigorous physical activity and sedentary time in the elderly through the multi-linear regression model. The moderate-to-vigorous physical activity and sedentary time among urban elderly are regarded as dependent on factors including population density, residential density, street connectivity, total road length, land-use mix, distance to public transport stations, distance to recreational facilities, and distance to commercial facilities. Model 1 mainly evaluated the effect of the built environment on moderate-to-vigorous physical activity in the elderly, and model 2 mainly evaluated the effect of built environmental factors on sedentary time in the elderly.

As can be seen in Table 3 model 1, the land-use mix distance to fitness venue is a factor affecting moderate-to-vigorous physical activity in the urban elderly ( $p < 0.05$ ). The results showed that the land-use mix in which the elderly were located could promote physical activity, and each additional unit of land-use mix could increase physical activity by 8.80 units.

Model 2 showed that population density and land-use mix are important factors affecting sedentary time in the elderly ( $p < 0.05$ ). High population density increased sedentary time among the elderly, with sedentary time increasing by 13.9 units for each additional unit of population density. Each additional unit of land-use mix could reduce sedentary time by 21.62 units.

## Discussion

The present study examined the association of objective neighborhood built environment factors with moderate-to-vigorous physical activity and sedentary time in an older population in NanJing, China. The study used Buffer Technology to measure the population density, residential density, street connectivity, total road length, land-use mix, number of public transport stations, distance to public transport station, distance to recreational facilities, and distance to commercial facilities within 1,000 meters.

The MVPA time in elderly men and women was around 47 and 40 min. The amount of daily exercise recommended by the World Health Organization (WHO) is at least 150 minutes/week of moderate-strength physical activity or at least 75 minutes/week of high-intensity physical activity, or an equivalent combination of moderate and high-intensity physical activity. In this study, 74.7% of older adults were able to meet these recommendations, of which 76.2% were men and 73.5% were women. It is at a moderate-to-high level compared with similar research reports in other countries.

At present, the domestic setting of the radius of the physical activity buffer for the elderly has not yet reached consensus. With the setting of the buffer radius needing more analysis and demonstration, this study used matched accelerometer and GPS-data to calculate longitude. The straight-line distance between the latitude and longitude of the family house and the latitude and longitude of the physical activity place was used to determine the outdoor physical activity buffer range. The study found that when the distance from home is in the 0 to 1000 m range, the percentage of frequencies reached 76.12%. Most of the outdoor physical activity for the urban elderly took place within 1000 m from home, in line with many other studies that concluded that the suitable buffer distance for the built environment should

be set at 1,000 m. At the same time, the distance in this study is calculated based on the home address and not the community's mind as the center. This effectively avoids inconsistencies in the quality of the community area to affect data validity.

Participation in recreational physical activity by older people is affected by various factors of the built environment. We found a continuous quantitative relationship between land-use mix and MVPA in the elderly. Our findings are consistent with prior work (18) suggesting that elderly people living in higher land-use mix areas are more likely to engage in increased physical activity time and frequency. In the face of the rapid development of urbanization, the burden on land resources is increasing. The land-use mix can promote the diversification of urban land use functions. The elderly are able to find space for various activities, which has a significant impact on physical activity.

The present study also found positive associations between the distance to recreational facilities and MVPA in the elderly, in line with previous studies. Increased park accessibility was positively associated with engaging more time in MVPA (19). Due to physiological decline, reduced mobility, narrow life circle, the stickiness of the activity space, fitness and leisure places accessibility, comfort requirements for the elderly are high. Given the geographical location of the households surveyed, the situation to reach the fitness and leisure venues is larger. The average distance to fitness and leisure places was 279.71 m, which showed that the construction of fitness and leisure places in NanJing city has achieved great success. It is beneficial to the elderly in the city to carry out physical activities.

Besides MVPA, evidence also showed a solid relationship between objective neighborhood built environment features and sedentary time. In the social ecology model (20), sedentary behavior is mainly affected by four aspects: occupation, family, traffic, leisure sedentary time. Neighborhood built environment is listed as the main factor affecting these four aspects. Population density and land-use mix were associated with older people ST. Sedentary leisure is a more established lifestyle for the elderly. Their daily sedentary time was more than 500 min, which increases their health risks. Another study of the relationship between built environment and ST found that land-use mix, public transport, recreational facilities, and ST had no associations with older people (21). It is suggested that more built environment indexes should be selected in the future to study their influence on sedentary behavior.

The present study has some advantages. Some studies have recently reported associations between BEs and PA in China; however, they were mainly based on subjective perceived measures. A few studies have analyzed a limited set of BE characteristics using GIS techniques. In contrast, we measured various BEs using GIS, which makes the results more objective. The present study also has some limitations. First, our study was cross-sectional in design, which prevents inferences being made about causality from the observed associations. A longitudinal study should be used to determine causal relationships. Second, the built environment is a large system that needs to include more indicators for analysis. Other variables including mental health, blood pressure, body mass index, and other health indicators should be included in a deeper study of this specific social group.

China's research on PA and BE is still in the exploratory stage. The research lacks systematic theory foundations, the results are preliminary, and the findings indicate values below international standards. Research in China needs to document main achievements and development dynamics in the provision of physical activity spaces for the elderly and provide more systematic and reliable quantified results to improve the evidence base.

## Conclusions

In summary, our findings provided support for the association between the built environment and physical activity among the Chinese elderly. Some characteristics of the built environment (e.g., land-use mix and distance to fitness venue) may affect MVPA, and a few more characteristics (e.g., population density and land-use mix) may also affect ST. In formulating urban planning policies, the above factors can be taken into consideration to promote physical activity among older people, helping them to modify their sedentary lifestyle and improve their overall health.

## Abbreviations

BE  
built environment  
MVPA  
moderate-to-vigorous physical activity  
ST  
sedentary time  
WHO  
World Health Organization

## Declarations

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### Author contributions

SYLQ and LY drafted the manuscript. WZJ, ZF, and WHL assisted with the data collection and participated in study coordination. WL and WZY modified and approved the final version. All authors took part in research meetings concerning data analysis goals, strategies and challenges. All authors have read and approved the final manuscript as submitted.

### **Ethics approval and consent to participate**

This study does not involve invasive interventions on the human body. It is only a questionnaire survey, so it was approved orally by the Humanities Research Ethics Committee of Nanjing Normal University. All participants read a statement that explained the purpose of the survey and provided written informed consent before participation in the study. For those not willing to take part in the study, their right was respected to withdraw from the study. The study did not adversely affect the rights and welfare of the subjects and no financial compensation or provision was made.

### **Availability of data and materials**

The datasets generated and/or analyzed during the current study are not publicly available due to maintain participant privacy and confidentiality requirements but are available from the corresponding author on reasonable request.

### **Consent for publication**

Not applicable.

### **Competing interests**

The authors declare that they have no competing interests.

### **Declaration**

This manuscript has not been published or presented elsewhere in part or in entirety and is not under consideration by another journal. All study participants provided informed consent, and the study design was approved by the appropriate ethics review board. We have read and understood your journal's policies, and we believe that neither the manuscript nor the study violates any of these. There are no conflicts of interest to declare.

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## Tables

Table 1. Participant characteristics (mean ± SD)

	Male	Female
Sample size	258	328
Age (years)	68.6±8.9	67.8±7.8
Education		
No schooling	31[12.0%]	85[25.9%]
Junior high-school graduate	87[33.7%]	117[35.7%]
High-school graduate	83[32.2%]	103[31.4%]
College	56[21.7%]	23[7.0%]
Annual household income		
<500 RMB	11[4.3%]	14[4.3%]
500-1000 RMB	17[6.6%]	34[10.4%]
1001-2000 RMB	18[7.0%]	53[16.2%]
2001-4000 RMB	153[59.3%]	195[59.5%]
>4000 RMB	58[22.5%]	28[8.5%]

**Table 2. Daily LPA, MVPA, and sedentary time (mean ± SD)**

Physical Activity	Male	Female
Sample size	258	328
LPA time (min)	157.63±51.86	182.05±55.09
MVPA time (min)	47.85±35.91	40.64±26.92
Sedentary time (min)	584.49±116.82	569.65±116.29

**Table 3. Multi-linear regression model of factors that affect moderate-to-vigorous physical activity and sedentary time factors in the elderly**

Variable	Model 1			Model 2		
	$\beta$	SE	sig.	$\beta$	SE	sig.
Constant	56.370	10.265	.000	546.531	40.214	.000
Population	.864	1.370	.529	.382	5.375	.943
Income	-.123	.507	.809	1.680	1.987	.398
Population	.760	.835	.363	-5.612	3.277	.087
	5.769	2.572	.025	13.760	10.089	.173
Population density	-2.106	1.733	.225	13.998	6.788	.040
Population density	-2.415	1.839	.190	-1.062	7.206	.883
Street connectivity	-1.754	2.094	.403	7.610	8.203	.354
Street road length	-.496	1.976	.802	4.228	7.741	.585
Land-use mix	8.800	2.583	.001	-21.620	10.120	.033
Distance to recreational	-5.876	2.054	.004	1.402	8.048	.862
Distances						
Distance to commercial	-2.954	1.924	.125	9.038	7.539	.231
Distances						
Distance to public	.731	1.792	.684	.611	7.022	.931
Sport station						
Model fit	$R^2=0.114$			$R^2=0.170$		
Significance	$F=9.31$ $p=0.00$			$F=1.21$ $p=0.00$		

## Figures

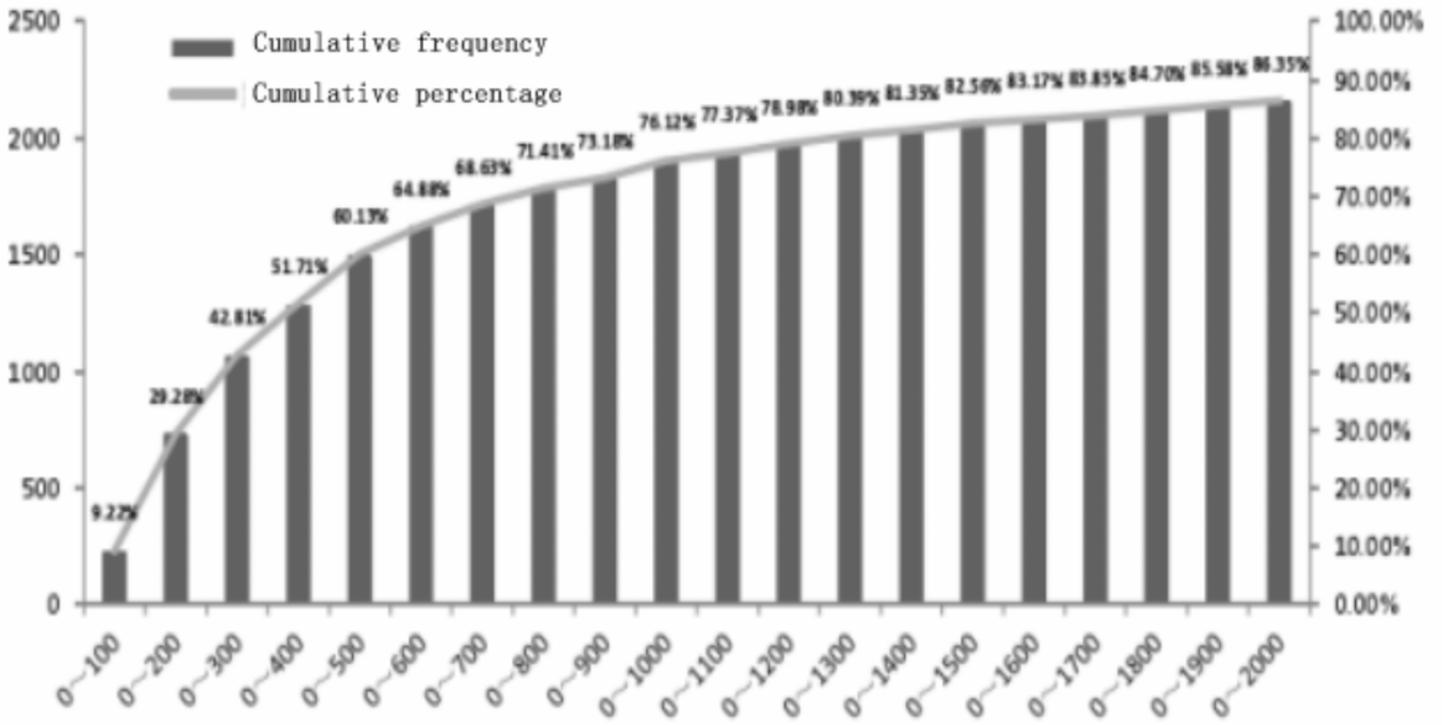


Figure 1

Frequency histogram and line chart of distance from home in different intervals. When the distance from home is within the 0-1000 m interval, the frequency percentage reached 76.12%. Most often, the physical activity distance for the elderly fell within the range of 1000 m away from home. Thus, the suitable buffer distance for the study of the built environment was established at 1000 m.



Figure 2

## Schematic of the Gossip Garden 1000 m buffer zone