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Living in school catchment neighborhoods: Perceived built environments and active commuting behaviors of children in China

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ABSTRACT

The contribution of the current study to the existing literature of school trips is twofold. First, we estimate the proportion of children living in neighborhoods within walking-distance who actively commute to school taking into consideration the educational system policy in China of "attending nearby school". Secondly, we identify how and to what extent the neighborhood and individual-level built environment characteristics affect the behaviour of active school traveling. We recruited 1090 children from four primary schools in Shenzhen, China. Multilevel models examined the relationship between built environments and school commuting behavior (that is, mode choice, travel time to and from, and route difference to and from school). We found the average distance to school was 575 m [min = 206 m, max = 1303 m]. Three out of four children (N = 805) lived within their school catchment neighborhoods in our study samples, of which 87% were active commuters and 6% arrived in school by their parents' cars. For children living outside of school catchment areas (N = 285), 22% of them walked or cycled to school and 23% arrived to school by their parents' cars. Having more gates, measured by density of neighborhood entrances, was positively associated with active mode choice. Route aesthetics greatly impacted the active mode choice. Safety was associated with different route use to and from school. Compared to children who commuted alone, children who traveled with classmates or parents were less likely to use different routes to and from school. This study highlights the importance of considering the local built environment context of school catchment planning in understanding school commuting behaviors in China.

1. Introduction

Physical activity has many known health benefits including improvements to cardiovascular health, lung function, bone strength, and mental health, and a decreased risk of diabetes, obesity, cancer, and overall mortality (Bauman et al., 2012; Lee et al., 2012). Studies have shown that levels of physical activity among children are low. Ninety-three percent of Canadian children ages 5–11 do not meet the recommended physical activity guidelines of at least 60 min of daily moderate-to-vigorous-intensity physical activity (Gray et al., 2014). In the UK, the proportion of children aged 5 to 15 years meeting recommendations between 2008 and 2012 declined from 28% to 21% (Panter et al., 2008; Townsend et al., 2015). In the USA, 42% of children ages 6–11 year obtain the recommended 60 min of physical activity, whereas only 8% of adolescents achieve this goal (Troiano et al., 2008). In China, 77% of students in primary and middle schools failed to meet the recommendation in the "2010 National Physical Fitness and Health Surveillance" survey (Zhang et al., 2012). Low levels of physical activity may predispose children to developing childhood obesity, which has become a global epidemic (Boreham and Riddoch, 2001). The

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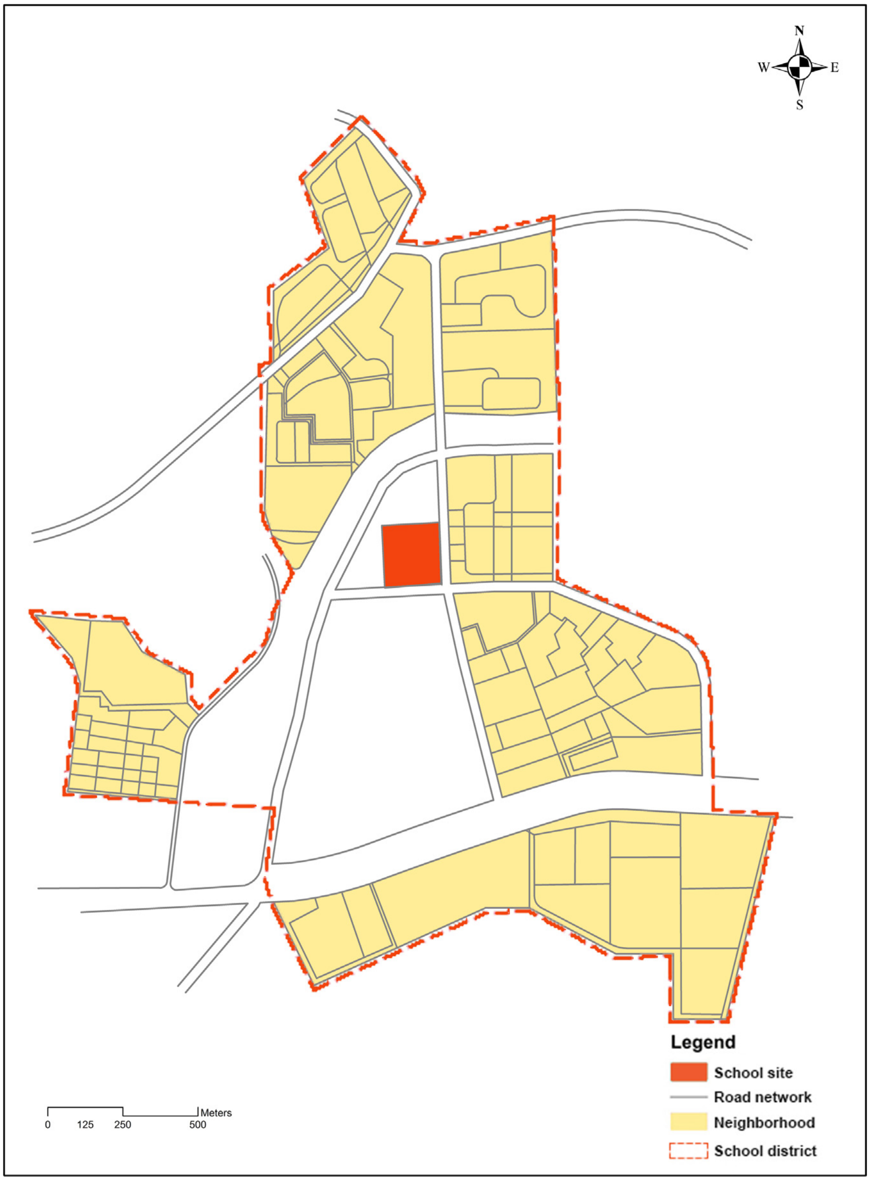

Fig. 1. Catchment neighborhoods of a primary school in China.

journey to school is a potentially important opportunity for increasing children's daily physical activity (Fulton et al., 2005; Rowland et al., 2003). Encouraging active commuting to school (ACS) can further foster healthy active commuting habits during later adolescence and adulthood (Merom et al., 2006; Yang et al., 2014).

Studies in Western cities have shown that fewer than a half of all ACS trips are by walking or bicycling mode even for distances under one mile (Martin et al., 2007; Rothman et al., 2014b; Salmon et al., 2007). Little is known about the pattern of school commuting in mainland China where physical inactivity has increased among children in recent decades (Kerr et al., 2016; Zong and Li, 2014). Urban planning guidelines recommend that the service area of a primary school is at around 500 m radius buffer, and a middle school is at 1000 m (Shenzhen Planning and Land Resource Committee, 2017). With the planning guidelines, the "attending nearby school" policy restricts primary school admission to children living within a defined catchment neighborhoods based on parental hukou (household registration) and housing ownership (Feng and Lu, 2013), which ensures that children in mainland China live within walking distance of an affiliated primary school. Fig. 1 illustrates an example of the catchment neighborhoods for a primary school in Shenzhen, China. Education resource planning in China is strikingly different from many Western countries, where parents can often choose which schools their children attend, with often only families with limited resources (e.g., fewer cars) sending their children to the local school (Bostock, 2001; Goodman et al., 2012). However, there is limited research assessing the proportion of children in China who live within walking distance to school who actively commute.

Previous studies have attempted to promote physical activity of children by focusing on time at school or leisure time activities. Research has shown built environment correlates with physical activity of children. However, links between the built environment and ACS has received less attention (D'Haese et al., 2015b; van Goeverden and de Boer, 2013). A few environmental factors associated with ACS have been examined such as: distance; connectivity of streets; traffic calming on streets; path infrastructure; aesthetic qualities; intersection density; safety; and land use mix (Curtis et al., 2015; Ewing et al., 2004; Larouche et al., 2015; Larsen et al., 2009; Panter et al., 2008; Pont et al., 2009; Wong et al., 2011). Apart from a consistent negative association between distance, findings of the built environment indicators associated with children's ACS were inconsistent and nuanced (Wong et al., 2011). For example, the relationship between street connectivity and ACS has been positive in some studies and negative in others (Carlson et al., 2014; Panter et al., 2010). Some studies reported null association between land use mix and ACS (Ewing et al., 2004; Panter et al., 2010), others reported positive relationship (McMillan, 2005; Rosenberg et al., 2009). The inconsistencies potentially hinder designing effective interventions to promote ACS.

Some researchers suggested that objective built environment elements influence ACS of children. While the inconsistent use of spatial concepts, including buffer size, objective measures, and quality of pedestrian network datasets, limits the ability to draw conclusions (Pont et al., 2009; Wong et al., 2011). Other studies found that parental perceptions are more influential (Fyhri and Hjorthol, 2009; Mackett, 2013), which have focused predominantly on distance from home to school and safety. Fewer studies have been conducted on children's own experiences of the walking environment to school (Fusco et al., 2012). Evenson identified positive associations between knowledge of the number of destinations in the neighborhood and ACS of girls (Ortega et al., 2006). In another study of Australian girls, no association was found between having convenience stores near the home and walking for transport during the week (Carver et al., 2005).

Most of the previous ACS studies were conducted in urban areas of the USA, Canada, Australia and Western Europe. In China, less is known about the role of physical and perceived built environments on children's ACS. Though some commonalities may exist across countries, reviews of the literature suggest that how the environment impacts ACS is not universal (Van Kann et al., 2015). USA, Canada, Australia and Western Europe have different urban layouts and walking culture, and most importantly different education planning system, compared to China. Studies in Australia indicated that children residing in denser and urban areas are significantly associated with more ACS (Curtis et al., 2015). There is a lack of research in urban areas in China, which have much greater density than their western counterparts (Sun et al., 2017a).

Understanding of the local context through examining both objective and perceived built environment characteristics is essential for identifying effective intervention strategies to promote ACS (Larouche et al., 2015; Rojas Lopez and Wong, 2017). The investigation of built environmental correlates of ACS in a developing country such as China is urgently needed to reverse the rapid trend towards inactivity (Lu et al., 2017). The purpose of this paper is to examine this relationship by looking at a range of objective and subjective factors that may impact children's multiple aspects of ACS in China, taking into consideration China's "attending nearby school" education system.

2. Methods

2.1. Study areas and populations

Four primary schools located in different city districts of Shenzhen, a megacity with a population of over 10 million in the south of mainland China, were systematically selected for this study. The selection of the schools is based on the criterions of geographic locations of the school (city center or fringe), density, greenery diversity, and representative of the built environment. Types of the catchment neighborhoods of each school include open and gated communities. The open communities are self-built urban villages and other public housing neighborhoods. The gated communities are built for residents from a range of socio-economic backgrounds, which in China are different from in Western countries where gated communities are often walled-off enclaves of houses where more affluent people live (Sun et al., 2017b).

The four primary schools comprise of 28 catchment neighborhoods in total. The students are mostly from those neighborhoods according to the "attending nearby school" policy. Study participants were recruited from the school sites instead of neighborhoods. Two recruiting methods were applied: i) subjects were intercepted arriving at and leaving school; and ii) in classroom surveys. All surveys are interviewer administered. Four trained interviewers administrated the questionnaire, and explained the items if children had questions. Data were collected from October to November 2015. All participants and their parents provided informed consent. The Ethics Committee of Peking University approved this study.

2.2. Active commuting behaviors

Active commuting behaviors were collected using four measures. Self-reported travel mode was assessed, with response options of walking, bicycling, automobile, public transit, and other. Self-reported daily travel time to and from school was assessed, with answers categorized as less than 5 min, 5–10 min, 10–15 min, and greater than 15 min. We asked subjects if they had different routes to and from school, with response options being exactly the same, totally different, and partially different. Commuting patterns were categorized into binary data as active (walking or bicycling) vs. non-active (automobile, transit, other). Travel time was categorized as less than 10 min vs. 10 min or more. Route choices were categorized as same vs. different.

Age, gender and companionship were collected as covariates. The commuting companionship was measured by an item with options of: alone, classmates or friends, parents, and grandparents or nannies.

2.3. Neighborhood-level environmental measures

We measured five neighborhood-level built environmental characteristics: i) pedestrian network distance from the neighborhood geographic center to the school gate; ii) density of neighborhood entrances, defined as the number of entrances in every 1000 m of neighborhood boundaries. The entrance is where people/children can enter into the neighborhoods. It could be road intersections at the boundary of an open community. It could also be the gates of a gated community. iii) sidewalk ratio along motorized roads; iv) ratio of traffic calming roads, defined as roads jointly used by pedestrians and cars equipped with traffic calming techniques (Melia, 2012); v) permeable pedestrian network ratio, defined as the number of small alleys and informal paths that are routes not official or legally sanctioned but frequently used by local residents and children.

These measures were calculated using a detailed pedestrian network we constructed using high resolution aerial photographs, street views, and field visits with GPS ground truthing techniques, to avoid the missing pedestrian network issue of urban road networks that has previously been shown to confound built environment and active travel studies (Chin et al., 2008; Iacono et al., 2010; Sun et al., 2015; Tal and Handy, 2012). We identified gate access points – locations that allow a pedestrian free access to the school catchment neighborhood – by field observation, as enclosure of gated communities has been reported but does not appear in official records (Webster et al., 2017). All measures were calculated using geographic information systems (ArcGIS 10.3.1, Esri, USA).

2.4. Perceived environmental measures

Perceptions of the route environments were assessed using a 24-item questionnaire. The questionnaire was based on a review of studies assessing the relationship between environmental attributes and ACS behaviors. We adapted items from the validated Neighborhood Environmental Walkability Scale for Youth (Rosenberg et al., 2009). This questionnaire was used for 11- to 12-year old children in a previous study in Taiwan, who share the same culture and language with our study samples (Sheu-jen et al., 2010). It also has been applied in children in Belgium (D'Haese et al., 2015a). We adjusted items for differences from Western countries to better reflect China's physical environment (Day, 2016; Day et al., 2013; Sun et al., 2017a). We conducted pilot validation using three waves of focus group studies on 21 children. The researchers discussed with respondents what they believed the questions were asking, if there were any vocabularies they did not understand. The questionnaire was revised until no ambiguities remained. Items, using a four-point Likert-scale ranging from the most negative to the most positive result for that situation, were constructed by semantic differential principles.

Principal component analysis using varimax rotation was applied to identify the groups of related environmental attributes. Five factors, accounting for 52% of the variance, were identified from the analysis. Six items were excluded from further analysis because they cross-loaded across several of the factors or did not fit with the interpretation of the factors. Loadings ranged from 0.46 to 0.76 across the five factors. Five dimensional factors were obtained for the perceived environment characteristics: permeability, route across public open space, route across points of interest (e.g., stationers, snack shops), route aesthetics, and safety. Appendix A is a full list of study items, factor groupings, and response options.

Items in each factor were summed to provide a total score for each category of perceived environmental attribute. These summed scores were then divided by the number of items in each category. This facilitates comparisons across the categories, with all having a final score out of four. The scores of permeability, route across public open space, route across points of interest, route aesthetics and safety were transformed into categorical variables with three levels: low (a less positive perception of the environment); moderate; or high (a highly positive perception of the environment). The cut-off points used for these levels were those that most closely approximated the tertiles of the distributions.

2.5. Statistical analysis: Multilevel modeling

Multilevel binary logistic regression models were used to examine the associations of the neighborhood-level environmental characteristics and individual-level perceived environmental factors with the four ACS behaviors. All models were adjusted for age, gender and companionship. We standardized the neighborhood-level variables. All analyses were conducted in R (Version 3.4.2).

3. Results

3.1. Descriptive analysis

The distribution of school commuting mode, travel times, and route differences to and from school are shown in Table 1. A neighborhood group-based descriptive analysis of the neighborhood-level environmental measures, the individual-level perceived factors, and covariates are shown in Appendix B.

The average network distance for the 28 neighborhoods was 575 m from the geographic centre of catchment neighborhood to school [SD = 267; min = 206 m, max = 1303 m]. Descriptive statistics of the neighborhood-level variables include: 'density of entrances of the neighborhood' [mean = 4.1, SD = 3.4], 'ratio of sidewalk along motorized road' [mean = 0.7, SD = 0.3], 'ratio of traffic calming road' [mean = 0.5, SD = 0.3], and 'ratio of permeable pedestrian network' [mean = 0.2, SD = 0.3].

We recruited 1,090 children, of which 805 (74%) lived within the school catchment neighborhoods and were included in data analyses. Participants were 48% female, with a mean age of 11 years (SD = 1.2, range 9–14), with most children between the ages of 10 to 12 years (78%). Thirty-nine percent used different routes for commuting to and from school. Thirty-eight percent of participants commuted to school alone, 49% commuted with classmates, and 13% commuted with parents or grandparents.

There were stark differences in commuting patterns between children who lived within and outside of school catchment neighborhoods. For children living within school catchment neighborhoods (N = 765, after deleting missing values), the majority (87%) walked or cycled to school, while few (6%) arrived to school by their parents' cars. For children living outside of school catchment neighborhoods (N = 285), 22.4% walked or cycled to school with 23% arriving by car. Fifty-one percent of children commuted to school by bus or metro.

Table 1
Descriptive statistics of school commuting behaviors (N = 764, after deleting missing values).

	Percent
Commuting mode	
Walking	82.8
Cycling	3.8
Automobile	6.3
Transit	3.9
Others	3.3
Travel time from home to school (H2S)	
Less than 5 min	26.8
6–10 min	40.2
11–15 min	21.7
Greater than 15 min	11.4
Travel time from school to home (S2H)	
Less than 5 min	22.9
6–10 min	36.6
11–15 min	24.4
Greater than 15 min	16.2
Route difference between H2S and S2H	
Same	61.5
Different	38.5

3.2. Multilevel models

Intra-class correlation (ICC1) is used to assess the reliability of individual data aggregated at neighborhood group level in the hierarchical models. Table 2 shows the multilevel binary logistic regression modeling of the built environment correlates of ACS behaviors of children living in Shenzhen, China.

3.2.1. Active commuting

Neighborhood differences accounted for 17% of the variance in explaining school commute mode choice. Distance to school was inversely associated with active mode choice [OR = 0.33, CI = 0.20–0.56]. Neighborhoods with greater density of entrances were associated with a greater likelihood of active mode choice [OR = 3.13, CI = 1.21–8.11]. Several perceived characteristics of the built environment were associated with active commuting. A moderate number of points of interest along the commuting route predicted active commuting to school [OR = 5.64, CI = 2.79–11.38]. A greater route aesthetics was also associated with a greater likelihood for active travel. Perceived safety was significantly correlated with active commuting. Having a high degree of perceived open space along the route was negatively associated with active commuting [OR = 0.32, CI = 0.15–0.69]. Female students were less likely to actively commute to school.

The companionship influenced the active mode choice. Compared with students who traveled alone, those who traveled with parents [OR = 0.03, CI = 0.01–0.09] or with grandparents/nannies [OR = 0.12, CI = 0.03–0.48] were less likely to actively commute.

3.2.2. Travel time

Neighborhood differences accounted for 5–6% of the variance in predicted travel times to and from school. A longer distance predicted a longer commuting time. A denser permeable pedestrian network did not reduce travel time to and from school. Ratio of traffic calming road was positively related to travel time from home to school [OR = 1.43, CI = 1.06–1.91]. Females had shorter travel times from school to home [OR = 0.70, CI = 0.51–0.98].

3.2.3. Route difference between to and from school

Neighborhood differences accounted for 4% of the variance in predicted route differences. Having a high degree of perceived permeability was negatively associated with using different routes for commuting between to and from school [OR = 0.55, CI = 0.34–0.89]. A moderate number of perceived points of interest along the commuting route positively associated with different route choices [OR = 1.60, CI = 1.14–2.25]. The safety is related to whether children want to explore the environment by different routes. A high degree of perceived safety was associated with a high likelihood of using different routes to and from school [OR = 1.55, CI = 1.06–2.28]. Compared to independent commuters, children traveling with classmates and friends [OR = 0.57, CI = 0.41–0.81] or parents [OR = 0.55, CI = 0.21–0.99] were less likely to use different routes to and from school.

In summary, distance was shown to be consistently negatively associated with active commuting to school and with longer travel times to and from school. A higher ratio of permeable pedestrian network did not yield a shorter travel time, and perceived high permeability was unlikely to encourage children to use different routes to and from school. Perceived routes aesthetics greatly impacted active commuting, having the largest odds ratio for predicting active commuting in the model. A higher degree of perceived safety encouraged students to use active modes of travel. Perceived safety also can encourage students to choose different routes to and from school to explore the environment. Independent travelers were more likely to be active commuters and choose different routes to and from school, compared to those travelling with companions.

Table 2
Environmental correlates of active commuting to school behaviors for children living in Shenzhen, China (N = 764).

	Active commuting mode choice OR (CI)	Travel time from home to school(H2S) OR (CI)	Travel time from school to home (S2H) OR (CI)	Route difference between H2S and S2H OR (CI)
Neighbourhood Level				
Distance to school	0.33 (0.20–0.56) ***	2.65 (2.00–3.50) ***	2.38 (1.80–3.16) ***	0.99 (0.76–1.28)
Density of entrances of the neighborhood	3.13 (1.21–8.11) *	0.72 (0.46–1.12)	0.77 (0.50–1.19)	0.70 (0.48–1.04)
Ratio of sidewalk along motorized road	0.79 (0.47–1.32)	1.03 (0.79–1.33)	1.01 (0.78–1.32)	1.05 (0.83–1.34)
Ratio of traffic calming road	0.77 (0.45–1.33)	1.43 (1.06–1.91) *	1.33 (0.99–1.79)	1.11 (0.84–1.46)
Ratio of permeable pedestrian network	0.50 (0.20–1.23)	1.68 (1.07–2.63) *	1.59 (1.01–2.49) *	1.19 (0.80–1.78)
Individual level				
Permeability				
Low	1.00	1.00	1.00	1.00
Moderate	0.74 (0.36–1.49)	1.08 (0.73–1.58)	0.80 (0.55–1.14)	0.72 (0.51–1.03)
High	1.12 (0.39–3.20)	1.04 (0.62–1.75)	0.63 (0.38–1.05)	0.55 (0.34–0.89) *
Route across open space				
Low	1.00	1.00	1.00	1.00
Moderate	0.63 (0.28–1.42)	0.92 (0.59–1.44)	0.90 (0.59–1.37)	0.79 (0.53–1.19)
High	0.32 (0.15–0.69) **	0.92 (0.60–1.40)	0.89 (0.60–1.33)	0.71 (0.48–1.04)
Route across points of interest				
Low	1.00	1.00	1.00	1.00
Moderate	5.64 (2.79–11.38) ***	1.01 (0.70–1.46)	0.99 (0.70–1.41)	1.60 (1.14–2.25) **
High	0.08 (0.00–1.84)	3.09 (0.45–21.10)	1.53 (0.27–8.79)	0.69 (0.11–4.23)
Route aesthetics				
Low	1.00	1.00	1.00	1.00
Moderate	6.14 (3.00–12.55) ***	1.31 (0.89–1.92)	1.15 (0.80–1.65)	1.24 (0.87–1.76)
High	633.03 (9.46–42370.52) **	0.36 (0.05–2.51)	0.61 (0.10–3.53)	6.18 (0.83–46.06)
Safety				
Low	1.00	1.00	1.00	1.00
Moderate	4.54 (2.00–10.31) ***	1.33 (0.87–2.01)	0.90 (0.61–1.35)	1.14 (0.78–1.67)
High	4.83 (2.05–11.38) ***	0.84 (0.55–1.28)	0.73 (0.49–1.09)	1.55 (1.06–2.28) *
Companionship				
Travel alone	1.00	1.00	1.00	1.00
With classmates or friends	0.91 (0.43–1.92)	1.31 (0.90–1.90)	1.20 (0.85–1.71)	0.57 (0.41–0.81) **
With parents	0.03 (0.01–0.09) ***	1.07 (0.56–2.07)	0.89 (0.48–1.65)	0.55 (0.31–0.99) *
With grandparents or nannies	0.12 (0.03–0.48) **	1.43 (0.59–3.46)	1.07 (0.46–2.50)	1.16 (0.49–2.74)
Female	0.51 (0.27–0.98) *	0.81 (0.57–1.15)	0.70 (0.51–0.98) *	1.01 (0.74–1.39)
Age	1.21 (0.93–1.57)	0.96 (0.83–1.11)	0.97 (0.84–1.12)	0.91 (0.80–1.04)
Random parts				
N: Neighbourhood	28	28	28	28
ICC1: Neighbourhood	0.171	0.05	0.056	0.043
Observations	764	764	764	764
AIC	348.797	883.09	958.546	1007.246

Notes: OR = Odd Ratio; CI = the 95% confidence interval;
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

4. Discussion

Living within walking distance from school is a government-led planning policy initiative for school-age children in mainland China. In this study, we investigated the school commuting pattern of children living in Shenzhen, and examined the perceived built environmental characteristics associated with active commuting behaviors. We found objective built environment characteristics at the neighborhood level and perceived built environment attributes at the individual level are associated with active commuting to school in children who living within walking-distance neighborhoods. This study highlights the importance of considering the local context of school catchment planning in understanding ACS in mainland China.

We found that nearly three quarters of children live within a half a kilometre from school, indicating that the “attending nearby school” policy has resulted in most students living within walking distance to school. The vast majority (87%) of children who lived within walking distance to school actively commuted to school (either by foot or bicycle), and only 6% arrived by car. On the contrary, the ratio of walking and cycling was considerably lower (22%) among children who lived outside the school catchment neighborhoods, while the ratio of children arriving by car was greater (23%). Previous studies have found ACS rates of 50–55% in Canada (Buliung et al., 2009), and 48% in the United States among children who live within walking distance to school (Martin et al., 2007; Salmon et al., 2007). In a study of Australian children, even when using a broad definition of active commuting to include any leg of a trip to or from school that includes walking or cycling, only one third of children were found to be active commuters (Merom et al., 2006). It is reasonable to infer that the high ACS rate in our study suggests the 'attending nearby school' policy has been successful at promoting active commuting, and that the local context of school catchment planning is leading to very different commuting patterns than observed in many Western communities.

Perceived built environment characteristics were associated with active commuting to school. Interestingly, routes that were perceived to be more aesthetically pleasing were positively associated with active commuting modes, and having the most impact on active mode choice among environmental factors. This finding is different from a literature review finding that environment aesthetics were unimportant in children's decisions surrounding commuting to school (D'Haese et al., 2015b). This difference might be due to Shenzhen city context, with its subtropical climate and dominant concrete high-rises, offering a recognizable building landscape with a tree canopy that provides shade that might greatly encourage ACS.

Routes across open spaces were inversely associated with active travel modes. Previous studies that have examined the relationship between open spaces and ACS have found mixed results. Parks and recreation facilities were not found to be associated with observed walking, but were associated with increased reported walking (Kerr et al., 2007; Rothman et al., 2014b; Zhu et al., 2011). The neighborhoods represented in this study include several gated communities. In China, contemporary gated communities are usually large in size, involving hundreds of acres and thousands of residents. The built forms within these communities tend to be high-rise arrangements with much of the ground area devoted to open space (Miao, 2003), but spatially segregated from the surrounding areas. In contrast, open communities in China have better pedestrian accessibility but lack open spaces. The perception of the presence of open spaces might therefore be a less important factor than the spatial segregation of the gated communities in determining children's school commuting behaviors. This may also be partially confirmed by the findings that at a higher density of neighbourhood entrances – indicating a lesser spatial segregation of the community – was positively associated with the activity commuting.

Safety was another concern identified in this study. We found that children who reported higher perceived safety were more likely to use alternate routes to and from school. This suggests that perceived safety of the environment may encourage children to actively explore their environment. General safety and traffic safety have been found to be associated with ACS in North America and Australia but not in Europe (D'Haese et al., 2015b). This might be due in part to the increased dangers of walking and cycling to school in the US and Australia, due to substantial urban sprawl (Pucher and Dijkstra, 2000; Rothman et al., 2015, 2014a).

We found that neighborhood level built environment characteristics were associated with ACS. Distance was consistently inversely correlated with ACS. Having more neighborhood entrances was associated with active mode choice. However, a higher ratio of permeable routes did not appear to translate into shorter travel times for school commuting. Permeable routes are more prevalent in open communities than gated communities. In both focus group and survey discussions, children reported the lack of light in permeable routes as a deterrent to using those routes. Furthermore, there are many e-bikes using these narrow routes which was also cited as a traffic safety concern (potential collisions).

Using multilevel models, we found that neighborhood differences explained differences in active commuting behaviors. Specifically, neighborhood level built environment characteristic accounted for variations in ACS. These important findings, in this study involving a simultaneous analysis of neighborhoods and children provide support for the notion that the built environment should be taken into consideration when planning and promoting active commuting to school policies in China.

4.1. Implications

This study revealed that various physical and perceived built environment characteristics effect active commuting to school in China. These findings could assist urban/transport planners, public health practitioners and school planners to improve ACS in China.

Aesthetic and safety features in the school neighborhood environment were correlated with ACS among children. Increasing ratio of permeable routes alone might be not able to promote children's ACS. More attentions are needed to improve the quality of the routes. Urban designer could enhance lighting in and around such street to improve the use of permeable routes. In addition, we found route aesthetics can encourage children's ACS. Practitioners can intervene aesthetics by increasing street greenery and tree shading. The attractiveness of the routes will get enhanced by tree shading, especially in the subtropical Shenzhen city where the weather is hot.

Permeable routes may also limit car traffic and increase safety. In our study areas, however, many e-bikes were observed on permeable streets, increasing the collision risk for children. Traffic safety such as traffic volume and speed have also been identified as factor that influences school travel mode decisions. Designers can employ traffic calming measures including, using devices (e.g., piles, speed bumps) to restrict e-bikes activity in permeable alleys, lower speeds in motorized roads by curving the street, and pushing traffic out of collector routes in school catchment areas (Brown et al., 2017). Streets and permeable routes may then offer greater opportunities for both active transport and leisure-time physical activity of children.

We found that children who are active commuters tended to explore spaces when they traveled independently. Studies on independent mobility suggested that children who have the freedom to play outdoors and travel actively without adult supervision accumulate more physical activity than those who do not (Schoeppe et al., 2013). One example of a policy proposal could be for school planners in China to recommend that children actively commute to school for one week of every semester, and use different routes during ACS to explore the environment of their neighborhoods. This ACS week activity should ideally be done by children independently, without companionship of parents, provided the children are age appropriate, and chaperoned by an adult (parents or teachers) at major road intersections.

4.2. Limitations and strengths

This study has several limitations. The study was restricted to a single geographical area, the city of Shenzhen, a subtropical megacity in China with a high population density, and these results may only be generalizable to similar city contexts. The cross-sectional study design makes it impossible to draw conclusions about causal relationships of the "attending nearby school" policy and ACS patterns. Nevertheless, the strikingly difference in ACS patterns between children who live within and outside of school catchment neighborhoods suggests that there may be a significant impact of the policy on active travel in China. Our active commuting behaviors are based on self-report which may be subject to recall bias and may not capture all domains of this activity. We aimed to assess similar themes of the perceived individual level and objective neighborhood level measures of the built environment, however our measures do not match perfectly (Lin and Moudon, 2010). Detailed streets audits (Cerin et al., 2011; Sun et al., 2017a) might help relate perceived measures to their objective counterparts and help optimize the use of these findings in formulating planning recommendations.

This study has several strengths, including sample size, novelty, and the use of multilevel statistical methods. The study's large sample allows for a representative description of children's perceptions on route preferences and the perceived import of built environment attributes. We provide, to our knowledge, the first description of children's commuting behaviors under the unique school catchment planning system in mainland China. This information is especially important as there are currently few such studies in Asia. We used multilevel modelling to control for neighborhood level environmental characteristics as a way to better understand Chinese children's perceptions of their built environment and their school commuting behaviors.

5. Conclusion

Living within a designated school catchment neighborhood in mainland China was associated with active commuting to school. This study reports on the active commuting patterns of children in China and offers an important addition to the literature, providing the Chinese context for school commuting patterns, which represents an important juxtaposition to Western studies. In Asia, none of the physical environment attributes previously studied in the international literature have been sufficiently investigated to draw conclusions with regards to active commuting to school (D'Haese et al., 2015b). Our findings may support urban planners and health practitioners to intervene the built environment to promote ACS for children living in Shenzhen and other similar cities.

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Appendix A. Perceived environmental attributes measured in the study, factor groupings, and response options

1. Your commuting route includes short cut.
2. You have multiple commuting route choices thus do not have to use same route.
3. You can avoid large arterials.
4. The distance is usually short between road intersections.
5. You can use alleys which don't not along the commuting route.
6. Your commuting route is across playgrounds.
7. Your commuting route is across open space with excises facilities.
8. Your commuting route is across small greenery.
9. Your commuting route is across large greenery.
10. Your commuting routes is across stationers.
11. Your commuting route is across snack shops or convenient stores.
12. Your commuting route has tree shading.
13. Your commuting route has beautiful urban landscape.
14. Your commuting route have many traffic noise.
15. The cars usually drive very fast along your commuting route.
16. There are many unfriendly strangers along your commuting routes.
17. Your commuting route has fresh airs.
18. Your commuting route has bird songs.

Note: Factor groupings—Permeability 1,2,3,4,5; Cross public open space 6,7,8,9; Cross stationers and stores 10, 11; Commuting route Aesthetics 12, 13, 17,18; Safety 14,15,16.

* Items in safety dimension is reversed coding.

Reponses options- each item is measured in four-level Likert scale: strongly disagree, disagree, agree, strongly agree.

Appendix B. School catchment neighborhood group-based environmental characteristics (N = 764, after deleting missing values)

Neighborhoods	Distance to School (meter)	Density of entrances of the neighborhood	Ratio of sidewalk along motorized road	Ratio of traffic calming road	Ratio of permeable pedestrian network	Route cross open space	Permeability	Across points of interest	Route aesthetics	Safety	Female	Age	Companionship
1	456	8.07	1	0.32	0.61	2.09	1.90	1.67	1.64	2.05	0.44	10.93	1.78
2	206	9.82	0.73	0.83	0.17	2.11	1.68	1.53	1.74	2.32	0.47	10.58	1.84
3	532	0	0.68	0	0	1.78	1.78	1.52	1.59	1.85	0.52	11.00	1.74
4	377	4.05	1	0.46	0.2	1.90	1.70	1.60	1.90	2.10	0.20	10.70	1.80
5	717	0.69	0.52	0.17	0	1.81	1.75	1.69	1.63	1.81	0.44	11.00	2.44
6	813	5.96	0.39	0.94	0.06	1.81	2.00	1.81	1.81	2.06	0.31	10.75	1.75
7	707	5.69	0.15	0.34	0.66	2.23	2.08	1.54	1.46	1.54	0.46	10.38	2.23
8	391	11.47	1	0.42	0.58	1.61	1.83	1.65	1.91	1.87	0.57	11.57	1.70
9	331	7.03	1	0.55	0.34	2.00	1.96	1.71	1.88	2.13	0.58	11.00	1.75
10	635	0	1	0	0	1.90	1.69	1.41	1.76	1.76	0.52	10.86	1.93
11	904	0	0.89	0	0	2.09	2.11	1.77	2.00	1.89	0.37	11.31	1.83
12	787	4.24	0.95	0.72	0.28	2.47	2.00	1.53	1.71	1.88	0.29	11.59	1.88
13	364	3.44	0.6	0.81	0.19	2.00	2.06	1.69	1.81	1.94	0.31	11.19	1.94
14	993	1.12	0.18	0.06	0.04	1.50	1.67	1.33	1.42	1.42	0.75	10.67	2.08
15	1303	0.95	0.79	0.07	0	2.31	2.08	1.62	1.92	1.62	0.23	11.85	1.85
16	163	2.96	1	0.97	0.03	1.60	1.54	1.66	1.60	2.20	0.57	10.43	2.00
17	270	0.55	1	0.54	0	1.69	1.79	1.69	1.62	1.96	0.54	10.77	1.65
18	277	0	1	0.89	0.11	1.94	1.44	1.67	1.61	1.89	0.44	10.83	2.06
19	575	1.83	0.44	0.79	0.21	2.00	1.53	1.74	1.53	2.00	0.37	11.05	1.84
20	744	3.56	0.23	0.55	0.45	2.18	1.91	1.45	1.55	1.82	0.18	11.45	1.91
21	741	0	1	0	0	1.71	1.83	1.54	1.63	1.67	0.54	11.71	1.79
22	369	8.5	0.31	0.39	0.61	1.71	1.65	1.54	1.46	2.08	0.58	10.91	1.58
23	296	7.42	0.18	0.36	0.64	1.82	1.76	1.71	1.47	2.05	0.45	11.11	1.79
24	674	5.55	0.88	0.39	0.03	2.19	1.69	1.66	1.56	1.91	0.38	11.16	1.78
25	452	1.88	0.83	0.67	0	1.89	1.56	1.52	1.52	1.81	0.70	11.19	1.74
26	819	7.66	0.79	0.11	0.89	1.77	1.64	1.68	1.68	2.32	0.50	10.77	1.86
27	750	5.21	0.9	1	0	1.73	1.73	1.73	1.45	1.64	0.64	10.18	1.55
28	481	6.05	0.27	1	0	2.05	2.00	1.84	1.89	2.32	0.58	10.63	1.68

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