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Influence of social and built environment features on children walking to school: An observational study

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ABSTRACT

Objectives. To estimate the proportion of children living within walking distance who walk to school in Toronto, Canada and identify built and social environmental correlates of walking.

Methods. Observational counts of school travel mode were done in 2011, at 118 elementary schools. Built environment data were obtained from municipal sources and school field audits and mapped onto school attendance boundaries. The influence of social and built environmental features on walking counts was analyzed using negative binomial regression.

Results. The mean proportion observed walking was 67% (standard deviation = 14.0). Child population (incidence rate ratio (IRR) 1.36), pedestrian crossover (IRR 1.32), traffic light (IRR 1.19), and intersection densities (IRR 1.03), school crossing guard (IRR 1.14) and primary language other than English (IRR 1.20) were positively correlated with walking. Crossing guard presence reduced the influence of other features on walking.

Conclusions. This is the first large observational study examining school travel mode and the environment. Walking proportions were higher than those previously reported in Toronto, with large variability. Associations between population density and several roadway design features and walking were confirmed. School crossing guards may override the influence of roadway features on walking. Results have important implications for policies regarding walking promotion.

Introduction

The effect of the built environment on physical activity is a topical issue in public health (Shay et al., 2003). Interventions directed at the "walkability" of the built environment have been promoted to encourage healthy active living. Walkability is a complex concept, and definitions are varied as are approaches to operationalizing the concept using modeling techniques. The concept of walkability will continue to be context-specific until there exists a validated and consistent list of environmental correlates of walking.

Many studies have examined the correlates of adult walking, with some consensus that adult walking is related to density, mixed land use, pedestrian infrastructure (e.g. sidewalks, crosswalks) high connectivity (grid network, short block lengths, many intersections, few cul-de-sacs/dead ends) and accessibility to multiple destinations (Saelens and Handy, 2008; Saelens et al., 2003; Shay et al., 2003). Walkability studies for elementary school children generally focus on walking to school, which has consistently been negatively associated with distance (Pont et al., 2009; Sirard and Slater, 2008; Wong et al., 2011), and positively associated with population density (Braza et al., 2004; Bringolf-Isler et al., 2008; Kerr et al., 2006; Kweon et al., 2006; McDonald, 2007; Mitra et al., 2010b; Wong et al., 2011). Associations with land use, pedestrian infrastructure and connectivity have been inconsistent and often contradictory to findings in adult studies (Pont et al., 2009; Wong et al., 2011). Environmental features correlated with adult walking may be different than those for children because of differing destinations and purposes for walking.

Varied methods of measurement for both built environment and walking outcomes may contribute to inconsistent results (Pont et al., 2009; Saelens and Handy, 2008; Sirard and Slater, 2008; Sirard et al., 2005; Wong et al., 2011). Walking outcome has generally been measured through parent/child report using different outcome definitions (e.g. usual trip, trip per/week), time frames, and targeted age ranges. To date, only one study incorporated direct observational counts of children walking to school; however, that study was limited by small sample size and little geographic diversity (Sirard et al., 2005).

Abbreviations: JK, junior kindergarten; TDSB, Toronto District School Board; DA, dissemination area; MPAC, Municipal Property Assessment Corporation; LOI, learning opportunities index; ATLICO, after tax, low income cut-offs; VIF, variance inflation factor; IRR, incident rate ratio; 95% CI, 95% confidence intervals.

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The purposes of this study were to 1) estimate the proportion of children living within walking distance to school who walk to school in a Canadian city and 2) correlate built and social environment features (with a focus on roadway design), with observational counts of children walking to school.

Methods

Study design, setting and population

A prospective observational study was conducted in the spring, 2011, involving junior kindergarten (JK) to grade 6 elementary schools in Toronto, Canada. Toronto consists of an older urban core characterized by pre-World War II traditional neighborhoods, and 5 inner suburb municipalities, representing newer, car-oriented post-World War II neighborhoods (City of Toronto, 2001).

Exclusion criteria were schools with 1) other grade combinations 2) special programs, which accept children from outside the school attendance boundaries (e.g. French immersion) and 3) involvement in other walking studies. Children arriving by school bus were excluded as they don't live within walking distance to the school. The Toronto District School Board (TDSB) transportation policy states that children grades JK-5 who live ≥1.6 km and those grades 5+ who live ≥3.2 km from their school are eligible for school bus transportation (TDSB, 2005). Ethics approval was obtained from the Hospital for Sick Children Research Ethics Board and the TDSB.

Outcome variable

Trained observers counted children arriving to school walking, by other active means (i.e. bicycle and scooter) or by private motorized vehicles. Observations were repeated at 10% of the schools, one week apart to determine test–retest reliability. The proportion of children walking to school was calculated from the total number of children observed and excluded those arriving by school bus.

Independent variables

Built environment features were identified from a literature review. All variables were mapped onto school attendance boundaries provided by the TDSB. Features were classified according to Cervero and Kockelman's 3D's: Density, Diversity and Design, originally developed to study adult walking behavior but which has since been applied to children's school transport (Cervero and Kockelman, 1997; Lin and Chang, 2010; Wong et al., 2011). The focus of the analysis was on roadway design features, as these are most feasible to change in existing neighborhoods compared with those related to density and diversity. Table 1 presents the variables considered for the multivariate modeling.

Built environment

Density

Population density variables were obtained from the 2006 Canadian census by dissemination area (DA). DAs are the smallest standard geographic area for which all census data are disseminated with approximately 400–700 residents. DAs were mapped onto school boundaries and area-weighted proportionate analysis was used to estimate the census variables for each boundary (Braza et al., 2004; Falb et al., 2007).

Diversity

Diversity variables reflect different land uses. Recreational facilities and parks data were obtained from the City of Toronto and parcel level data by land use category was obtained from the Municipal Property Assessment Corporation (MPAC). Individual land uses were calculated as percentage of the school boundary. The mix of residential, commercial, industrial, institutional, and vacant land use (including parks and walkways) within school boundaries was measured using an entropy index:

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

where u = land use classification, p = proportion with specific land use, and n = total number classifications. Scores of 0 = single land use, 1 = equal distribution of all classifications (Frank et al., 2004; Larsen et al., 2009).

Design

Roadway design variables were obtained at the school level from school site audits conducted by two trained observers. The presence of adult school guards employed by Toronto Police Services was recorded. Vehicle speed and volume were measured using manual short-based methods by a third observer along a roadway within 150 m of the school (Donroe et al., 2008; Marler and Montgomery, 1993).

Design variables at the school boundary level were obtained from the City of Toronto and densities were calculated per school boundary area or linear km of roadway. The school was designated urban if over 50% of the attendance boundary fell within the inner urban area.

Table 1
Descriptive statistics of candidate variables for multivariate modeling.

Variable description	Mean (SD)/N (%)
Outcome	
Proportion walking to school[a,1]	67.3% (14.50)
Natural environment	
Poor weather (rain or cold) [c,5]	35 (29.66)
Built environment	
Density	
School boundary level	
Child population (#)/1000 m^2 [b,2]	0.54 (0.26)
Total population (#)/1000 m^2 [b,2]	6.09 (3.57)
Multi-dwelling (apartments, duplexes) (#)/1000 m^2 [b,2]	1.43 (1.30)
Diversity	
School boundary level	
Recreational facilities (#)/km^2 [b,3]	1.78 (1.58)
Park land area/boundary[a,3]	7.60% (6.85)
Entropy (mixed land use) [b,4]	0.61 (0.13)
Commercial land use area/boundary [a,4]	6.49% (7.32)
Residential land use area/boundary [a,4]	44.2% (2.23)
Industrial land use area/boundary[a,4]	6.31% (8.96)
Institutional land use area/boundary[a,4]	8.65% (6.67)
Vacant land area/boundary[a,4]	8.75% (7.03)
Design	
School level	
School crossing guard observed[c,5]	45 (38.14%)
Cars appear to be driving fast near school[c,5]	56 (47.46%)
Traffic congestion seen around school during drop off [c,5]	76 (64.41%)
Dangerous midblock crossing near school [c,5]	70 (59.32%)
Dangerous intersection near school [c,5]	40 (33.9%)
Drop offs opposite side of road [c,5]	83 (70.30%)
Double parking[c,5]	54 (45.80%)
Cars blocking view[c,5]	73 (61.90%)
Mean speed >5 km over speed limit[c,5]	16 (13.56%)
School traffic/minute[b,5]	2.14 (1.00)
School boundary level	
Other schools within school boundary (#)[c,6,7]	39 (33.1)
Old houses (pre 1946) (#)/1000 m^2 [b,2]	0.57 (0.82)
Collector roads km/km roads[b,3]	0.15 (0.09)
Crossing guard (#)/km roads[b,3]	0.12 (0.10)
Dead end (#)/km roads[b,3]	0.16 (0.20)
Flashing lights (#)/km roads [b,3]	0.07 (0.09)
Intersection (#)/km roads[b,3]	5.63 (1.75)
Route connectivity (intersections/dead ends)[b]	1.16 (0.20)
Local road km/km roads[b,3]	0.61 (0.15)
Major roads km/km roads[b,3]	0.16 (.10)
Minor roads km/km roads[b,3]	0.08 (.07)
One way streets km/km roads [b,3]	0.07 (.12)
Pedestrian crossover (#)/km roads[b,3]	0.10 (0.12)
Roads km/km^2 [b,3]	12.53 (4.99)
Sidewalks (one) missing km/km roads[b,3]	0.08 (.09)
Sidewalks (both) missing km/km roads[b,3]	0.04 (.09)
Traffic calming segment km/km roads (e.g. speed bumps)[b,3]	0.05 (.07)
Traffic light #/km roads[b,3]	0.53 (.29)
Trails km/km road[b,3]	0.51 (0.67)
Urban area[c,3]	39 (33.05%)
Social environment	
School level	
Total school population[b,6]	309.67 (143.94)
Males at school (#)[a,6]	51.64 (31.61)
New immigrants (≤5 years)[a,6]	11.57 (8.73)
Primary language other than English[a,6]	47.99 (24.98)
Children grades 4 to 6[a,6]	32.75 (4.56)
School LOI[b,6]	0.50 (0.28)
At below LICO cut-off (school DA)[a,2]	13.76 (10.88)

Data type: [a]proportion, [b]continuous [c]dichotomous.
Data source: [1]Observational counts, [2]Canadian Census, [3]City of Toronto, [4]MPAC, [5]Site Survey, [6]Toronto District School Board, [7]Toronto Catholic District School Board.

Social environment

Student socioeconomic status (SES) was measured using the TDSB learning opportunities index (LOI) which is a composite index including parental education, income, housing and immigration (TDSB, 2011). Scores range from 0 to 1, with 1 indicating lower SES. The proportion of households in the school's DA which fell below after tax, low income cut-offs (ATLICO) was obtained from the Canadian census as a measure of the SES of the area surrounding the school. The low income cut-off is an income threshold below which a family devotes a larger share of its income than the average family, on necessities i.e. food, shelter and clothing (Statistics Canada, 2009). The proportion of children at the school whose primary language was other than English was included as provided on the TDSB website.

Statistical analysis

The unit of analysis was the school attendance boundaries, with all features processed and mapped onto boundaries using ArcMap (ArcMap, version 10). Road network distance buffers were created around the schools to assess the proportion of roadways within the boundaries within 1.6 km walking distance of the school.

Statistical analysis was conducted using SAS (SAS, version 9.3). Multicollinearity of variables was identified by variance inflation factors (VIF) >10. When pairs of variables were highly correlated, the variable with the higher standardized unadjusted beta coefficient was retained. Descriptive statistics were calculated for all independent variables. Mean values and standard deviations were calculated for continuous variables, and numbers with percentages were calculated for dichotomous variables (Table 1).

The proportion of children walking to school was modeled as the dependent variable using negative binomial regression due to over dispersion of the count data. Features with $p \leq 0.2$ in the unadjusted analysis were included in a forward manual stepwise regression with the entry order determined by the magnitude of standardized betas. A p value ≤ 0.2 in unadjusted analyses was used to screen for inclusion in the multivariate models, as using lower p values may miss important correlates once other variables are taken into account (Hosmer and Lemeshow, 2004). At each stage of the modeling, the variables included were re-examined and dropped if not significantly related to the outcome (Chatterjee and Hadi, 2006). Model fit was assessed using the Akaike information criteria (AIC) (Agresti, 2007). Poor weather during observations was retained in the model regardless of significance level. As there were 42 potential independent variables, a Bonferroni adjusted significance level of $\leq$.001 (.05/42) was used.

Effect modification was assessed by conducting stratified analysis by tertiles for roadway design features. Results of the negative binomial models were presented as incident rate ratio (IRR) with 95% confidence interval (CI). Pearson product–moment correlation coefficients were used to determine test–retest reliability.

Results

Of 436 elementary schools, 318 schools were excluded, primarily due to ineligible grade combinations (Fig. 1). The analysis included 118 schools. The mean observed walking proportion was 67% (range = 28–98, standard deviation (SD) = 14.5). High test–retest reliability was noted in 10% (n = 12) of the schools (Pearson's r = .96). School attendance boundaries were small, with 75% having an area less than 1.3 km^2. The mean proportion of roads within the boundaries and within 1.6 km of the school along the road network was 95% (SD .10). A total of 34,099 students lived within the attendance boundaries, and of these, only 424 who attended regular programs, lived ≥1.6 km from school and traveled by school bus.

The descriptive statistics of all variables considered for multivariate modeling are provided in Table 1. Several built environment design variables had very low densities (i.e. less than .1/km roads), including flashing lights, minor roads, one way streets, missing sidewalks and traffic calming. Variables associated with the walking to school in the unadjusted analyses are presented in Table 2. Densities of old housing, multi-family dwellings, male children, residential land use, roads and local roads were dropped from further analyses because of multicollinearity. The final main effects multivariable model indicated significant positive associations between walking to school and density and design built environment variables (Table 3). Child population (IRR = 1.36, 95% CI = 1.21, 1.53), pedestrian crossovers (IRR = 1.32, 95% CI = 1.01, 1.72), traffic lights (IRR = 1.19, 95% CI = 1.07, 1.32), and intersection densities (IRR = 1.03, 95% CI = 1.01, 1.05), the presence of a school crossing guard (IRR = 1.14, 95% CI = 1.07, 1.21) and primary language other than English (IRR = 1.20, 95% CI = 1.05, 1.36) were associated with more walking. Child population density, traffic lights and school crossing guards exhibited the most significant associations. Effect modification was evident only for school crossing guard (Table 4). With no crossing guard present, walking proportions were positively associated with environmental variables and negatively associated with poor weather. Lower IRRs were evident when crossing guards were present, except for child population density.

Discussion

This is the first large study to correlate direct observational counts of walking to school with objective built environment data. The mean proportion of observed walking was high at 67%; with large variability between schools. The mean proportion of other active modes (i.e. cycling

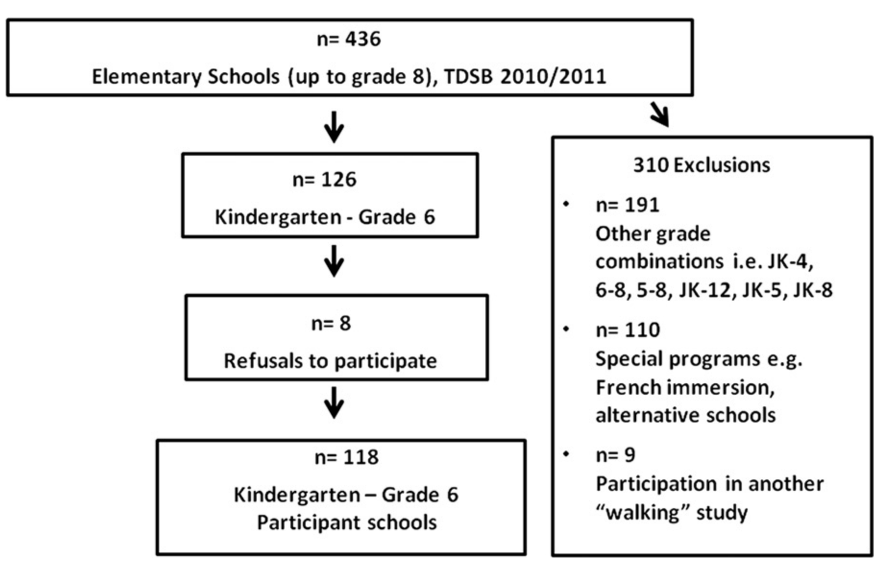

Fig. 1. Flowchart of school participation.

Table 2
Unadjusted incident rate ratios (95% CI) for candidate variables (p ≤ .2) for multivariate modeling.

Variable description	Unadjusted IRRs (95% CI)
Outcome	
Proportion walking to school[a,1]	–
Natural environment	
Poor weather (rain or cold) [c,5]	0.93 (0.85, 1.02)
Built environment	
Density	
School boundary level	
Child population (#)/1000 m^2 [b,2]	1.46 (1.29, 1.65)
Total population (#)/1000 m^2 [b,2]	1.03 (1.02, 1.04)
Diversity	
School boundary level	
Recreational facilities (#)/km^2 [b,3]	1.03 (1.00, 1.05)
Commercial land use area/boundary[a,4]	1.81 (1.07, 3.05)
Industrial land use area/boundary[a,4]	0.65 (0.41, 1.03)
Institutional land use area/boundary[a,4]	1.73 (0.96, 3.11)
Design	
School level	
School crossing guard observed[c,5]	1.12 (1.03, 1.21)
Double parking[c,5]	0.94 (0.87, 1.02)
School boundary level	
Other schools within school boundary (#)[c,6,7]	1.05 (0.98, 1.13)
Crossing guard (#)/km roads[b,3]	2.03 (1.39, 2.97)
Intersection (#)/km roads[b,3]	1.04 (1.02, 1.06)
Pedestrian crossover (#)/km roads[b,3]	1.88 (1.36, 2.59)
Traffic light (#)/km roads[b,3]	1.28 (1.13, 1.46)
Urban area[c,3]	1.12 (1.03, 1.22)
Social environment	
School level	
Total school population[b,6]	1.03 (1.01, 1.06)
New immigrants (≤5 years)[a,6]	2.14 (1.39, 3.29)
Primary language other than English[a,6]	1.20 (1.03, 1.40)
School LOI[b,6]	1.26 (1.10, 1.45)
At below LICO cut-off (school DA)[a,2]	1.72 (1.21, 2.45)

and scootering) was 1.7%. On average, 31% of children arrived by car. Previous population-based national and local Canadian surveys reported 50–55% of children walking to school (Buliung et al., 2009; Cragg et al., 2006). The higher proportions in this study were likely due to sampling children within 1.6 km of schools, whereas previous estimates were not restricted to children living within walking distance. Observed proportions were also higher than those in Australia and the U.S., where approximately 48% of children living within walking distance reported walking to school (Martin et al., 2007; Salmon et al., 2007).

Strong associations with walking were found for child population density and traffic lights, which validated previous findings (Braza et al., 2004; Bringolf-Isler et al., 2008; Mitra et al., 2010b; Salmon et al., 2007; Timperio et al., 2006). In addition to the strong positive association found between walking and school crossing guards, there was evidence of crossing guards acting as an effect modifier between the environment and walking which has not been previously reported. With a school crossing guard present, other built and social environmental factors had less impact on walking which has important implications for potential interventions. Although road design features may be more easily modified in existing neighborhoods than those related to population density and land use, roadway modification can be a highly contested, politicized process. The process to install crossing guards is much simpler in Toronto, and involves a reported need by the community to the Toronto Police, followed by an assessment of the location. If the presence of school crossing guards overrides other negative effects of the built and social environments on walking, adding crossing guards may a feasible and effective method to increase walking proportions.

Table 3
Correlates of walking to school in adjusted analysis (IRR = incident rate ratio (IRR, 95% CI = confidence interval).

	Variable	Adjusted IRR (95% CI)
Built environment	Child population (#)/1000 m^2	1.36 (1.21, 1.53)
Density		
Design	Pedestrian crossovers (#)/km roads	1.32 (1.01, 1.72)
Design	Traffic lights (#)/km roads	1.19 (1.07, 1.32)
Design	Intersections (#)/km roads	1.03 (1.01, 1.05)
Design	School crossing guard	1.14 (1.07, 1.21)
Social environment	Primary language other than English	1.20 (1.05, 1.36)
Natural environment	Poor weather	0.93 (0.87, 0.99)

Table 4
Correlates of walking to school in adjusted analysis stratified by presence of school crossing guard (IRR = incident rate ratio, 95% CI = confidence interval).

	Variable	Adjusted IRR (95% CI)	
		School crossing guard not present	School crossing guard present
		(n = 73)	(n = 45)
Built environment	Child population (#)/1000 m^2	1.29 (1.10, 1.52)	1.41 (1.23, 1.61)
Density			
Design	Pedestrian crossovers (#)/km roads	1.42 (0.98, 2.06)	1.21 (0.89, 1.66)
Design	Traffic lights (#)/km roads	1.29 (1.11, 1.51)	1.06 (0.95, 1.19)
Design	Intersections (#)/km roads	1.04 (1.02, 1.06)	1.00 (0.98, 1.02)
Social environment	Primary language other than English (school)	1.27 (1.05, 1.53)	1.13 (0.98, 1.30)
Natural environment	Poor weather	0.87 (0.80, 0.95)	1.06 (0.97, 1.16)

Although results were less significant for pedestrian crossovers and intersection design features, the effect size of pedestrian crossover was high with an IRR = 1.32 (95% CI: 1.01, 1.72). This feature requires further investigation as it has rarely been addressed and generally is combined with other crossing features (de Vries et al., 2010). Several other studies have also reported a positive relationship between intersections and walking, either alone or when combined with low traffic volume (Giles-Corti et al., 2011; Greene and Daniel, 2009; Kerr et al., 2006; Schlossberg et al., 2006; Trapp et al., 2012).

Null results were found for several design and land use diversity features and observed walking. Although higher road classification (Greene and Daniel, 2009; Panter et al., 2010; Timperio et al., 2006), traffic volume (Giles-Corti et al., 2011; Kweon et al., 2006; Salmon et al., 2007; Trapp et al., 2012) and speed (Kweon et al., 2006; McMillan, 2007) have been associated with less reported walking, other studies using reported outcomes have also reported null results (Bringolf-Isler et al., 2008; Mitra and Buliung, 2012). No association was found with traffic calming which has been associated with more reported walking (de Vries et al., 2010; Panter et al., 2010). Parks and recreation facilities were not associated with observed walking; however, positive associations with reported walking have been identified in the literature (Kerr et al., 2007; Zhu et al., 2011). Finally, although some studies have reported similar null results between land use diversity and walking to school (Ewing et al., 2004; Greene and Daniel, 2009; Mitra et al., 2010a; Panter et al., 2010; Yarlagadda and Srinivasan, 2008), others have reported positive associations (Kerr et al., 2006; McMillan, 2007; Rosenberg et al., 2009). Further validation of these relationships is required using observational data.

The proportion of children whose primary language was other than English had a strong association with walking. Although several studies have found small independent effects of ethnicity on walking (Kerr et al., 2007; McDonald, 2008; Schlossberg et al., 2006), there is little research investigating cultural associations with active school transportation. Mixed findings have been reported regarding walking to school and SES (Davison et al., 2008; Sirard and Slater, 2008). Neither the student level nor the school geographic level SES variables were significant in this analysis.

Limitations

This was an ecological study and individual level information was unavailable. Car ownership and distance to school, two important walking correlates, were not included (DiGuiseppi et al., 1998; Pont et al., 2009). Distance was unlikely to have had a large influence on results, as children included in the walking proportions likely lived within walking distance of the school, as defined by TDSB transportation policy (TDSB, 2005). Child population density and intersection density (an indicator of route directness) were also included as proxies for distance, similar to other studies (Braza et al., 2004; Gallimore et al., 2011; McDonald, 2008). The lack of individual-level data also prohibited analysis of family characteristics which may affect choices regarding school transportation. For example, more active families may choose to live in more walkable neighborhoods, which may be reflected in their modes of school transportation.

Walking was assessed at the school level, whereas built environment features were quantified at the school attendance boundary level. School attendance boundaries were selected as the unit of analysis, as these are most relevant to policy makers at TDSB. The application of school walking proportions to the whole school boundary was relevant, as attendance boundaries generally were within 1.6 km walking distance of the school.

This study only looked at travel to school; however in Toronto, more children walk home from school in the afternoon than walk to school in the morning (Buliung et al., 2009). Therefore, the estimated walking proportions are conservative. Different built environment characteristics are also relevant at the home, route and school level and on the trip to and from school (Mitra et al., 2010a,b; Panter et al., 2010; Wong et al., 2011). Individual home and route characteristics could not be assessed given the ecological nature of the data. Results generally confirmed previous null findings of the effect of school level characteristics and walking (Panter et al., 2010), with the only significant characteristic being the presence of a school crossing guard.

In this study, only objectively measured built environment features were assessed. Parent or child perceptions of the built environment are also important when explaining walking behavior in children, as ultimately, together they make decisions regarding school transportation mode (Kerr et al., 2006; McMillan, 2005; Timperio et al., 2006). The use of both objective measurements together with perceptions of the traffic environment has been recommended, as these measures can differ (Pont et al., 2009; Wong et al., 2011). Future work is planned to incorporate parent perceptions of the built environment and traffic danger along with the objective measures presented in this analysis.

Strengths

This study was the first to implement a large scale collection of objective observational counts of walking to school, together with objective built environment data from city databases and field surveys. The strengths of this study included the objective observational outcome data and the generalizability of results. The large sample represented virtually all regular program JK-6 schools in Toronto and results are likely generalizable to other regular program elementary schools in Toronto. Finally, this was the first time objective parcel level land use data that were used in a study of children's active transportation to school in Toronto.

Conclusion

To summarize, average walking proportions to school in Toronto were high, with large variability between schools. Direct observation confirmed associations between walking and child population density, and with several specific roadway design features. No association was found between walking to school and land use diversity, indicating that land use, while important for adult walking, may not be as important for children. Of particular interest was the association between school crossing guards and walking, and their modifying effect on reducing the influence of other roadway features on walking. The addition of school crossing guards may be a feasible and effective method of increasing walking proportions. These results may have important implications for policies regarding walking promotion around schools.

Conflict of interest

The authors declare that there are no conflicts of interest.

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References

Agresti, A., 2007. An Introduction to Categorical Data Analysis, 2nd ed. John Wiley & Sons, Inc., Hoboken, New Jersey.
Braza, M., Shoemaker, W., Seeley, A., 2004. Neighborhood design and rates of walking and biking to elementary school in 34 California communities. Am. J. Health Promot. 19, 128–136.
Bringolf-Isler, B., Grize, L., Mäder, U., Ruch, N., Sennhauser, F.H., Braun-Fahrländer, C., 2008. Personal and environmental factors associated with active commuting to school in Switzerland. Prev. Med. 46, 67–73.
Buliung, R.N., Mitra, R., Faulkner, G., 2009. Active school transportation in the Greater Toronto Area, Canada, an exploration of trends in space and time (1986–2006). Prev. Med. 48, 507–512.
Cervero, R., Kockelman, K., 1997. Travel demand and the 3Ds: density, diversity, and design. Transp. Res. D: Transp. Environ. 2, 199–219.
Chatterjee, S., Hadi, A., 2006. Regression Analysis by Example. John Wiley & Sons, New Jersey.
City of Toronto, 2001. Building the New City of Toronto: Final Three Year Status Report on Amalgamation, January 1998–December 2000, 2013, Toronto, Canada.
Cragg, S., Cameron, C., Craig, C., 2006. 2004 National Transportation Survey, Ottawa, ON. Canadian Fitness and Lifestyle Research Institute.
Davison, K.K., Werder, J.L., Lawson, C.T., 2008. Children's active commuting to school: current knowledge and future directions. Prev. Chron. Dis. 5, A100.
de Vries, S.I., Hopman-Rock, M., Bakker, I., Hirasing, R.A., van Mechelen, W., 2010. Built environmental correlates of walking and cycling in Dutch urban children: results from the SPACE study. Int. J. Environ. Res. Public Health 7, 2309–2324.
DiGuiseppi, C., Roberts, I., Li, L., Allen, D., 1998. Determinants of car travel on daily journeys to school: cross sectional survey of primary school children. BMJ 316, 1426–1428.
Donroe, J., Tincopa, M., Gilman, R.H., Brugge, D., Moore, D.A.J., 2008. Pedestrian road traffic injuries in urban Peruvian children and adolescents: case control analyses of personal and environmental risk factors. PLoS ONE 3, e3166.
Ewing, R., Schroeer, W., Greene, W., 2004. School location and student travel: analysis of factors affecting mode choice. Transp. Res. Rec. 2004, 55–63.
Falb, M.D., Kanny, D., Powell, K.E., Giarrusso, A.J., 2007. Estimating the proportion of children who can walk to school. Am. J. Prev. Med. 33, 269–275.
Frank, L.D., Andresen, M.A., Schmid, T.L., 2004. Obesity relationships with community design, physical activity, and time spent in cars. Am. J. Prev. Med. 27, 87–96.
Gallimore, J.M., Brown, B.B., Werner, C.M., 2011. Walking routes to school in new urban and suburban neighborhoods: an environmental walkability analysis of blocks and routes. J. Environ. Psychol. 31, 184–191.
Giles-Corti, B., Wood, G., Pikora, T., et al., 2011. School site and the potential to walk to school: the impact of street connectivity and traffic exposure in school neighborhoods. Health Place 17, 545–550.
Greene, J., Daniel, D., 2009. The Built Environment, Neighborhood Safety, and Physical Activity Among Low Income Children, Portland. Oregan, Oregon Transportation Research and Education Consortium (OTREC).
Hosmer, D.W., Lemeshow, S., 2004. Applied Logistic Regression. Wiley-Interscience, New York, NY.

Kerr, J., Rosenberg, D., Sallis, J.F., Saelens, B.E., Frank, L.D., Conway, T.L., 2006. Active commuting to school: associations with environment and parental concerns. Med. Sci. Sports Exerc. 38, 787–794.
Kerr, J., Frank, L., Sallis, J., Chapman, J., 2007. Urban form correlates of pedestrian travel in youth: differences by gender, race-ethnicity and household attributes. Transp. Res. D: Transp. Environ. 12, 177–182.
Kweon, B.S., Woo-Hwa, S., Folzenlogen, R., Jun-Hyun, K., 2006. Children and Transportation: Identifying Environments that Foster Walking and Biking to School. Texas Transportation Institute, College Station, Texas.
Larsen, K., Gilliland, J., Hess, P., Tucker, P., Irwin, J., He, M., 2009. The influence of the physical environment and sociodemographic characteristics on children's mode of travel to and from school. Am. J. Public Health 99, 520–526.
Lin, J.-J., Chang, H.-T., 2010. Built environment effects on children's school travel in Taipai: independence and travel mode. Urban Stud. 47, 867–889.
Marler, N., Montgomery, R., 1993. Urban road Traffic Surveys: Overseas Road Note 11. Transport Research Laboratory, Berkshire, United Kingdom.
Martin, S.L., Lee, S.M., Lowry, R., 2007. National prevalence and correlates of walking and bicycling to school. Am. J. Prev. Med. 33, 98–105.
McDonald, N.C., 2007. Active transportation to school: trends among U.S. schoolchildren, 1969–2001. Am. J. Prev. Med. 32, 509–516.
McDonald, N.C., 2008. Children's mode choice for the school trip: the role of distance and school location in walking to school. Transportation 35, 23–35.
McMillan, T.E., 2005. Urban form and a child's trip to school: the current literature and a framework for future research. J. Plan. Lit. 19, 440–456.
McMillan, T.E., 2007. The relative influence of urban form on a child's travel mode to school. Transp. Res. A Policy Pract. 41, 69–79.
Mitra, R., Buliung, R., 2012. Built environment correlates of active school transportation: neighborhood and the modifiable areal unit problem. J. Transp. Geogr. 20, 51–61.
Mitra, R., Buliung, R., Faulkner, G., 2010a. Spatial clustering and the temporal mobility of walking school trips in the Greater Toronto Area, Canada. Health Place 16, 646–655.
Mitra, R., Buliung, R., Roorda, M.J., 2010b. The built environment and school travel mode choice in Toronto, Canada. Transp. Res. Rec. 2156, 150–159.
Panter, J.R., Jones, A.P., Van Sluijs, E.M.F., Griffin, S.J., 2010. Neighborhood, route, and school environments and children's active commuting. Am. J. Prev. Med. 38, 268–278.
Pont, K., Ziviani, J., Wadley, D., Bennett, S., Abbott, R., 2009. Environmental correlates of children's active transportation: A systematic literature review. Health Place 15, 849–862.
Rosenberg, D., Ding, D., Sallis, J.F., et al., 2009. Neighborhood Environment Walkability Scale for Youth (NEWS-Y): reliability and relationship with physical activity. Prev. Med. 49, 213–218.
Saelens, B.E., Handy, S.L., 2008. Built environment correlates of walking: a review. Med. Sci. Sports Exerc. 40, S550–S566.
Saelens, B.E., Sallis, J.F., Frank, L.D., 2003. Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures. Ann. Behav. Med. 25, 80–91.
Salmon, J., Salmon, L., Crawford, D.A., Hume, C., Timperio, A., 2007. Associations among individual, social, and environmental barriers and children's walking or cycling to school. Am. J. Health Promot. 22, 107–113.
Schlossberg, M., Greene, J., Phillips, P.P., Johnson, B., Parker, B., 2006. School trips: effects of urban form and distance on travel mode. J. Am. Plan. Assoc. 72, 337–346.
Shay, E., Spoon, S., Khattak, A., 2003. Walkable Environments and Walking Activity: Final Report, 2013, Chapel Hill, NC.
Sirard, J.R., Slater, M.E., 2008. Walking and bicycling to school: a review. Am. J. Lifestyle Med. 2, 372–396.
Sirard, J.R., Ainsworth, B.E., McIver, K.L., Pate, R.R., 2005. Prevalence of active commuting at urban and suburban elementary schools in Columbia, SC. Am. J. Public Health 95, 236–237.
Statistics Canada, I. S. D., 2009. Low Income Cut-offs for 2008 and Low Income Measures for 2007. Statistics Canada, Ottawa, Canada.
TDSB, 2005. Transportation of Students, Toronto, Canada.
TDSB, 2011. The 2011 Learning Opportunities Index: Questions and Answers, Toronto, Canada.
Timperio, A., Ball, K., Salmon, J., et al., 2006. Personal, family, social, and environmental correlates of active commuting to school. Am. J. Prev. Med. 30, 45–51.
Trapp, G.S.A., Giles-Corti, B., Christian, H.E., et al., 2012. Increasing children's physical activity: individual, social, and environmental factors associated with walking to and from school. Health Educ. Behav. 39 (2), 172–182.
Wong, B.Y.-M., Faulkner, G., Buliung, R., 2011. GIS measured environmental correlates of active school transport: a systematic review of 14 studies. Int. J. Behav. Nutr. Phys. Act. 8, 39.
Yarlagadda, A.K., Srinivasan, S., 2008. Modeling children's school travel mode and parental escort decisions. Transportation 35, 201–218.
Zhu, X., Lee, C., Kwok, O.M., Varni, J.W., 2011. Context-specific correlates of walking behaviors to and from school: do they vary across neighborhoods and populations? J. Phys. Act. Health 8, S59–S71.