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Association between perceived urban built environment attributes and leisure-time physical activity among adults in Hangzhou, China

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ABSTRACT

Background. Neighborhood built environment may influence residents' physical activity, which in turn, affects their health. This study aimed to determine the associations between perceived built environment and leisure-time physical activity in Hangzhou, China.

Methods. 1440 participants aged 25–59 were randomly selected from 30 neighborhoods in three types of administrative planning units in Hangzhou. International Physical Activity Questionnaire long form and NEWS-A were used to obtain individual-level data. The China Urban Built Environment Scan Tool was used to objectively assess the neighborhood-level built environment. Multi-level regression was used to explore the relationship between perceived built environment variables and leisure-time physical activities. Data was collected in Hangzhou from June to December in 2012, and was analyzed in May 2013.

Results. Significant difference between neighborhood random variations in physical activity was identified ($P = 0.0134$); neighborhood-level differences accounted for 3.0% of the variability in leisure-time physical activity. Male residents who perceived higher scores on access to physical activity destinations reported more involvement in leisure-time physical activity. Higher scores on perception of esthetic quality, and lower on residential density were associated with more time in leisure-time walking in women.

Conclusions. The present study demonstrated that perceived urban built environment attributes significantly correlate with leisure-time physical activity in Hangzhou, China.

Background

Physical activity is an important, modifiable behavior for the prevention of non-communicable chronic diseases (WHO). Epidemiological studies have shown that physical activity is associated with reduced risks of obesity, diabetes, cardiovascular disease, and other chronic diseases (Bize et al., 2007; Warburton et al., 2006). A growing number of studies have focused on the ecological context of physical activity (Sallis et al., 2008), i.e. the influence of the residential built environment on it (Trost et al., 2002).

The built environment refers to the physical form of communities (Brownson et al., 2009), which has been operationalized according to 6 dimensions: residential density, street connectivity, accessibility to services and destinations, walking and cycling facilities, esthetic quality, and safety. There has been increasing evidence that the neighborhood built environment may influence residents' physical activity, especially on transport-related physical activity (TRPA) and leisure-time physical activity (LTPA) (Fraser and Lock, 2011; Owen et al., 2004).

Chinese society has undergone rapid urbanization and urban sprawl, which have contributed to the decline of physical activity (Ng et al., 2009) and changes in residents' physical activity pattern. For example, the escalation of vehicle numbers (National Bureau of Statistics of China) is causing a reduction in traditional modes of TRPA (through walking, cycling and public transportation) in urban areas. Thus, it is critical to understand what and how built environment correlates with physical activity. Studies have been conducted in the U.S. (King et al., 2006), Australia (Humpel et al., 2002), Japan (Kondo et al., 2009), and Brazil (Hallal et al., 2010) to explore this possible relationship, yet few were carried out in China (Zhou et al., 2013). Furthermore, the demographic profile and SES (social-economic status) of the Chinese population could modify this relationships observed in other countries. In addition, there are substantial differences in built environmental features between cities in China and other countries, which could cause different associations with physical activities. For instance, the availability and accessibility of physical activity resources could have more decisive influence on LTPA in densely settled Chinese cities.

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As a result, it is important to understand these relationships in the Chinese context.

This study aimed to investigate the association of perceived neighborhood built environment (subjective measurement) with LTPA using a sample of the general adult population in Hangzhou, China.

Methods

Participants and study design

This study was conducted in Hangzhou from June to December in 2012. The city of Hangzhou, the capital of Zhejiang Province, is situated in the southeast coastal area of China. As an economically developed city, it ranked eighth in 2011 in terms of economic development (Office Information Processing Center et al.). Three districts of the city were included in this study, i.e., Shangcheng, Xiacheng, and Xihu Districts.

All administrative planning units in these three districts are classified into five categories (Yu et al., 2010) based on the degree of land-use mix and public services capacity. A Type I unit is characterized by developed commercial and residential areas, and a high degree of land-use mix. A Type II unit has developed but scattered public buildings (usually consist of buildings for office and governmental, commercial, scientific, educational, cultural, and health related purposes), and lacks comprehensive service capacity. A Type III unit is featured by partly developed and single functional public buildings. Type IV and type V units are mainly composed of farmland and storage warehouses and thus were excluded from this study.

The eligible subjects were individuals aged 25–59 who had lived in the neighborhood for at least one year. University students aged 18–24 were not eligible for this study because they tended to live on campus or were studying in other cities. A multistage random sampling strategy with stratification by functional unit was used in this study. In the first stage, 30 out of 170 neighborhoods (ten neighborhoods in each functional unit) were randomly selected. In the second stage, households were randomly sampled in each neighborhood from the lists of community households. And the final stage identified one of the eligible persons in each household using the Kish method. All interviewers were asked to have a maximum of three door-to-door visiting attempts per sampled household. A total of 2570 households were selected for participation, and 1444 people completed the survey. At last, 1434 participants were eligible for analysis (ten subjects were excluded because of incomplete data). The study was approved by the Peking University Institutional Review Board (Certificate Number: IRB00001052-11030).

Measurements

Outcome assessment and individual-level data collection were conducted by local CDC staff. Face-to-face interview was used to collect data and all the participants provided written informed consent before the interview. A two-day training procedure was given before investigation, which included explanation of the questionnaire, presentation of the proper use of the GPS positioning device and a pre-investigation of 3–5 subjects.

Outcome assessment (leisure-time physical activity)

The long version of the International Physical Activity Questionnaire (IPAQ long) was used to measure the frequency and duration of walking, moderate, and vigorous intensity physical activity for leisure purposes during the past seven days (International Physical Activity Questionnaire). The IPAQ data were then converted into metabolic equivalent (MET) scores following the IPAQ scoring procedure. The number of total minutes dedicated to each activity class was multiplied by MET score to calculate the weekly LTPA and leisure-time walking (LTW) level (MET-min) (Guidelines for Data Processing).

Individual-level correlates

Individual-level data includes residents' perceptions on built environment and their personal (demographic, anthropometric, and SES) variables. Considering the coverage of various dimensions of built environment and number of items, the present study chose the Neighborhood Environment Walkability Scale (NEWS-A) to be our environmental module (Cerin et al., 2006). Participants were asked to evaluate their neighborhood by responding to statements concerning various environmental attributes. The "neighborhood" was defined as an area within a 10–15 min walk from home. The subscales included the following seven variables: 1) Residential density: five items about the frequency of various types of neighborhood residence on a 5-point scale ("none", "a few", "some", "a lot", and "all"). 2) Access to commercial and physical activity destinations: the average walking distance in minutes to the nearest destination of that kind. 17 kinds of destinations were assessed; nine of them were classified as physical activity facility destinations based on the PANES questionnaire (Sallis). 3) Access to public services: six items including accessibility to neighborhood shopping area, ease of access to a public transportation stop, and barriers to walking in the neighborhood. 4) Street connectivity: three items inquiring the perceptions of street connections, distance between intersections and route selection. 5) Sidewalk and bike lane quality: eight items including the availability, maintenance, separation, and barriers on sidewalks and bike lanes. 6) Esthetic quality: six items about road greenery, attractive buildings, and natural sights within the neighborhood. 7) Safety from traffic and crime: eight items including traffic volume, driving speed, facilities helping to cross the street, street lighting, and perception of safety during the day and at night.

The response format was a 4-point scale ranging from "strongly disagree" (score 1) to "strongly agree" (score 4). Items were reverse coded if necessary to make sure that increasing score reflected better perception of built environment. A cutoff point of 5-min walking was used to create sum scores for access to commercial and physical activity destinations. Mean score of the corresponding items was calculated for each environmental subscale measured by 4-point scale items.

After translation and back translation, NEWS-A and the IPAQ were tested for their reliability and validity in a previous study conducted among 168 Hangzhou residents who had similar characteristics with the current study population. The results showed moderate to good test–retest reliability, construct validity, and criterion validity for the questionnaires (waiting to be published).

Neighborhood-level built environment characteristics

Neighborhood-level built environment correlates were assessed through in-the-field audits of neighborhood street segments. A typical neighborhood in most urban areas of China usually shows a shape of square or rectangle with 0.2 to 0.5 km^2 in area. In this study, we extended 400 m out from each side of the original administrative boundaries to form a study area with 1.0 to 1.5 km^2 in area. All the street segments in these 30 extended study areas were evaluated using environmental audit instrument, the China Urban Built Environment Scan Tool (CUBEST). A street segment was defined as a section of street or road between two intersections with a maximum length of 400 m.

Street audit was conducted by trained graduated students. A standard operating procedure for environmental audit was developed using detailed written instructions and field pictures to achieve uniformity in the performance of evaluation. A two-day intensive rater training was developed, including explanation of the principles, operation, potential problems and solutions of the CUBEST and GPS positioning device. Seven aspects of neighborhood-level built environment were assessed, including: 1) Access to commercial destinations; 2) Access to physical activity destinations; 3) Street connectivity; 4) Sidewalk quality; 5) Bike lane quality; 6) Esthetic quality; and 7) Safety from traffic. All environmental scans were conducted during daylight hours. The average time required for data collection was 6.2 min per segment.

The CUBEST is a reliable and valid instrument that can be used to assess the physical activity-related urban built environment. Additional details about its development, reliability and validity test results are available in print (Su et al., 2014).

Data analysis

Descriptive statistics were calculated for demographic, anthropometric, and SES variables. Body mass index (BMI) was calculated as weight divided by the square of height (kg/m^2). The median and inter-quartile range was calculated for LTPA and LTW due to their skewed distributions. Participants who did not meet the moderate or high physical activity criteria were classified as physically inactive according to the IPAQ scoring procedure. After logarithmic transformation of MET-min score, t-test was used to compare physical activity between genders. The chi-square test was used to compare the proportion of physically inactive between genders. One-way ANOVA was used to differentiate the perceived scores on neighborhood environment variables among three functional units.

Before running the regression analysis, categorical variables were created for education attainment and employment. MET-min scores of LTPA and LTW were selected to be the outcome variables. A series of multi-level regression analyses were performed in order to understand the individual- and neighborhood-level correlates associated with physical activity within this hierarchical data structure. A two-step modeling procedure was used. Running the empty model (Step 1) examined if differences in physical activity were random or fixed across neighborhoods. The neighborhood-level variance term from Step 1 was used to calculate the intra-class correlation (ICC) for the outcomes, where the ICC represents the proportion of the total variance in physical activity that is due to differences across neighborhoods. In Step 2, a multi-level model was developed to simultaneously examine how the individual- (perceived built environment) and the neighborhood-level (objectively assessed built environment) characteristics were associated with leisure-time physical activity (Final Model). Income variable was not included in the multi-level regression analysis due to nearly one third missing. A two-tailed P value of <0.05 was considered to be significant. The PASW version 18.0.0 (IBM Corporation, Somers, NY, USA) was used for data analysis. Data was analyzed in May 2013.

Results

The demographic, anthropometric, SES, and physical activity information of 1343 participants are shown in Table 1. Among all participants, 54.5% were women, who had lower BMI than men. For SES indices, men had a higher level of educational attainment and lower proportion of unemployment (due to different legal retirement age) than women. Income and living space were not significantly different between genders. No difference of LTPA and total physical activity was observed between men and women. Percentage of physically inactive was 21.2% for men and 17.2% for women, respectively.

As shown in Table 2, one-way ANOVA demonstrated statistically significant differences in perceived scores on environmental variables (individual-level) among three functional units. Perceived scores of type III units were significantly lower than the other two units for most of the environmental attributes (except for residential density, and access to physical activity destinations). Compared with Type II units, residents in type I units perceived higher scores on access to commercial destinations and street connectivity, and lower scores on residential density, sidewalk and bike lane quality, and safety from crime.

Scores on various neighborhood-level built environment correlates also showed statistically significant differences among the three functional units. Similarly as residents' perceptions, audit scores of type III units were lower than the other two units. Type I units had higher scores on access to commercial and physical activity destinations, street connectivity, and esthetic quality, while type II units had highest scores on sidewalk and bike lane quality, and safety from traffic. Even with clear distinctions of scores on built environment between units, no statistical differences of LTPA and LTW were observed.

Significant difference between neighborhood random variation in physical activity was identified ($^{2}_{u0}$ = 49,884, $P = 0.0134$); neighborhood-level differences accounted for 3.0% of the variability in leisure-time physical activity. Results of multi-level regression analysis for LTPA and LTW are summarized in Table 3. Access to physical activity destinations was positively related with more involvement in LTPA in men. Women who perceived higher scores on esthetic quality tended to spend more time in LTPA and LTW. While residential density was inversely associated with participation in LTW in women.

Discussion

The present study examined the associations of perceived neighborhood built environment with LTPA in a general population in Hangzhou, China. Male residents who perceived higher scores on access to physical activity destinations reported more involvement in LTPA. Higher scores on perception of esthetic quality were associated with more time in LTW in women. Neighborhood density was inversely associated with LTW in women.

Besides LTPA, evidence also shows a solid relationship between the neighborhood built environment features and TRPA. However, the present study did not involve TRPA because the most common form of it is the daily commute to workplace/schools. These destinations usually locate distance away from home because of rapid urbanization and urban sprawl. Thus it would not be a convincing or even become a misleading result unless the built environment around both home and workplace were evaluated. Work-related and domestic physical activities were also not included in this analysis because few studies have found a significant association of them with neighborhood built environment.

Each type of administrative planning unit has its own features in Hangzhou. Having the West Lake Scenic Area and large commercial centers, Type I units play the role of commercial and tourist center of Hangzhou. This could be reflected by the highest perceived and audit scores on access to commercial destinations and esthetic features. Neighborhoods in Type II units place more emphasis on residential function, which is reflected by their higher scores on residential density and transport related variables. The rapid expansion of residential space towards the city periphery has lead to the problem that newly built neighborhoods located at the city outskirts (type III units) focused just on the residential function. As a result, these neighborhoods usually have limited numbers of accessible destinations and are less friendly to walking and cycling. Results showed that perceived and audit scores of Type III units were significantly lower than the other two units in most of the environmental attributes. These findings indicated that the residents' perceptions of environmental features were in accordance with the objective assessment.

The present study found positive associations of accessibility, esthetic quality with LTPA or LTW, which was in line with previous studies.

Table 1
Demographic, anthropometric, SES, and physical activity information of 1434 study participants by gender.

	Men (N = 652)	Women (N = 782)	P
Demographic and anthropometric info			
Age (yr)	42.8 ± 9.6	43.8 ± 10.4	0.087
Height (cm)	172.2 ± 5.1	160.3 ± 4.7	<0.001
Weight (kg)	71.6 ± 12.9	56.9 ± 9.4	<0.001
Waist circumference (cm)	84.9 ± 8.4	75.9 ± 7.6	<0.001
BMI (kg·m^{-2})	24.1 ± 4.2	22.1 ± 3.5	<0.001
SES info			
Education beyond middle school (%)	78.7	68.5	<0.001
Unemployment (%)	9.6	35.3	<0.001
Per capita disposal annual income (10 K RMB)	4.0 ± 5.0	3.6 ± 2.9	0.082
Per capita living space (m^2)	27.9 ± 17.7	28.1 ± 16.0	0.787
Physical activity[a]			
Leisure-time physical activity	480(1188)	594(1353)	0.462
Total physical activity	2656 (4034)	2835 (3477)	0.908
Percent of physical inactive (%)	21.2	17.2	0.053

Data was collected in Hangzhou from June to December in 2012.
[a] Physical activities were reported as median and inter-quartile range for their skewed distributions.

Table 2
One-way ANOVA for the perception and objectively assessment scores on environmental variables among the three types of functional units.

Variables	Type I unit (n = 477)	Type II unit (n = 478)	Type III unit (n = 479)	*P*
Individual level (perception)				
Residential Density[a,c]	395.4 ± 94.8	421.4 ± 100.0	382.2 ± 142.8	<0.001
Access to commercial destinations[a,b,c]	3.47 ± 2.56	2.72 ± 1.99	2.18 ± 1.78	<0.001
Access to PA destinations	1.15 ± 1.56	1.20 ± 1.33	1.07 ± 1.23	0.32
Access to service[b,c]	3.10 ± 0.43	3.08 ± 0.44	2.98 ± 0.48	<0.001
Street connectivity[a,b,c]	3.35 ± 0.59	3.22 ± 0.56	3.03 ± 0.62	<0.001
Sidewalk quality[a,b,c]	2.64 ± 0.60	2.82 ± 0.59	2.48 ± 0.65	<0.001
Bike lane quality[a,b,c]	2.39 ± 0.54	2.56 ± 0.63	2.28 ± 0.68	<0.001
Esthetic[b,c]	2.67 ± 0.40	2.62 ± 0.46	2.38 ± 0.53	<0.001
Safety from traffic[b,c]	2.59 ± 0.40	2.66 ± 0.44	2.45 ± 0.49	<0.001
Safety from crime[b,c]	2.81 ± 0.29	2.86 ± 0.30	2.80 ± 0.32	0.007
Neighborhood level (objectively assessment)				
Access to commercial destinations[a,b,c]	91.61 ± 33.31	72.58 ± 24.21	44.24 ± 20.16	<0.001
Access to PA destinations[a,b]	12.76 ± 6.71	10.80 ± 5.93	10.95 ± 8.90	<0.001
Street connectivity[a,b,c]	44.95 ± 23.59	30.10 ± 11.36	21.34 ± 12.26	<0.001
Sidewalk quality[a,b,c]	2.00 ± 0.54	2.28 ± 0.65	1.64 ± 0.99	<0.001
Bike lane quality[a,b,c]	2.34 ± 0.74	2.59 ± 0.92	1.79 ± 1.75	<0.001
Safety from traffic[a,b,c]	2.35 ± 0.20	2.48 ± 0.15	2.29 ± 0.26	<0.001
Esthetic[a,b,c]	4.35 ± 0.18	4.25 ± 0.37	3.77 ± 0.50	<0.001
Self-report PA level				
LTPA[d]	495 (1141)	495 (1216)	594 (1386)	0.125
LTW[d]	297 (693)	238 (693)	256 (693)	0.071

Data was collected in Hangzhou from June to December in 2012.
[a] Statistical significance between Type I and Type II units.
[b] Statistical significance between Type I and Type III units.
[c] Statistical significance between Type II and Type III units.
[d] LTPA and LTW were described as median and interquartile range, respectively, due to their skewed distribution.

Accessibility refers to the proximity and ease of access to commercial and physical activity destinations and public services within the neighborhood. Reviews and studies conducted in other countries have shown that living in a neighborhood with higher access to non-residential destinations and public services was positively associated with more time engaged in LTPA (Hino et al., 2011; McCormack et al., 2008). Residents with good access to a park, play ground or public open spaces were more likely to achieve higher levels of walking and cycling (Giles-Corti et al., 2005; Wendel-Vos et al., 2004). Mixing residential and non-residential properties with a shorter distance to facilities could increase the perception of convenience and promote physical activity accordingly (Badland and Schofield, 2005). Esthetic quality refers to the attractiveness and appeal of the neighborhood. It has been demonstrated previously that esthetically pleasing environments are positively a ssociated with LTPA (Ball et al., 2001; Humpel et al., 2004a), and the current study adds to the evidence base.

Contrary to previous studies, results of this study showed inverse associations of residential density with LTW. Residential density refers to the number of residential dwelling units per unit of land area (e.g., acre) (Saelens et al., 2003). It was historically thought to have positive association with more time engaged in physical activity because higher residential density is usually associated with smaller blocks, more mixed land-use and shorter distance to destinations (Cervero and Kockelman, 1997). But higher density alone does not appear to be a proven factor for increasing physical activities. A recent meta-analysis showed residential density to be only weakly associated travel behavior once other variables were controlled (Ewing and Cervero, 2010). When it comes to LTPA, studies have suggested the possibility that densely settled Chinese cities could hinder LTPA due to decreased availability of physical activity resources and increased concerns about traffic safety (Xu et al., 2010). On the other hand, residential densities of Shangcheng, Xiacheng and Xihu District are 18,156, 12,935 and 2394 persons/km^2, respectively, which is much greater than the usual definition of 500 persons/km^2 for densely populated areas used in the Western countries (Alexander et al., 1999). This is also likely to be an important factor contributing to the differences in the associations of residential density with physical activity.

The present study analyzed the data by gender due to significant differences between genders in physical activity pattern and perceptions on built environment. Yet only a few of current studies reported data

Table 3
Multi-level regression analysis for LTPA and LTW by gender.

Perceived environmental variables (Individual level)	Leisure-time physical activity						Leisure-time walking					
	Men			Women			Men			Women		
	Parameterestimate	SE	*P*	Parameterestimate	SE	*P*	Parameter estimate	SE	*P*	Parameter estimate	SE	*P*
Residential density	0.04	0.5	0.93	−0.6	0.5	0.20	−0.1	0.2	0.45	**−0.5**	**0.2**	**0.03**
Access to commercial destinations	4.1	30.4	0.89	−3.6	26.2	0.89	6.2	11.8	0.60	2.2	13.2	0.87
Access to PA facility	**126.5**	**46.4**	**0.01**	59.9	39.7	0.13	9.7	18.0	0.59	−30.6	20.1	0.13
Access to public service	302.6	162.2	0.06	52.8	126.6	0.68	90.3	62.6	0.15	36.9	64.1	0.57
Street connectivity	191.1	106.7	0.07	97.9	95.1	0.30	47.9	41.3	0.25	78.6	48.0	0.10
Sidewalk quality	−87.0	154.5	0.57	40.5	129.2	0.75	−108.7	59.9	0.07	−115.4	65.3	0.08
Bike lane quality	134.5	148.4	0.37	−115.1	122.3	0.35	63.0	57.5	0.27	42.8	61.72	0.49
Esthetic	69.9	136.0	0.61	**310.2**	**117.2**	**0.01**	−17.8	52.8	0.74	**148.5**	**59.0**	**0.01**
Safety from traffic	−234.5	146.2	0.11	−176.4	124.9	0.16	−6.8578	56.7	0.90	−64.1	62.9	0.31
Safety from crime	−8.0	193.1	0.97	104.3	157.8	0.51	9.1707	75.2	0.90	26.5	79.4	0.74

Data was collected in Hangzhou from June to December in 2012.

on gender differences in the relationships of environmental attributes with LTPA or LTW. Humpel's study found that neighborhood walking had notable gender-specific associations with certain perceived physical environment attribute. The relationship between access to services and walking was positive for men, and negative for women (Humpel et al., 2004b). Other studies also indicated possible differences in environment determinants between genders, for instance, safety from crime (Roman and Chalfin, 2008) and traffic volume (Humpel et al., 2004a). The gender differences showed in the present study may be caused by the disparity in leisure-time physical activity pattern. Men usually take more time in vigorous intensity LTPA than women (*t*-test results showed $P < 0.0001$), which could be affected more by the accessibility of physical activity destinations, while women chose to do more leisure-time walking (also $P < 0.0001$), which usually takes place in areas with higher esthetic quality.

While the present study had some advantages over previous work in terms of rigorous sampling strategy and quality control, several limitations are worthy of note. Firstly, this study took place in one city of China, which may limit the application of the results to other Chinese cities. However, we evaluated the built environment in 30 neighborhoods in three different types of administrative planning units, which to some extent ensured sufficient variation in the environmental features shared by other similar large Chinese cities. Secondly, besides perceived built environment, it is important to use objectively measured environmental variables, such as the use of systematic observations. Finally, the use of a cross-sectional design means that the causality cannot be addressed. Well-designed prospective studies of environmental correlates of physical activity are warranted (Humpel et al., 2004a; Titze et al., 2005).

Conclusions

In general, urban built environment attributes significantly correlate with residents' leisure-time physical activity in Hangzhou. Access to physical activity destinations andesthetic quality may be the important environmental factors affecting leisure-time physical activities, while the role of residential density needs to be further explored.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

Authors' contributions

MS, YYT, LLM, and JL conceptualized and conducted the study. QML and YJR assisted with the data collection, and participated in study coordination. MS, IK, and JL assisted with the data management and analysis. All authors contributed to the manuscript writing, and modified and approved the final version.

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