Association between perceived access to public transport stops and physical activity among adults in Nanjing, Mainland China: A cross-sectional study

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A B S T R A C T

Background: The public transport access, an important dimension of neighborhood built environments and usually defined as the access to public transport stops/stations (PTS), has been revealed to be associated with more participation in physical activity (PA) in western countries. The perceptions of such features could have additional benefits to healthy behaviors. However, such research is lacking in developing countries. This study aimed to explore the association between perceived PTS access and PA participation among urban adults in China.

Methods: A population-based cross-sectional survey conducted in Nanjing in 2017 was used, where 1,568 participants aged 35–74 were recruited from eight randomly selected urban neighborhoods under a multi-stage sampling strategy. The individual's PTS access and PA participation were self-reported using the Physical Activity Neighborhood Environment Scale and the International Physical Activity Questionnaire, respectively. Mixed-effect logistic regression models were used to estimate the association between perceived PTS access and PA participation.

Results: Among 1,551 participants who completed the survey, 84.7% of participants achieved the World Health Organization (WHO) recommended PA level. After adjusting for potential individual- and neighborhood-level confounders, participants who perceived a PTS within 10–15 min' walking distance from their residence were 3.18 (95%CI = [1.74, 5.80]) times more likely to meet WHO recommended PA guidelines than their counterparts who did not perceive any PTS in their neighborhoods. This association also held true in either men (OR = 2.71, 95%CI = [1.07, 6.86]) or women (OR = 3.50, 95%CI = [1.59, 7.70]), separately.

Conclusions: Such findings will provide health practitioners and urban planners evidence-based insights on potential health effects of expanding and improving public transport systems, and on how to incorporate these effects into strategies of PA promotion and chronic disease prevention.

1. Introduction

Insufficient physical activity (PA) for adults is defined as engaging in less than 150 min of moderate-intensity physical activity (MPA) in a typical week (World Health Organization, 2018a,b). It has been documented that insufficient PA is not only one of the most important modifiable risk factors for many chronic disease outcomes, such as cardiovascular diseases, cancers, diabetes, and obesity (Bennett et al., 2017; Lear et al., 2017; Lee et al., 2012; World Health Organization, 2018a,b), but also one of leading causes of morbidity and mortality

worldwide (Lear et al., 2017; Nocon et al., 2008). Although PA promotion has been encouraged globally, approximately 25% of adults remain physically inactive worldwide (World Health Organization, 2018a,b). Moreover, the prevalence of physical inactivity is usually higher in urban residents relative to their rural counterparts, especially in low- and middle-income countries (Sallis et al., 2016).

Recently, walkable neighborhood built environment (BE) attributes have been found to be associated with population-level PA promotion in Western societies (Ewing and Cervero, 2010; McCormack and Shiell, 2011; Silfee et al., 2016; Van Holle et al., 2012). The PA-related built environment characteristics mainly include residential density, land-use mix, street connectivity, access to recreational amenities (e.g., park and fitness center), and transport-related factors (e.g., proximity and access to transit stops and bicycle facilities) (Ewing and Cervero, 2010; McCormack and Shiell, 2011; Saelens et al., 2012). Of these built environment features, the access to public transport stops/stations (PTS) has long-term influences on commuting modes (Ewing and Cervero, 2001) and PA participation of residents in regular days (Besser and Dannenberg, 2005). Once the transportation facilities had been constructed, it would not be changed in short times. So, it may alter the mode choice, e.g., taking more transit, walk or bike for Commutes in their daily life. However, perceived and objective built environments may have different associations with PA patterns, and the perceptions could have additional benefits to healthy behaviors and human health (Ma and Dill, 2015). Some previous studies have revealed that the perceived access to PTS around neighborhoods was positively associated with regular PA participation among adults (Ding et al., 2013; Sallis et al., 2009). For example, Sallis et al. (2009) found in a sample of 11,541 participants from 11 countries that residents with PTS access within 10–15 min from their residence were 1.32 times more likely to meet PA guidelines than were those who did not have such PTS access. In addition, this association may vary across genders as men and women perceive and interact with their neighborhood built environments in different ways. Men usually spend more time on vigorous-intensity while women conduct more leisure-time walking (Berke et al., 2007; Ho et al., 2005). However, those findings are mixed and inconclusive and all from developed countries (Ding et al., 2013; Molina-García et al., 2010; McCormack and Shiell, 2011; Sallis et al., 2009). Further research may be likely to provide more evidence on this association, especially in the context of developing countries.

China, as the largest developing country in the world, has been experiencing unprecedented development in economy and urbanization over the past 30 years. Consequently, China also witnesses a fast expansion of urban public transport, such as bus and subway systems. To date, China has been running a large public transport system in the world, which is still expanding in both the vehicles number and geographic coverage (China Association Of Metros, 2017). To fill the research gap, this study, for the first time in Mainland China, aimed to explore the relationship between public transport access and PA participation in urban Mainland China, on the basis of a population-based cross-sectional study conducted in Nanjing in 2017. Findings will be of great importance for future design and optimization of public transport systems and PA-friendly built environments in China and other developing countries.

2. Methods

2.1. Study design and participants

Nanjing is a mega-city in the east of China (located to the northwest of Shanghai), which occupies $6,587 \, km^2$ with a registered population of more than eight million in 2016. It comprises eleven administrative districts, six urban (Xuanwu, Qinhuai, Gulou, Jianye, Qixia, and Yuhua) and five suburban districts (Jiangning, Pukou, Liuhe, Lishui, and Gaochun). The public transport system in Nanjing includes seven metro lines (a total length of 225 km with 128 stops) and 705 bus lines (8,395 working buses), which served approximately 2.7 million and 5.6 million person-times per day in 2016, respectively (Nanjing Municipal Bureau of Statistics, 2016).

The data from a population-based cross-sectional survey conducted in Nanjing between March and July of 2017– the Built Environment and Chronic Health Conditions - Adults (BEACH-Adults) – were used in this study. A multi-stage sampling approach was adopted to recruit participants, which has been detailed elsewhere (Zhao et al., 2018). To recap briefly, two out of six urban districts were randomly selected, and then four neighborhoods were randomly chosen from each selected urban district. Thus, eight neighborhoods were finally included in this study.

A total of 1568 adults aged 35–74 years who lived in selected neighborhoods and without physical disability were eligible to be enrolled in the BEACH-Adults study, with 1551 successfully interviewed (response rate = 98.9%). All these participants were chosen based on gender- and age-matched frequency (men: women = 1:1, 5-year interval of age groups). All the data were collected by fourteen well-trained and qualified team members via face-to-face interviews. We obtained written informed consent from each participant before the interview and removed all identifiable personal information prior to data analysis. This study was approved by the Academic and Ethical Committee of Nanjing Municipal Center for Disease Control and Prevention (Nanjing CDC).

2.2. Outcome variable

The information on PA participation in the week prior to the survey was self-reported by participants, following the validated Chinese version of the short form of the International Physical Activity Questionnaire (IPAQ-CHN) (Qu and Li, 2004). The time spent on vigorous-intense PA (VPA), moderate-intense PA (MPA), and walking was separately computed based on the respective frequency and duration. Then, the doubled time for VPA and the time for MPA and walking were summed to create a new variable– PA time (unit: minute/week) – for each participant. Finally, the individual outcome variable was defined as dichotomous: *1* denotes having sufficient PA ($\geq 150 \, min/week$) and *0* denotes insufficient PA ($< 150 \, min/week$) (U.S. Department of Health and Human Services, 1996; Ding et al., 2013; Molina-García et al., 2010; McCormack and Shiell, 2011; Sallis et al., 2009).

2.3. Explanatory variable

The PTS access was perceived by participants, following a validated Chinese version of Physical Activity Neighborhood Environment Scale (PANES-CHN) (Zhao et al., 2018). Participants reported whether they perceived the presence of a PTS (bus or metro) within 10–15 min' walking distance from their residence, by responding to the question " It is within a 10–15 min walk to a transit stop (such as bus, train, trolley, or tram) from my home. Would you say that you … ". The answers were four-likert options: "strongly disagree, somewhat disagree, somewhat agree or strongly agree". Then, participants were accordingly categorized into two subgroups: perceived PTS (somewhat agree or strongly agree) or not perceived PTS (somewhat disagree or strongly disagree) in analysis (Sallis et al., 2009).

2.4. Covariates

Five individual-level covariates were controlled for in adjusted models: age (35–49, 50–64, or 65–75 years old), gender (men or women), education level (≤ 9, 10–12, or ≥ 13 years), occupation (blue collar workers or white collar workers) (Xu et al., 2018), and body weight status. Body weight status was assessed based on body mass index (BMI), calculated as the measured body weight in kilogram divided by the measured height in squared meters (kg/m^2), using recommended cutoffs for Chinese adults (Zhou, 2002).

Two neighborhood-level potential confounders were also controlled for: residential density and green space area. The residential density (number of residents per km^2) within a neighborhood was defined as the number of registered population divided by the neighborhood area. The green space area (m^2) was calculated as the area of public green space to which local residents have free access within the neighborhood. Data on the registered population, objectively-measured geographic area and green space area for each neighborhood were all obtained from local Bureau of statistics (Nanjing Municipal Bureau of Statistics, 2016).

2.5. Statistical analyses

The Chi-square test was used to compare socio-demographic characteristics and weight status of participants between genders and between participants with and without perceived PTS access. Three mixed-effect regression models were used to examine the association between perceived PTS access and PA participation with odds ratio (OR) and 95% confidence interval (CI): Model 1 was an unadjusted model with perceived PTS access as the single predictor; Model 2 was a multivariate analysis with adjustment for selected individual-level covariates, including participants' age, gender, educational level, occupation, and body weight status; Model 3 was also a multivariate analysis with further consideration of some neighborhood covariates (including the neighborhood's residential density and green space area, and neighborhood-level potential clustering effects) in addition to all the individual-level confounders controlled for in Model 2. The stratified analyses were also performed to examine the potential variation of the PTS-PA association across genders.

Three additional sensitivity analyses were undertaken to further examine 1) whether perceiving PTS access was associated with more PA when PA was treated as a continuous variable (without categorization), by using a Mann-Whitney test to compare PA between those perceiving and not perceiving PTS; 2) whether perceiving PTS access was associated with more PA among those who were physically active, by using a Mann-Whitney test to compare PA (as a continuous variable) between those perceiving and not perceiving PTS (Ding et al., 2013; Molina-García et al., 2010; McCormack and Shiell, 2011; Sallis et al., 2009); and 3) whether the association between perception of PTS access and PA occurred the other way around (i.e., participants who were more physically active were more likely to perceive or see PTS while being physically active), by randomly splitting participants in each neighborhood in half and using one half of each neighborhood to generate an exposure measure which was regressed against the outcome measure in the other half (Roux and Ana, 2007).

All statistical analyses were performed using SPSS 20.0 (Version 20.0, 2011; SPSS Chicago, Illinois, USA).

Table 1
Basic characteristics of participants included in this study.

Variables	% (n) or Mean $\pm$ SD	% (n) or Mean $\pm$ SD		p-value[†]	% (n) or Mean $\pm$ SD		p-value[†]
	All (N = 1,551)	Men (N = 741)	Women (N = 810)		Perceiving PTS[*] (N = 1,486)	Non-perceiving PTS[*] (N = 65)	
Age (year)	54.7 $\pm$ 11.1	54.8 $\pm$ 11.4	54.7 $\pm$ 10.9	0.97	54.7 $\pm$ 11.1	54.8 $\pm$ 11.2	0.96
Education level (year)							
≤ 9	47.3 (733)	40.2 (298)	53.7 (435)	< 0.01	47.1 (700)	50.8 (33)	0.35
10-12	30.0 (466)	32.4 (240)	27.9 (226)		29.9 (444)	33.8 (22)	
≥ 13	22.7 (352)	27.4 (203)	18.4 (149)		23.0 (342)	15.4 (10)	
Occupation							
White collar	54.8 (850)	53.4 (396)	56.0 (454)	0.30	44.9 (667)	52.3 (34)	0.24
Blue collar	45.2 (701)	46.6 (345)	44.0 (356)		55.1 (819)	47.7 (31)	
Body weight status							
Normal	48.7 (755)	45.5 (337)	51.6 (418)	< 0.01	48.5 (721)	52.3 (34)	0.55
Overweight	51.3 (796)	54.5 (404)	48.4 (392)		51.5 (705)	47.7 (31)	

[*]PTS – public transport stop.
[†]p-values tested the differences in each variable between genders and between participants who perceived and did not perceive PTS access in their neighborhoods, and were based on χ^2 tests for categorical variables or t-tests for continuous variables.

Table 2

Associations between perception of access to public transport stops (PTS) and physical activity (PA) among urban adults in Nanjing, China[*].

Variables	Model 1	Model 2	Model 3
Perception of PTS			
Non-perceiving (ref)	1	1	1
Perceiving	**2.20 [1.26, 3.87]**	**2.24 [1.27, 3.96]**	**3.18 [1.74–5.80]**
Gender			
Men (ref)	–	1	1
Women	–	1.22 [0.92–1.62]	1.30 [0.97–1.74]
Age (year)			
< 50 (ref)	–	1	1
50-64	–	1.51 [0.81–1.63]	1.28 [0.89–1.84]
≥65	–	1.07 [0.69–1.65]	1.28 [0.82–2.02]
Education level (year)			
≤9 (ref)	–	1	1
10-12	–	0.79 [0.56–1.13]	0.93 [0.65–1.33]
≥13	–	0.75 [0.49–1.34]	1.05 [0.67–1.66]
Occupation			
Blue collar (ref)	–	1	1
White collar	–	1.10 [0.81–1.49]	0.98 [0.72–1.35]
Body weight status			
Normal (ref)	–	1	1
Overweight	–	1.14 [0.86–1.51]	1.10 [0.82–1.47]
Residential density			
Low (ref)	–	–	1
High	–	–	0.47 [0.14–1.55]
Green space			
Low (ref)	–	–	1
High	–	–	1.49 [0.45–4.93]

[*]Model 1 is the unadjusted model; Model 2 adjusted for five individual-level covariates; Model 3 adjusted for five individual-level and two neighborhood-level covariates.

Table 3

Gender-stratified associations between perception of access to public transport stops (PTS) and physical activity (PA) among urban adults in Nanjing, China[*].

	Model 1		Model 2		Model 3	
	Men	Women	Men	Women	Men	Women
Perception of PTS						
Non-perceiving (ref)	1	1	1	1	1	1
Perceiving	1.53 [0.64, 3.65]	**3.02 [1.44, 6.36]**	1.53 [0.57, 4.07]	**3.04 [1.46, 6.32]**	**2.71 [1.07, 6.86]**	**3.50 [1.59, 7.70]**
Age (year)						
< 50 (ref)	–	–	1	1	1	1
50-64	–	–	1.02 [0.59–1.74]	1.31 [0.79–2.18]	1.41 [0.68–1.90]	1.48 [0.87–2.53]
≥65	–	–	0.97 [0.50–1.88]	1.26 [0.67–2.38]	1.25 [0.67–2.37]	1.44 [0.72–2.85]
Education level (year)						
≤9 (ref)	–	–	1	1	1	1
10-12	–	–	0.75 [0.45–1.26]	0.87 [0.53–1.42]	0.81 [0.50–1.32]	1.14 [0.67–1.94]
≥13	–	–	0.85 [0.45–1.61]	0.65 [0.36–1.19]	1.15 [0.61–2.18]	0.96 [0.50–1.85]
Occupation						
White collar (ref)	–	–	1	1	1	1
Blue collar	–	–	1.09 [0.67–1.76]	1.07 [0.70–1.63]	0.97 [0.61–1.53]	0.94 [0.60–1.47]
Body weight status						
Normal (ref)	–	–	1	1	1	1
Overweight	–	–	1.16 [0.75–1.78]	1.06 [0.70–1.60]	1.09 [0.72–1.63]	1.04 [0.67–1.60]
Residential density						
Low (ref)	–	–	–	–	1	1
High	–	–	–	–	0.48 [0.12–1.90]	0.44 [0.13–1.56]
Green space						
Low (ref)	–	–	–	–	1	1
High	–	–	–	–	1.36 [0.35–5.33]	1.63 [0.47–5.71]

[*]Model 1 is the unadjusted model; Model 2 adjusted for five individual-level covariates; Model 3 adjusted for five individual-level and two neighborhood-level covariates.

3. Results

The socio-demographic characteristics of participants were presented in Table 1. The mean age (standard deviation) was 54.7 (11.1) years for overall participants. There were 22.7% participants having 13 + years' educational attainment and 51.3% with overweight or obesity (BMI ≥ 24). 22.1% of participants were elders (aged 65 + years old) and 54.8% were white collar workers. No significant differences were observed in age, gender, educational attainment, occupation, and body weight status between those perceived and not perceived PTS.

Among the overall participants, 84.7% (1,313/1,551) achieved sufficient PA, while 95.8% (1,486/1,551) perceived PTS around their neighborhoods. There was a significant difference ($\chi^2 = 7.96, p < 0.05$) in the proportion of participants who achieved sufficient PA between those perceived (85.2%, 1,266/1,486) and not perceived (72.3%,47/65) PTS. Table 2 showed the association between PTS and sufficient PA among overall participants. The unadjusted analysis (Model 1) showed that participants who perceived PTS were more likely to achieve sufficient PA among this urban adult population (OR = 2.20, 95%CI = [1.26, 3.87]) relative to those who did not perceive PTS around their neighborhoods. After consideration of five individual-level covariates (Model 2) and further additional two neighborhood-level covariates (Model 3), such significant positive relationship between perception of PTS and sufficient PA remained significant (OR = 2.24, 95%CI = [1.27, 3.96] and OR = 3.18, 95%CI = [1.74, 5.80], respectively). Table 3 displayed the results via gender-stratified analysis. After controlling for all individual-level and neighborhood-level covariates (Model 3), perception of PTS was also positively associated with sufficient PA among either men (adj.OR = 2.71, 95%CI = [1.07, 6.86]) or women (adj.OR = 3.50, 95%CI = [1.59, 7.70]).

Sensitivity analyses in which PA was treated as a continuous variable (i.e., PA time) showed no significant differences in PA participation between those perceiving and not perceiving PTS among both overall participants ($p = 0.83$) and those who were physically active ($p = 0.41$). Also, after randomly splitting participants in each neighborhood in half and adjusting for the exposure measure generated from one half of each neighborhood, participants in the other half who perceived PTS were more likely to achieve sufficient PA (OR = 2.45, 95%CI = [1.03–5.83]) than their counterparts who did not perceive PTS.

4. Discussion

Insufficient PA has been a serious public health problem worldwide, and also contributed to overweight and obesity problems in many countries including China (Jia et al., 2017; World Health Organization, 2019). As an important built environmental indicator for a walkable neighborhood, the access to public transport could promote PA participation of residents in developed countries/regions by increasing their outdoor activities and reducing sedentary time in vehicles. However, very few studies have examined this relationship in developing countries, especially the association between perception of public transport access and PA participation in China.

In this study, we found that urban adults who perceived PTS around their neighborhoods were more likely to meet PA guidelines recommended by WHO, compared to their counterparts who did not perceive any PTS in Nanjing, Mainland China. This association was observed not only among the overall study population, but also in either men or women, separately. Also, this positive association between PTS and PA was independent of participants' body weight status and residential density and green space area within neighborhoods in which participants lived. Moreover, it was further verified by sensitivity analysis that no significant difference in PA time (continuous variable) was found between participants perceiving and not perceiving PTS access.

Our findings were in line with those reported from studies in developed countries (Ding et al., 2013; Li et al., 2008; Sallis et al., 2009). One study from USA reported that easy access to PTS was positively associated with walking and overall physical activity in adults (Li et al., 2008). In an internationally collaborative study conducted in 11 countries, PTS around neighborhoods was in positive relation to physical activity among adults not only in developed western countries, such as Belgium, but also in some Asian communities, like Japan and Hong Kong, China. (Ding et al., 2013).

There are mainly two possible mechanisms which may provide part of explanation for this association. One mechanism is that residents who could perceive easy access to public transport in their neighborhoods are more likely to commute via public transport. In that situation, they probably go to the nearest PTS and make transfer (i.e., changing buses and subways) by foot, which could consequently result in more daily PA (Besser and Dannenberg, 2005; Brown and Werner, 2007; King et al., 1995; Lee and Moudon, 2006). The other is that perceived PTS access in the neighborhood may imply or concur with a high degree of land use mix and subsequently increase recreational PA (Gebel et al., 2007; Heath et al., 2006).

As described in the social–ecological framework, human behaviors can be influenced by individual, social/cultural, and built environmental factors (Sallis et al., 2015). For built environment, once successfully constructed, it will exert a long-term compulsory and sustainable influence on residents' behavior (Sallis et al., 2006). The PA-friendly built environment will help local residents engage in and maintain long-term physical activity at community level (King et al., 1995; Sallis et al., 2006), generally increased in two forms: one is that residents' participation in programmed or incidental physical activity during leisure time, such as walking to parking pedestrian or shopping malls. The other is that encourage PA participation in more routine forms, such as walking/bicycle lanes or public transportation interchanges. Therefore, design and construction of PA-/health-friendly built environment may be a priority strategy for population-level physical activity promotion, particularly for the rapidly-urbanizing communities where city planning and construction are happening.

Of these built environment features, public transport availability has long-term influences on residents' commuting modes (Ewing and Cervero, 2001), such as increasing the residents' choice of Transit, walk or bike for Commutes, and transport-related PA in regular days (Besser and Dannenberg, 2005). As an effective alternative to private cars, it has been documented that the increasing use of public transport service could effectively reduce physical inactivity at a population level and also emissions from vehicles, which in turn might promotes more PA by providing better natural environments (e.g., less air pollutants and noise) (Giles-Corti et al., 2016). In addition, from the perspective of

urban planning and construction, it is generally easier to modify the access to public transport service (e.g., bus and subway stops) than many other built environment features, such as street connectivity and land use mix.

This is the first study to examine the association between the perceived PTS and PA participation in Mainland China. The enlarging public transport system in China needs strong evidence from human health research for its expansion and optimization. Also, this study was conducted at a critical time when China central government has initiated a call to put health promotion into all policies according to President Jinping Xi's address in the National Health and Hygiene Congress in 2016 (National Health and Hygiene Congress, 2016). For example, the goal of Healthy China 2030 was set to align many efforts in different sections with the construction of healthy cities (Yang et al., 2018) Therefore, it is vital to assess the roles of expanding public transport systems in improving healthy lifestyles and health status of residents. It also has particular implications for urban planners, as it will provide health practitioners and urban planners evidence-based insights on potential health effects of expanding and improving public transport systems, with consideration of other neighborhood environmental features.

Participants in this study were randomly selected from typical urban areas in regional Mainland China. In addition to the well-designed structure of this study, validated instruments were used to assess PA and PTS (Zhao et al., 2018; Qu and Li, 2004). Further strengths of this study included: (1) The classical confounding factors were controlled in our analysis. And (2) community-level potential clustering effects were also considered using the appropriate data analysis approach.

There are some limitations worth noting here. First, BEACH-Adults is a cross-sectional study, which could not imply causality between PTS and PA participation. Second, the PA level was measured with questionnaires, which, although validated, may cause potential recall bias. The location-aware technologies should be used in future research to improve the accuracy of PA measurement. Moreover, objective measurement of PTS access was not used in this study; also, having access to PTS does not mean the actual utilization of public transport. Spatial technologies can objectively measure built environments, such as Geographic Information Systems and remote sensing (Jia and Stein, 2017), and ecological momentary assessment approaches allow us to look into the decision-making process related to health behaviors at a specific moment in time. Such information would add extra values to this study in terms of result interpretation (Jia, 2019). Third, the short not long term of IPAQ was used to gather information on participants' physical activity, which did not allow us to do additional analysis regarding participants' potential affordances between different modes of physical activity. We will use the long form of the IPAQ in our future surveys to differentiate different PA types, so additional analyses could be conducted to answer more detailed PA-related research questions (e.g., do people who already conduct transport-related PA undertake less recreational activity?) for well-thought-out strategies for overall PA promotion. Fourth, eight included neighborhoods in one city may have insufficient variance in neighborhood built environment characteristics. Future expanded studies are warranted to examine, with the aid of advanced spatial technologies, longitudinal influences of public transport access on residents' PA participation among more neighborhoods and in different cities, for achieving larger variance in both individual- and neighborhood-level features. Fifth, Residential density was adjusted for as a neighborhood-level confounding factor in the model. For the choice of commuting modes, other factors, particularly employment densities at destinations, are as important as residential density at origins which may influence this association. More neighborhood-level variables could be adjusted for in such study designs, to remove some potential confounding effects in this study, such as land use mix. However, due to data limitation, they were not included in the analysis.

5. Conclusions

In this population-based study conducted in urban areas of Nanjing, Mainland China, a significantly positive relationship between perception of public transport stops/stations and physical activity was observed among urban adults in regional China. Our study has some public health and policy implications. From the aspect of public health, further research should be well-designed and well-implemented to identify potential PA-favorable BE attributes at neighborhood level, particularly to investigate the causal relationship between them. With perspective of policy making, PA-friendly BE characteristics, including public transport stops, should be emphasized and prioritized in city planning and construction for sustainable community-based physical activity promotion in regular days.

Authors' contributions

Conceived, designed and directed the study: FX (the PI of the project). Performed the experiments: ZW, YM, ZQ, QY and FX. Analyzed the data: YM, ZQ and FX. Wrote the article: ZW, YM, ZQ, QY, ZX, LH, PJ and FX. Critical revision of the manuscript: ZW, YM, ZQ, QY, ZX, LH, PJ and FX.

Ethical approval and consent to participate

The Academic and Ethical Committee of Nanjing Municipal Center for Disease Control and Prevention approved this study. Written informed consent was obtained from each participant before our survey.

Competing interests

None declared.

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