Preventive Medicine Reports 12 (2018) 170–175

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Longer afterschool active commutes and the travel environment of middle schools in Shenzhen, China

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A R T I C L E   I N F O

Keywords:
Afterschool commute
Route environment
Active travel
Route choice
Middle school

A B S T R A C T

The afterschool commute is a major part of children's daily activity. This study examines the relationship between student extended active travel routes and route environment characteristics. Route environment characteristics may be related to an extended route for students who walk or bike home. Self-reported itineraries were collected from 12 to 15-year old students in 3 middle schools in Shenzhen in May and June (n = 1257). Itineraries involving a detour from the shortest possible route home (n = 437) were compared with the shortest route. A field study coded all possible routes within the school districts by playable open spaces, sidewalk width, controlled crossings, road category, and public transit stops. Binary logistic regression reveals that routes with greater intersection density and number of open spaces are related to active travel choice. Sidewalk width, number of traffic lights and proportion of arterial roads are positively related to motorized travel. Linear regression reveals that travel distance, sidewalk width, number of open spaces and street crossings, as well as the proportion of secondary roads and pathways are positively related to detour distance. Higher numbers of public transit stops and traffic lights are related to shorter detours. Attending cram school is also negatively associated with active travel and detour. Younger students, females and students with longer moderate-to-vigorous physical activity time have extended active travel. Specific route environment characteristics are associated with longer and more active middle school student commutes and may be implemented to raise overall activity levels in children.

1. Introduction

Children face a future of rising rates of non-communicable disease as a consequence of insufficient physical activity (Hallal et al., 2012). Empirical research shows that the afterschool commute is a major contributor to daily moderate-to-vigorous physical activity (MVPA) (Arundell et al., 2015; Southward et al., 2012; Frazer et al., 2015). Active travel, including walking and biking, is a predictor of high-level MVPA (Aibar et al., 2015). Thus, it is important to explore the factors influencing active travel. Many studies demonstrate the relationship between travel mode and environment or socio-demographic factors. Although it is suggested that walking farther should be promoted as an alternative to motorized travel (Catrine, 2012), the specific factors that could extend active travel have not been sufficiently examined. After-school MVPA is related to certain environmental characteristics of the larger school environment (Remmers et al., 2016; Thornton et al., 2017), which suggests that students might select routes that offer more opportunity to engage in MVPA. For these reasons, route environment may influence route choice. The following hierarchical analysis firstly examines factors in travel mode choice in the afterschool commute. Secondly, active travel choices involving a detour from minimized commuting distance are examined for the associated play, walking and biking facilities, street width, street crossings and transit stops. The characteristics of these detour trips are compared with those of the minimized paths students did not choose.

A systematic review in North America shows that distance to school is negatively associated with active travel (Rothman et al., 2017), a finding repeated worldwide. Mixed land use is associated with active travel but mixed land use with greater landscape diversity has lower active travel among adolescents (Su et al., 2013). In contrast, single-family housing has higher levels of active travel and independent mobility among children in Finland (Broberg et al., 2013). Active transport infrastructure provision and improvements in safety, including traffic calming, are associated with increased levels of active transport. A

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https://doi.org/10.1016/j.pmedr.2018.09.009
Received 12 April 2018; Received in revised form 11 September 2018; Accepted 22 September 2018
Available online 29 September 2018

recent review shows that urban areas with higher street connectivity also have higher rates of active transport (Smith et al., 2017). They also find that the presence of parks and park improvements are associated with more visits by active transport. Higher rates of active travel are seen where there are fewer trafficked streets to cross (Carlson et al., 2014) and higher street connectivity (Oliver et al., 2015). Similarly, more pedestrian streets and fewer motorways, as well as lower socio-economic status, are associated with independent walking commutes among primary school children in Shenzhen, China (Zacharias et al., 2017).

Afterschool travel contributes more to students' daily physical activity (Heelan et al., 2005; Pabayo et al., 2012), in part because of the higher rate of active travel from school when compared with the trip to school (Leslie et al., 2010; Larsen et al., 2009). A Finnish study also finds that the school environment is more important than the home environment in travel mode choice (Broberg and Sarjala, 2015). In theory, there is more time available for elective activity in the after-school period before the next scheduled activity.

Better understanding of school journey route choice, in combination with travel mode research, is important to fully comprehend afterschool commute behavior. In keeping with utility theory, directness is an important factor in route choice (Hoogendoorn and Bovy, 2004), and dominates the travel decisions of students in Turkey (Ozbil et al., 2011). Although direct routes dominate pedestrian travel in Lille, France, environmental factors relating to built form, vegetation and visual obstacles are significant in detoured trips (Foltête and Piombini, 2007). Only a handful of studies consider route environment factors (Larsen et al., 2012). In a Japanese study, walking facility width and absence of impedance may modify pedestrians' default choice of the shortest distance route (Muraleetharan and Hagiwara, 2007). Similarly, sidewalk width and number of destinations are positively related to route choice in Boston (Guo, 2009). Greenway, sidewalk condition, safety and attractive destinations along the route are predictors of route choice (Rodríguez et al., 2015).

In summary, this paper has a twofold purpose: to assess the association between route environment factors and travel mode; for active travel, to understand the relationship between longer than necessary routes and environmental factors associated with the longer route.

Our reasoned hypotheses follow:

1. Active travel mode is negatively associated with travel distance, while detour distance in active travel is positively associated with travel distance. Longer trips generally afford more opportunities to engage in non-commuting activity.
2. Higher intersection density is related to active travel and lesser detour distance. Higher intersection density affords more opportunities to engage with the environment, which may promote active travel. Lower intersection density entails more deviation from a straight line, consistent with detours, which by definition involve deviation.
3. Sidewalk width is positively related to active travel and detour distance. There is evidence that greater sidewalk width is positively related to active travel and may also encourage deviation from the minimized commute path.
4. The number of playable open spaces, shops and designated crossings of the actual route are proportionally greater than those of the potential shortest route; that is, we expect that the detours in the route home are associated with opportunities and improved walking conditions. In contrast, the number of public transit stops and traffic lights is lesser on the actual route. Traffic lights imply more crossing of trafficked streets, already shown to accompany lowered active travel. Public transit may offer an attractive alternative to the walk home.
5. Students living in urban villages tend to choose active travel mode and have less detour distance. Such children of lower socio-economic status attend fewer extra-curricular cram schools and have fewer household cars. They also live in pedestrian environments with very high intersection density.

2. Methods

2.1. Study design and participants

Three middle schools in Shenzhen were selected to represent different environments, as indicated below. There is one middle school per school district. Students in first and second grade were considered, while third year students were excluded by the schools because of intensive preparation for high school. Three classes were randomly picked from each grade at all schools, with the participation of all students in those classes recording their route from school to home, travel mode in weekdays (from Monday to Friday) and extra-curricular activities after school for the entire study period. Students completed an in-class chart for each day and hour and traced their route on an attached map, under the supervision of a teacher and a research assistant. Students were also asked to provide age and sex and whether they lived in an urban village.

The route environment audit was based on traversed segment feature (Rodríguez et al., 2009). We used Baidu Street view to audit attributes of each segment in each school district where residents normally send their children to the sole middle school (Guo and Loo, 2013). The selected route environment factors include street intersections, sidewalk width, open spaces, shops, transit stops, designated crossings and traffic lights. Some parts of the school district were not covered by Baidu Street view, while sidewalk width is difficult to estimate in the picture. Assistants conducted fieldwork to verify street and sidewalk width, location of shops and playable open spaces. They also investigated pedestrian streets in the urban villages, which are generally not included in Baidu Street view.

2.2. Data collection

There were 765 participants in active transport, 492 in motorized modes. Of those in active transport, 437 made detours from the shortest possible route home. Apart from sidewalk width, represented by the mean of all segment sidewalk widths on the itinerary, and intersection density, represented as the number of street intersections divided by trip length, other factors were the sum of all segment attributes. The following were counted for each itinerary: shops and open spaces fronting the street; marked street crossings; pedestrian crossing lights. Major roads are generally four- or more lanes wide and are defined in the Shenzhen Master Plan. Secondary streets have two lanes, while community streets are located inside gated communities. Pedestrian streets do not allow car access. The total number of segments belonging to each of these street categories was counted for each itinerary and expressed by proportions.

Ethical approval was obtained from the Bio-medical Research Ethics Board of Peking University (no. 2015063).

2.3. Data analysis

Itineraries with detour were included in the analysis of the associated environmental factors. Walking and biking were regarded as the active travel mode (Faulkner et al., 2009). Shortest possible travel home was excluded from this dataset in order to focus on the associations with detour; however, executed trips with detour were compared with the attributes of the shortest possible route for each given origin-destination pair. All itineraries with environment factors coded for each network segment were entered into ArcGIS 10.2. The route environment factors for each itinerary were calculated by summing all segment environment attributes (Rodríguez et al., 2015). The shortest possible travel route and detour distance of students selecting active travel mode were calculated in ArcGIS 10.2. Actual and shortest possible routes

Table 1
Summary commute and environment data of 1257 itineraries for three school districts.

	Mean (SD)			
	Lihu	OCT	Taoyuan	Total
Age (y)	13.12 (0.60)	13.43(0.72)	13.46(0.74)	13.36(0.72)
Cram School (n)	0.67(0.36)	1.76(1.89)	1.19(1.55)	1.10(1.57)
Distance (m)	1739(825)	1443(646)	1003(606)	1260(756)
Sidewalk width (m)	2.83(0.26)	3.09(0.49)	2.46(0.44)	2.63(0.46)
Intersection density (n/km)	9.98(4.99)	9.69(2.38)	23.76(9.55)	18.35(10.44)
Open spaces (n)	1.24(1.12)	3.50(1.33)	2.18(1.22)	2.05(1.37)
Shops (n)	8.75(11.6)	5.89(4.6)	7.10(7.65)	7.45(8.78)
Crossings (n)	6.28(5.2)	8.04(4.12)	5.99(4.68)	6.29(4.81)
Transit stops (n)	3.37(3.71)	5.02(4.82)	1.48(2.55)	2.39(3.43)
Traffic lights (n)	3.12(2.245)	0.60(0.77)	0.88(1.49)	1.49(1.98)
Main street (%)	1.34(4.55)	11.23(21.15)	4.14(7.27)	4.08(9.58)
Secondary street (%)	59.78(35.48)	0.87(3.57)	3.61(10.86)	19.41(32.99)
Community street (%)	25.95(29.57)	69.46(23.59)	14.34(15.96)	23.41(27.12)
Pedestrian street (%)	13.07(18.73)	18.21(21.22)	78.04(19.77)	53.18(36.73)

were compared firstly, to uncover the relationship between detour distance and travel environment. Samples without detour were shortest routes and so excluded from the database (n = 328). Binary logistic regression was used to evaluate the impact of environmental variation on active travel. *t*-test and chi-square test demonstrated the difference between actual and shortest possible travel route. Finally, linear regression was used to examine the relation between route environment and detour distance. Because detour was exponentially distributed, the lognormal values were taken as the dependent variable. All statistical analyses were conducted in SPSS 22.

3. Results

3.1. School district characteristics

Route environment factors for three schools vary in travel distance, sidewalk width, number of open spaces, shops, crossings and traffic lights, in addition to road type according to the plan for school district selection (Table 1). Socio-demographic factors also varied among schools, including number of cram schools attended and residence in an urban village. Urban villages are the informally reconstructed rural villages within the city, housing mostly rural migrants with limited rights to urban services. In Shenzhen, rural migrant children may attend regular schools.

Shenzhen, a pioneer city after the Reform and Opening Up (1978), has a complex history in almost 30 years' rapid development. These three districts could be seen to represent three models for the middle school district, where the commute environments vary (Table 1). For example, in comparing the mean value of features per itinerary, OCT has generally high service level, with the highest sidewalk width (3.1 m), numbers of open spaces (n = 3.5), pedestrian crossings (n = 8.04) and transit stops (n = 5.0). Although the number of traffic lights (n = 0.6) is small, the traffic system has been organized for walking and biking. Taoyuan, whose intersection density (23.8/km) is the highest, also has many rebuilt urban villages, where the historic, pedestrian street network is conserved. Lihu contains gated communities and city colleges, which are accompanied by a large-scale street network, so that the average travel distance (1739 m) is much longer and the proportion of secondary roads (0.6) highest.

The results for mode choice, following the hypothesis statements in Introduction are reported in the next section, while the results for the relationship between environmental factors and active travel are reported in Section 3.3.

Table 2
Binary logistic regression for the travel mode.

		B	S.E.	VIF	OR
Sex		−0.254	0.188	1.082	0.776*
Urban village		1.283	0.208	1.558	3.609***
Distance		−0.179	0.173	4.749	0.836
Cram school		−0.194	0.092	1.126	0.823**
Sidewalk width		−0.614	0.253	6.676	0.541**
Intersection density		1.544	0.231	3.306	4.683***
Open spaces		0.357	0.113	1.707	1.429***
Crossings		0.013	0.170	3.307	1.013
Transit stops		−0.045	0.191	4.251	0.956
Traffic lights		−0.352	0.156	4.260	0.703**
Main street		−0.972	0.246	3.181	0.379***
Pedestrian street		−0.096	0.250	7.345	0.909
Model	−2 log likelihood	Cox & Snell R-square		Nagelkerke R-square	
Summary	828.936	0.493		0.668	

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

3.2. Active and motorized travel mode

There are significant differences ($p < 0.001$) between the route environments of active and motorized modes, with intersection density, cram schools attended, and pedestrian streets all being significantly greater for active travel modes ($p < 0.01$). Motorized travel mode routes have more open spaces, transit stops, traffic lights, and crossings as well as a higher proportion of main roads, and wider sidewalks ($p < 0.01$).

After standardizing the data and eliminating the collinear variables of secondary and community street, Table 2 shows the relationship between environment factors and travel mode. Itineraries with higher intersection density (OR = 4.683, p = 0.000) and number of open spaces (OR = 1.429, p = 0.002) are related to active travel mode. Sidewalk width (OR = 0.541, p = 0.015), number of traffic lights (OR = 0.703, p = 0.024) and proportion of the network in main streets (OR = 0.379, p = 0.000) are positively related to motorized travel. Students attending fewer cram schools (OR = 0.823, p = 0.035), and living in urban villages (OR = 3.609, p = 0.000), tend to select active modes.

3.3. Detoured travel route and the shortest potential route in active mode

The differences in route environment between actual and potential shortest route of active travel are shown in Table 3. Intersection density is higher for the shortest possible route. The detoured route has wider sidewalk, more open spaces, shops, crossings, transit stops and traffic lights. The relationship between active transport and the street hierarchy is less obvious and requires further investigation.

Table 4 is the outcome of stepwise linear regression for the logarithm of detour distance (InD), where 13 variables explain 58.4% of the variance in InD. Travel distance (p = 0.000), sidewalk width (p = 0.000), number of open spaces (p = 0.000) and crossings (p = 0.000), and proportion of secondary and pedestrian streets (p = 0.000) are positively associated with InD. Public transit (p = 0.000) and traffic lights (p = 0.000) are negatively related to InD. More MVPA is associated with longer InD (p = 0.000). Students who live in urban villages (p = 0.007) and attend fewer cram schools (p = 0.000) travel longer. Age is negatively related to InD (p = 0.000). There is a weak link between detour and gender (p = 0.075), with girls walking or biking farther than boys.

Table 3
Difference in means (*t*-test) between actual and shortest possible travel route for active mode.

	Mean (SD)				
	Actual (N = 437)	Shortest (N = 437)	Difference	T-value	p Value
Distance (m)	1091(583)	884(456)	207(36)	5.721	p < 0.001
Sidewalk width (m)	2.53(0.41)	2.35(0.36)	0.18(0.03)	7.111	p < 0.001
Intersection density (n/km)	22.62(8.92)	24.37(8.68)	−1.75(0.60)	6.582	0.003
Open spaces (n)	2.21(1.25)	1.63(0.90)	0.58(0.07)	7.888	p < 0.001
Shops (n)	8.94(10.01)	7.65(7.39)	1.29(0.60)	2.164	0.031
Crossings (n)	5.61(4.20)	3.5(2.84)	2.11(0.24)	8.683	p < 0.001
Transit stops (n)	1.25(2.48)	0.63(1.33)	0.62(0.13)	4.594	p < 0.001
Traffic lights (n)	0.70(1.50)	0.49(1.12)	0.21(0.89)	2.303	0.022
Main streets (%)	1.70(4.98)	0.31(1.09)	0.14(0.24)	5.68	p < 0.001
Secondary streets (%)	4.11(13.27)	8.01(20.93)	−0.04(1.19)	−3.291	0.001
Community streets (%)	29.32(27.19)	19.10(24.00)	10.22(1.73)	5.891	p < 0.001
Pedestrian streets (%)	64.91(30.44)	72.73(33.04)	−0.08(2.15)	−3.636	p < 0.001

4. Discussion

Travel distance is not significant in the homeward commute mode choice among middle school children in Shenzhen, in contrast with recent findings in the literature (Duncan et al., 2016; Rothman et al., 2017). When the urban village variable is eliminated, distance becomes significant for travel mode choice. Urban villages are farther away from the school (mean = 1602 m) than other planned residential areas (mean = 996 m), which may explain why travel distance is not significant in this study. The environmental attributes of the urban village, with high intersection density and narrow pedestrian streets, facilitate walking and biking. Although there is a higher rate of motorized trips for children in these communities farther from the school, much of their environment is already a non-motorized one. The gated communities clustered around the school have much shorter travel distances to school, but also higher rates of car ownership. The role of distance in travel behavior is clearly conditioned by these contextual factors.

A few studies examine the impact of route environment factors on travel mode. Intersection density (n/km) is strongly associated with active travel mode, in accordance with traditional walkability measurement (Owen et al., 2007; Sallis et al., 2009). A systematic review shows density of parks and accessibility to parks and other open spaces are related to walking and biking (Kaczynski and Henderson, 2007). The number of open spaces in the afterschool itinerary is relevant to active travel. The route, with increased proportion of major streets and quantity of traffic lights, is characterized by higher traffic volume, and a concomitant reduction in walking and biking. Greater sidewalk width is not associated with active travel in this study. The motorized traffic system includes sidewalks built to a high standard in contemporary urban planning in China. In this way, sidewalk width is positively but not exclusively related to variables that facilitate motorized travel.

The environments for the shortest and detoured routes of students in active travel mode are significantly different. This result suggests that routes with high levels of service, including increased sidewalk width, number of open spaces, shops, transit stops, crossings and traffic lights, may influence mode choice, which resonates with research on the topic (Muraleetharan and Hagiwara, 2007; Rodríguez et al., 2015), and in contrast with conventional utility theory. The present results also show that a mix of road types is a characteristic of extended routes, while the shortest possible route has the largest proportion of pedestrian streets. More studies are needed to explore the impact of a mix of road types on route choice.

While previous studies have hardly investigated trip detour, the present study provides some important insight into how such detoured travel might be instigated. Active travel distance is strongly associated with detour distance, so that distance from school to home remains the most important factor, influencing both travel mode and detour distance. Moderate travel distances to school are associated with the

Table 4
Linear regression for the logarithm of detour distance[a] of active travel mode.

Coefficients[a]					ANOVA	
Variables	Unstandardized coefficients		Standardized coefficients	VIF	R^2	F-value
	B	Std. error	Beta		0.584	45.702***
Activity time	0.007***	0.002	0.129	1.173		
Sex	−0.169**	0.095	−0.061	1.201		
Urban village	0.291***	0.108	0.100	1.401		
Age	−0.316***	0.068	−0.158	1.180		
Cram school	−0.143***	0.031	−0.156	1.136		
Distance	0.002***	0.000	0.644	4.035		
Sidewalk width	1.249***	0.224	0.375	4.592		
Open spaces	0.250***	0.041	0.226	1.409		
Crossings	0.123***	0.018	0.375	2.926		
Transit stops	−0.273***	0.035	−0.492	4.130		
Traffic lights	−0.219***	0.058	−0.238	4.119		
Secondary street	3.202***	0.496	0.309	2.323		
Pedestrian street	2.166***	0.298	0.479	4.428		

[a] Dependent Variable: ln (detour).
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

highest rates of active travel, because more steps are more than compensating for the switch to motorized modes at these distances (Duncan et al., 2016). The cut-off value for travel mode is 1174 m in Shenzhen, so how to maintain the active mode beyond this threshold and extend active travel is an important question. A Canadian study shows that open spaces could generate shortcuts to facilitate active travel by decreasing travel distance (Clark et al., 2015), a finding that does not contradict ours that a route with increased open spaces could help students walk longer. As a consequence, the location of open spaces and other playable places should be considered more in neighborhood planning. Although increased amounts of sidewalk are positively associated with motorized travel, our hypothesis that pedestrians prefer wide sidewalks is upheld. Street crosswalks which include zebra crossings, bridges and underground tunnels may offer opportunities for students to get access to points of interest (POI), in the process executing a detour. In addition, the crossing density for the actual route is larger than for the shortest route, which strengthens this possibility. Presence of public transit and traffic lights seem a barrier for students to walk or bike longer. It is suggested that planners pay more attention to the connection between transit stops and the organization of local community.

Students living in urban villages tend to walk or bike longer, confirming the popular view that the urban village is suitable for walking. Most urban village streets are in fact exclusively pedestrian. Although the urban village is associated with motorized modes to school, they are also an active living environment, in contrast with rural America (Hansen et al., 2015). In addition, longer detours are related to longer afterschool activity time, which strengthens the inference that environmental factors are related to the level of afterschool physical activity. Further observation of places where students play could better reveal the relation between playing and detouring. It should be emphasized that senior students have less detour distance, because Chinese students in middle school are under intense pressure to prepare for the high school entrance exam, especially when they reach the third and final grade. Since those final year students are excluded in this study, research that focuses not only on physical activity but also on mental health should be conducted in future.

This paper focused on attributes of the walk environment but clearly choices in favor of active and extended travel from school to home are conditioned by a host of other considerations, such as the effect of community gating, private motorized transport, enrolment in cram schools and parental attitudes. Intervention programs to promote active transport among children so far show modest positive results, mostly in participation efforts (Buttazzoni et al., 2018). A key question going forward is how to balance investment in social intervention with environmental improvement.

5. Conclusion

This study suggests that features of the route environment are related to both travel mode and active travel route choice. Extended active travel is positively associated with sidewalk width, open spaces, street crossings and secondary and pedestrian streets, and residing in an urban village. Increased number of transit stops is related to less detour distance in active travel. Active travel is related to higher intersection density, fewer arterial streets, greater sidewalk width and more traffic lights.

In addition, socio-demographic factors impact middle school students' afterschool travel. Attending cram school, an activity associated with planned residential communities and higher income, is related to the motorized mode and shorter active travel. Students who live in urban villages that are also farther from schools, tend to select motorized mode but travel farther when choosing active mode. Girls and students with extended MVPA time have longer active travel distance.

To our knowledge this is the first evidence that children will deviate from a minimized commuting trip for play opportunities and features associated with the walk environment. Since these detours are the result of conscious choice, related planned features of the environment should be considered. International efforts to promote active transport to and from school have focused mainly on safety and independent travel. Planned environmental change may also result in increased afterschool activity levels.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

The authors gratefully acknowledge funding from the Natural National Science Foundation of China, Grant number 41471119 and the State Administration of Foreign Expert Affairs of China.

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