The Influence of the Physical Environment and Sociodemographic Characteristics on Children's Mode of Travel to and From School

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Objectives. We examined whether certain characteristics of the social and physical environment influence a child's mode of travel between home and school.

Methods. Students aged 11 to 13 years from 21 schools throughout London, Ontario, answered questions from a travel behavior survey. A geographic information system linked survey responses for 614 students who lived within 1 mile of school to data on social and physical characteristics of environments around the home and school. Logistic regression analysis was used to test the influence of environmental factors on mode of travel (motorized vs ''active'') to and from school.

Results. Over 62% of students walked or biked to school, and 72% from school to home. The likelihood of walking or biking to school was positively associated with shorter trips, male gender, higher land use mix, and presence of street trees. Active travel from school to home was also associated with lower residential densities and lower neighborhood incomes.

Conclusions. Our findings demonstrate that active travel is associated with environmental characteristics and suggest that school planners should consider these factors when siting schools in order to promote increased physical activity among students. (*Am J Public Health.* 2009;99:520–526. doi:10.2105/AJPH.2008.135319)

Fewer than half of all children in Canada and the United States are active enough to experience the well-known health benefits of physical activity.[1] The most common form of physical activity for people of all ages is walking,[2] and for children and youths, the journey to school represents a significant opportunity to increase daily levels of physical activity by using nonmotorized travel modes, such as walking and biking.[2–6] Modes of travel to school have changed dramatically over the last 40 years, however, with ever-decreasing use of "active" (nonmotorized) travel.[7,8]

Studies of children's travel are limited and, in the United States, have found widely varying rates of active travel to school. A study in South Carolina reported that as few as 5% of elementary school students walked or biked to school,[9] and a study of North Carolina children found that 9% walked and 4% biked.[10] Research by Kerr et al.[6] based in the Seattle area found that 18% of students walked or biked to school 5 days a week and 25% used active travel at least 1 day a week. Meanwhile, a comprehensive nationwide study by Martin et al. found that 48% of students who lived within 1 mile of school were active travelers,[11] suggesting that geographical factors are at play.

We examine sociodemographic and environmental influences on a child's mode of travel between home and school in a midsized Canadian city (London, Ontario) and explore differences in travel mode between the journey to school and the trip home from school.

CHARACTERISTICS OF BUILT ENVIRONMENT THAT INFLUENCE WALKING

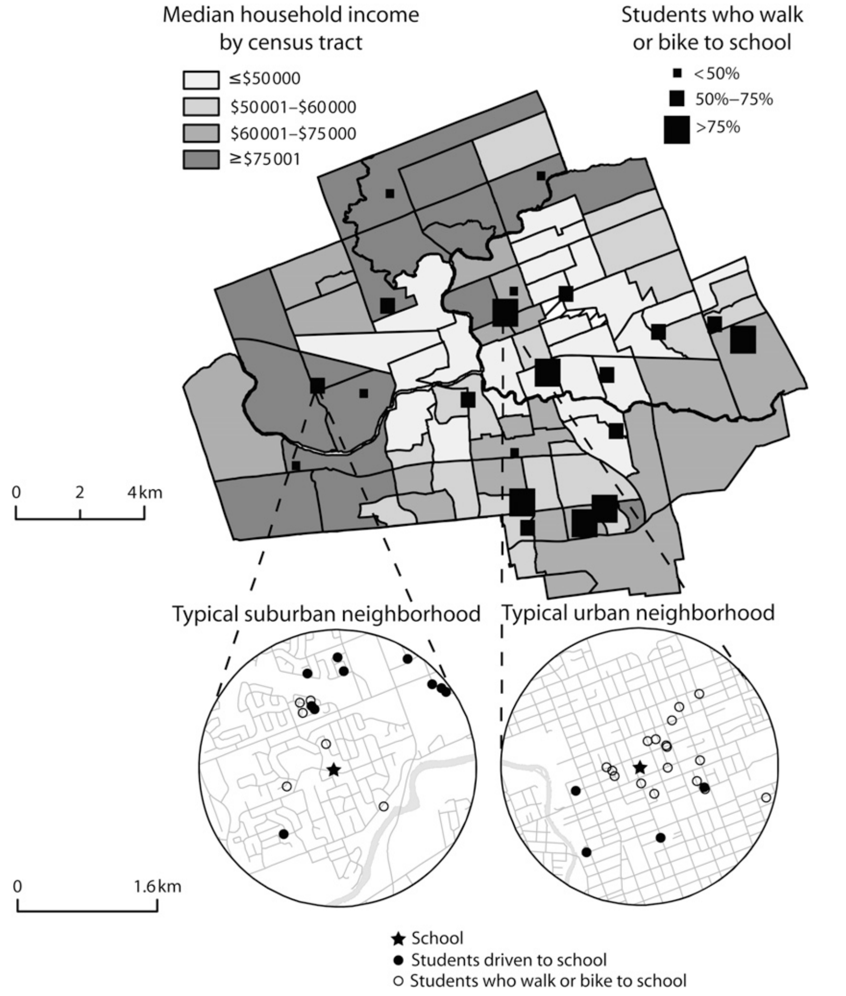
Previous research has indicated that neighborhood features such as parks, sidewalks, street connectivity, residential density, retail space, and land use mix influence walking behaviors among adults.[12–15] Less is known about the influences of the built environment on walking behaviors among children,[16,17] despite the fact that younger populations are less mobile and more influenced by the features in their local surroundings and therefore more likely to benefit from increased "walkability" in local neighborhoods.

Research on active travel among children, which has largely drawn its variables from studies of adults, has suggested that neighborhood factors such as distance to school, land use mix, parental perceptions, and characteristics of the built environment may influence decisions regarding a child's mode of travel to school.[7,18–20] Current evidence indicates that distance between home and school is the most important variable in determining mode of travel to school, with children less likely to use active modes as distance increases.[7,8,21,22] Nevertheless, research suggests that features of the built and social environment also play an important role in the choice of travel mode, although the evidence is somewhat mixed regarding how this occurs. The density of street intersections (i.e., the number of intersections per square mile in a neighborhood), for example, is related to route options and connectivity in the local neighborhood, and it has been shown to have positive associations with rates of active travel.[20,23,24] Intersection density is also related to increased roadway crossings, however, raising safety concerns that may negatively affect rates of active travel.[21]

Likewise, studies have indicated that higher residential densities are an important factor toward increasing active travel among adolescents,[20,23,24] but at least 1 study has found no relationship between residential density and walking to school.[16] The presence of sidewalks, which can increase pedestrian safety,[12,25] has been linked to increased walking and bicycling to school,[6,26,27] and T.E. McMillan[28] has suggested that neighborhood tree cover is positively associated with walking levels. Finally, although higher land use mix, which increases the number of potential nearby walking destinations, has been linked to increased rates of walking and physical activity in adults for utilitarian travel,[2,13,29,30] the relationship between land use mix and children's travel is less clear. Kerr et al.[6] found a positive correlation between land use mix and nonmotorized travel to school, but Ewing et al.[16] found the opposite. At this point, results are inconclusive, and more work needs to be done on younger populations before certain environmental factors can be confirmed as predictors of active travel to school.

SOCIODEMOGRAPHIC FACTORS THAT INFLUENCE WALKING

The sociodemographic characteristics of individuals and neighborhoods have also been shown to influence parental decisions on children's travel to school. Gender has been identified as an important factor, with girls less likely than boys to walk to school and after-school activities.[27,31,32] Research also indicates that use of nonmotorized travel among children decreases as the education levels of parents increases[11] and, similarly, that rates of active travel to school are often higher in low-income than in high-income neighborhoods.[24,31] Although relatively understudied, single parenthood has also been related to increased rates of active travel among children.[27] In an attempt to further develop researchers' understanding of a child's journey to school, we examine a combination of environmental and social predictors in relation to mode of travel.



Source. City of London[33] and Statistics Canada.[34]

FIGURE 1—Map showing median household income by census tract and schools by proportion of students who walked or biked to school: London, Ontario, 2006–2007.

METHODS

School-Based Survey Examining Journey Between Home and School

A comprehensive travel behavior survey was completed by students in grades 7 and 8 (aged 11–13 years) at a heterogeneous sample of elementary schools varying by income and built environment (Figure 1 shows the sample distribution) throughout the city of London, Ontario. Of the 51 schools eligible for study, 21 (41%) chose to participate, 11 from the London District Catholic School Board and 10 from the Thames Valley District School Board. A total of 1666 students were recruited to participate; 810 students received parental consent and were present on the day of data collection, for a response rate of 49%. The survey was conducted from October to December in 2006 and in April and May in 2007.

The survey asked students about their mode of travel both to and from school and neighborhood characteristics, as well as behavioral, demographic, and environmental questions. To obtain the demographic characteristics of individual households, parental questionnaires were distributed at the same time as forms requesting permission for their children's participation. Because previous research has suggested that children are more likely to walk to school if the distance is no more than 1 mile (1.6 km),[7,8,19,21] we included only children living within 1 mile of school (n=614) in our analysis. In addition, London school boards provide bus service to students who live more than 1 mile from school.

Geographic Information System Analysis of Home and School Neighborhoods

Questionnaire data for survey respondents were geocoded to the geographic center of their home postal code with ArcGIS 9.2 (Environmental Systems Research Institute Inc, Redlands, CA). Postal codes were used instead of exact home addresses to maintain the anonymity of respondents. Canadian postal codes represent much smaller geographic units than American zip codes, and previous research indicates that Canadian postal codes are suitable proxies of home neighborhoods in urban environments.[35] In our study, the median area of a postal code is 9699 m^2 (11 560 sq yd; maximum=154 402 m^2, or 184 663 sq yd).

In assessing neighborhood environmental and sociodemographic characteristics through use of a geographic information system, we delineated neighborhoods using "buffers" (defined rings of set distances) around both the school and the home postal code of each respondent. In accordance with the methodology adopted by local school boards for determining busing, we used a buffer 1.6 km in radius with the school at its center to delineate school neighborhoods. To capture characteristics of the immediate home environment and to identify differences between it and the general school neighborhood, we used a buffer only 500 m in radius, centered on the geographic center of a student's home postal code, to delineate home neighborhoods. A distance of 500 m is commonly used in studies of accessibility.[36,37]

Data on sidewalks, road networks, street trees, pathways, and land use type were obtained from the City of London Planning Department[33] and validated by researchers through field surveys and inspection of aerial photographs. We completed environmental audits for 11 schools, giving us a high degree of confidence in the interpretation of the photographs. London's street tree inventory, which was conducted in the field by the city's forestry group in summer 2002, is updated regularly to account for planting programs and removal of dead or hazardous trees. Data for this study were updated in fall 2006. We created a "circulation system" file by combining the City of London digital map files for road network, trail network, and pathways network. To ensure accuracy, we manually updated the circulation system file using 2006 aerial photography (15-cm resolution) and field surveys. This file allowed us to determine all possible walking routes (including shortcuts through parks, schoolyards, etc.) within the city.

Questions on household income, education, and single-parent families were asked in the parental questionnaire, but response rates on these questions were deemed too low (about 60%) to incorporate them into this analysis. Data on neighborhood-based levels of educational attainment (proportion of adults 20 years and older with a high school diploma), single parenthood (proportion of families headed by single parents), median household income, population, and numbers of dwellings were obtained from Statistics Canada, 2001.[34] Population and numbers of dwellings were available at the census block level, but all other data are suppressed at this scale; dissemination areas (average $=0.35\ km^2$, or 0.14 sq mi) were the smallest geographical unit for which data on educational attainment, single parenthood, and median household income could be obtained. For a buffer comprising more than 1 dissemination area, data were weighted according to the proportion of land taken up by each dissemination area.

We calculated the distance from home to school with ArcGIS 9.2, using the shortest path along the circulation system (which included roads, trails, and pathways) between the student's home postal code and school. The presence of street trees was computed by summing the number of trees within 5 m of each road edge. Intersection density was determined by finding the number of 3- and 4-way intersections per square kilometer. Net residential population and dwelling densities were assessed by taking the total area of residential land within each buffer divided by the sum of residents and dwellings from the Statistics Canada[34] census block data set. Finally, sidewalk length is the total length of sidewalks within each buffer.

To calculate the land use mix variable, every land parcel within the city of London was classified into 6 broad classes as defined by the city (recreational, agricultural, residential, institutional, industrial, and commercial); we then calculated the total area of each of the 6 classes of land use within each buffer. Following previous studies,[29,38] we used the following entropy index to determine land use mix within home and school neighborhoods:

$$(1)\quad \text{Land use mix} = \Sigma_u(p_u \times \ln p_u)/\ln n,$$

where u is the land use classification, p is the proportion of land dedicated to a particular land use, and n is the total number of land use classifications. Using this equation, land use mix scores will always fall within the range of 0 to 1, with 0 representing a single land use (e.g., all residential) and 1 representing even distribution of all 6 land use classifications.

All data were originally entered into hierarchical linear and nonlinear modeling; however, primary analysis revealed that there was no significant intraclass correlation ($P=.754$) between rates of active travel and the 21 school neighborhoods, which made multilevel analysis unnecessary. In this study, the 1.6-km buffer around each school is referred to as the school neighborhood. Data from both the questionnaire and the geographic information system were then entered into SPSS 15.0 (SPSS Inc, Chicago, IL) for statistical analysis. The P values of the correlations between use of nonmotorized travel and sociodemographic and environmental variables were tested with univariate logistic regression (Table 1), and all significant factors ($P<.05$) were used in a stepwise logistic regression equation.

RESULTS

Of the 614 study participants, over 71% lived in single detached homes, 7% in semidetached homes, 9% in townhouses, and 10% in apartment buildings. The median household income in the respondents' neighborhoods was Can$58124, and the average net residential population density was 5648 people/km^2 (residential land only). Nearly two thirds of students (62%; n=382) living within 1.6 km of their school used a form of nonmotorized (active) travel to get to school in the morning; the vast majority of this group walked (95%), and a few students biked, skateboarded, rollerbladed, or used a scooter (Table 2). Analysis of the journey home from school revealed an increase of almost 10% in the number of students using nonmotorized travel (n=442) compared with the journey to school (Table 2). Although rates for driving to school were low, automobile ownership in sample households was very high, with over 95% of students reporting at least 1 working automobile in their household.

Figure 1 shows the location of sample schools on a thematic map of median household income at the census tract level; schools, shown as squares, are graduated in size to indicate the proportion of students walking or biking to school. It shows that fewer students walked or biked to school in high-income, suburban neighborhoods (i.e., the northwest part of the city). The 2 inset maps reveal the different street patterns around schools in typical urban and suburban neighborhoods, along with the distribution of home postal codes of students who took motorized or nonmotorized modes of travel to school. The maps illustrate the impact of distance on mode of travel and how route directness can influence distance traveled.

TABLE 1—Significance of Correlations Between Children's Mode of Travel to and From School and Characteristics of Home and School Neighborhood: London, Ontario, 2006–2007

	Mode of Travel to School, *P*	Mode of Travel From School, *P*
Home neighborhood		
Street trees	<.001	.001
Intersection density	<.001	.001
Sidewalk length	<.001	<.001
Net residential density	.017	.024
Net dwelling density	.605	.762
Land use mix	.493	.001
Distance to school	<.001	<.001
Single parenthood	.646	.835
Educational attainment	.023	.004
Median household income	.055	.027
School neighborhood		
Street trees	<.001	<.001
Intersection density	.149	.053
Sidewalk length	.001	<.001
Net residential density	<.001	<.001
Net dwelling density	<.001	<.001
Land use mix	<.001	<.001
Single parenthood	.006	<.001
Educational attainment	.001	<.001
Median household income	.001	<.001
Gender	.061	.256
No. of vehicles in household	.288	.887

Note. Students were in grades 7 and 8 (aged 12–13 years). The home neighborhood extends for 500 m from the center of a student's home postal code, whereas the school neighborhood extends 1.6 km from a student's school.

TABLE 2—Descriptive Statistics of Children's Mode of Travel to and From School: London, Ontario, 2006–2007

	No. (%)
Schools, total	21 (100)
Urban	7 (33.3)
Suburban	14 (66.6)
Respondents, total	614 (100)
Girls	314 (53.5)
Boys	273 (46.5)
No. of vehicles in household	
0	29 (4.8)
1	158 (25.9)
2	320 (52.5)
3	72 (11.8)
≥4	26 (4.3)
Mode of travel to school	
Nonmotorized, total	382 (62.2)
Walking alone	177 (28.8)
Walking with friend/parent	183 (29.8)
Bike or scooter	17 (2.8)
Skateboard or rollerblade	5 (0.8)
Motorized, total	232 (37.8)
School bus	95 (15.5)
City bus	3 (0.5)
Driven in automobile	134 (21.8)
Mode of travel from school	
Nonmotorized, total	442 (72.0)
Walking alone	135 (22.0)
Walking with friend/parent	278 (45.3)
Bike or scooter	19 (3.1)
Skateboard or rollerblade	10 (1.6)
Motorized, total	172 (28.0)
School bus	96 (15.6)
City bus	3 (0.5)
Driven in automobile	73 (11.9)

Note. Students were in grades 7 and 8 (aged 11–13 years).

As expected, logistic regression analysis for the journey to school indicated that distance between home and school was the most important factor in determining whether a child used a nonmotorized form of travel to school (Table 3). Gender was the only sociodemographic variable that influenced choice of travel mode; boys were 1.5 times more likely to use nonmotorized travel than were girls. Land use mix and presence of street trees were the only significant physical environment variables; the likelihood of active travel rose with both increased land use mix and greater number of street trees. Intersection density was not shown to play a role.

Analysis of the journey home from school revealed similar results: gender, land use mix, and distance influenced choice of travel mode (Table 3); however, a few differences do appear in the model. The presence of street trees is no longer important, whereas active travel decreased with both higher residential density and greater median household income in the school neighborhood.

DISCUSSION

Our findings contribute to the understanding of how neighborhood characteristics influence a child's journey to and from school. Mix of land uses around the school, the presence of street trees, residential population density, distance between home and school, and gender were the most important determinants of active travel. These findings have implications for decisions regarding the siting of schools, planning and management of the urban environment, and the empowerment of girls and their parents.

New strategies to increase physical activity through active travel should consider empowering and targeting girls and their parents. Boys were 1.5 times more likely than were girls to participate in active travel to and from school; similar findings were reported in a study conducted in California.[32] Improving parental perceptions of how safe a neighborhood is for walking, and increasing independence for girls, have the potential to significantly raise levels of physical activity.[39]

Some of our results were similar to those of previous research conducted on adults, and others were different. In studies of adults, land

TABLE 3—Results of Stepwise Logistic Regression Estimation for Children's Mode of Travel to and From School: London, Ontario, 2006–2007

	Coefficient (SE)	Wald Test	*P*	OR (95.0% CI)
	To school			
Gender[a]	0.468 (0.190)	6.081	.014	1.597 (1.101, 2.318)
Street trees in home neighborhood[b]	0.263 (0.117)	5.047	.025	1.300 (1.034, 1.635)
Distance to school,[c] km	−0.647 (0.123)	27.846	<.001	0.523 (0.412, 0.666)
Land use mix in school neighborhood[d]				
Second quartile	0.307 (0.236)	1.699	.192	1.360 (0.857, 2.159)
Third quartile	0.826 (0.264)	9.788	.002	2.284 (1.361, 3.833)
Upper quartile	1.062 (0.291)	13.293	<.001	2.891 (1.634, 5.117)
Constant	0.036 (0.392)	0.009	.926	1.037
	Home from school			
Gender[a]	0.437 (0.219)	3.985	.046	1.548 (1.008, 2.376)
Net residential density in home neighborhood[d]				
Second quartile	−0.782 (0.338)	5.363	.021	0.457 (0.236, 0.887)
Third quartile	−1.142 (0.365)	9.808	.002	0.319 (0.156, 0.652)
Upper quartile	−1.351 (0.382)	12.525	<.001	0.259 (0.123, 0.547)
Distance to school,[c] km	−0.816 (0.123)	44.215	<.001	0.442 (0.348, 0.562)
Land use mix in school neighborhood[d]				
Second quartile	0.418 (0.278)	2.257	.133	1.518 (0.881, 2.617)
Third quartile	1.152 (0.346)	11.088	.001	3.165 (1.606, 6.236)
Upper quartile	1.240 (0.393)	9.960	.002	3.457 (1.600, 7.468)
Median household income in school neighborhood, Can $1000	−0.050 (0.011)	18.616	<.001	0.952 (0.930, 0.973)
Constant	5.284 (0.936)	31.841	<.001	197.091

Note. OR = odds ratio; CI = confidence interval. Students were in grades 7 and 8 (aged 11–13 years). Nonmotorized travel was the dependent variable throughout. Only significant variables are displayed. The home neighborhood extends for 500 m from the center of a student's home postal code, whereas the school neighborhood extends 1.6 km from a student's school.
[a]Girl as referent.
[b]Number of street trees (in groups of 10) within 5 m of road edge.
[c]Shortest path from home postal code to school.
[d]First (lower) quartile as referent.

use mix is often reported as a predictor of walking for utilitarian travel, because it increases the variety of destinations available within short distances.[12,13,40] In our study, land use mix was also found to be an important predictor of active travel for adolescents. Land use mix may contribute to a more appealing walking environment for youths, or it may be a proxy for other environmental or social factors; the reasons that mixed land uses are related to walking are not as clear for youths as for adults and need further theorizing and study. Although increased residential densities are often associated with increased walking levels among adults, we found that as residential density increased, the probability that a child would walk home from school decreased. It is unclear why this pattern has emerged, but it may be that increased residential densities are associated with increased levels of automobile traffic and crime,[41] which increases danger (real and perceived) and might be a deterrent to walking for children.[19]

We found that the rate of active travel was nearly 10% higher on the journey home from school than on the trip to school, and automotive travel dropped by nearly 10% (Table 1). This difference highlights how children's travel patterns are linked to parental scheduling and travel. In this case, the 10% difference in the journey to and from school was probably because some parents drove their children in the morning, before work, but were still at work when their children left school in the afternoon. This finding highlights the need for more work on the relationship between parents' commuting patterns and children's mode of travel to school.

For the trip home from school, many children had fewer options for mode of travel and were more likely to use nonmotorized travel. Higher neighborhood income was associated with lower rates of active travel on the journey home. Higher-income households may have only 1 parent working, or more flexible working hours, which allow parents to pick up their children after school. Furthermore, some higher-income households may employ caregivers to drive their children home from school, an option that may be financially unavailable to lower-income households.

Street trees provide shade and can contribute to a neighborhood's esthetic quality. Although higher numbers of street trees increased the likelihood of walking to school, they did not seem to affect the journey home. Perhaps the natural environment plays a more important role in the morning trip, when children may have more options for mode of travel. This finding suggests the potential health benefits of well-targeted tree-planting efforts.

Local school boards are currently pondering the closure of certain schools in older, inner-city neighborhoods; closure decisions are apparently based solely on the Ontario Ministry of Education's estimates of too much available floor space per student.[42] School capacities are calculated on the basis of total floor space in a school (including gyms, libraries, and unoccupied areas) and number of students. These unoccupied areas of schools are commonly used for community activities such as child care or inner-city health networks, not as classroom spaces for teaching.[42]

The closing of schools in older neighborhoods is not just a problem for Ontario residents; school boards and districts throughout Canada and the United States are dealing with similar issues. The potential negative health consequences associated with closing schools need to be weighed in these decisions. Older neighborhood schools commonly have a higher mix of land uses and shorter distances to travel, which increase the odds of children walking. Schools built on the urban fringe, which require most students to be bused, increase transportation costs[43] and limit the opportunity for children to participate in physically active travel.[2–6]

Limitations

Although this research moves beyond the typical ecological study, a number of limitations exist. We did not identify the actual route a child takes to school. Because of ethics board requirements, we used home postal codes rather than exact addresses; this procedure may have reduced the variability in the data, or in some cases, slightly altered distance estimates. In addition, parental response rates on certain social variables such as income and educational attainment were too low for this study, so neighborhood-level census data were employed for social variables. Finally, the questionnaire was completed by 49% of eligible students, and it may be that the other 51% were less or more "active" than the study participants. Future research will examine other factors such as parental concerns and characteristics of the route to school.

Conclusions

School siting should be an important issue not only for school boards but also for planning and public health professionals. School location determines the distances students must travel between home and school, and shorter distances are the best way to encourage physically active journeys to school. Consolidating schools will probably harm children's health. Although land use mix and population density should also be considered with regard to increasing rates of nonmotorized travel, planting trees may be the most efficient and cost-effective environmental intervention to encourage walking to school.

Given that the rate of active travel was 10% higher for the journey home from school than for the trip to school, there is a need for more research on the relationship between parents' commuting patterns and children's mode of travel to school. The use of nonmotorized travel to school is one step toward increasing daily levels of physical activity among children. Our study contributes to the growing body of research on how local environments and school location can influence mode of travel among children. Furthermore, our findings on environmental determinants of healthful behaviors such as active travel provide justification for greater collaboration between urban planning and public health professionals to provide healthful cities for all.[44–46] ■

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Contributors

K. Larsen assisted with data collection, conducted the data analysis and cowrote the article. J. Gilliland conceived, designed, and supervised the study, secured the geographical information system data, assisted with the data analysis and interpretation, and cowrote the article. P. Hess assisted with the study design and interpretation of the findings, and edited the text. P. Tucker collected survey data and contributed to the study design. J. Irwin and M. He contributed to the study design.

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Human Participant Protection

This study was approved by the research ethics boards of the University of Western Ontario, the Thames Valley District School Board, and the London District Catholic School Board.

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