There's No Such Thing as Bad Weather, Just the Wrong Clothing: Climate, Weather and Active School Transportation in Toronto, Canada

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ABSTRACT

Objective: Climatic conditions may enable or deter active school transportation in many North American cities, but the topic remains largely overlooked in the existing literature. This study explores the effect of seasonal climate (i.e., fall versus winter) and weekly weather conditions (i.e., temperature, precipitation) on active travelling to school across different built and policy environments.

Methods: Home-to-school trips by 11-12-year-old children in the City of Toronto were examined using data from the 2006 Transportation Tomorrow Survey. Binomial logistic regressions were estimated to explore the correlates of the choice of active (i.e., walking) versus non-active (i.e., private automobile, transit and school bus) mode for school trips.

Results: Climate and weather-related variables were not associated with choice of school travel mode. Children living within the sidewalk snow-plough zone (i.e., in the inner-suburban neighbourhoods) were less likely to walk to school than children living outside of the zone (i.e., in the inner-city neighbourhoods).

Conclusion: Given that seasonality and short-term weather conditions appear not to limit active school transportation in general, built environment interventions designed to facilitate active travel could have benefits that spill over across the entire year rather than being limited to a particular season. Educational campaigns with strategies for making the trip fun and ensuring that the appropriate clothing choices are made are also warranted in complementing built environment modifications.

Key words: Climate; weather; school travel; walking; built environment

La traduction du résumé se trouve à la fin de l'article.

Can J Public Health 2012;103(Suppl. 3):S35-S41.

Children who walk or cycle for school transportation tend to be more physically active overall than those who use other travel modes.¹ Policy and program initiatives in North America have focused on active school transportation (AST), i.e., walking and cycling, as a means to increase physical activity levels among children and youth, and in the longer term, to reverse the current trend of increasing obesity rates. This policy concern is matched by an emerging literature that has explored the barriers and correlates of active school transportation.² Much of the recent literature considers the potential influence of travel distance and the neighbourhood environment on AST uptake.³⁻⁶

For many North American cities that have marked seasonal variation in climate, weather conditions are popularly identified as enablers or barriers to participation in outdoor physical activity, including AST. For example, a study that analyzed data from a consumer styles survey in the US revealed that 18.6% of parents identified bad weather as a barrier to their children (5-18 years) walking to or from school at least once per week.⁷ In Canada, parents who continued to drive their children to school after a School Travel Planning intervention most often cited weather (21.0%) as the reason for doing so.⁸

However, it is not clear from such North American evidence whether the seasonal climate (e.g., summer, fall and winter) and short-term weather conditions related to climatic variations (e.g., temperature, rain, snow) do influence decision-making behaviour about school travel or whether perhaps these natural conditions are

used to externalize the reason for driving. The actual effects of seasonal climate and objectively measured weather conditions associated with these seasonal climates remain largely overlooked in the school transportation literature. Existing evidence on the association between climatic conditions and active travel is limited and inconclusive. For example, Sirard et al.⁹ studied rates of active travel among students going to eight elementary schools in Columbia, South Carolina, US, and found no association between weather conditions, temperature and the number of students actively travelling (walking and cycling) to school. Robertson-Wilson et al.¹⁰ studied students from 76 high schools in Ontario; season of the year (summer, fall and winter), average weekly temperature and weekly precipitation were not associated with AST. In Norway, where there are extreme differences in weather conditions between the summer and winter months, the number of children walking to and from school actually increases in winter (24% in the fall to 65% in the winter) as a result of a decline in cycling during that season.¹¹

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Acknowledgements: This research was funded by the Built Environment, Obesity and Health Strategic Initiative of the Heart and Stroke Foundation and the Canadian Institutes of Health Research. The first author wishes to acknowledge support from the Natural Sciences and Engineering Research Council, Canada.

Conflict of Interest: None to declare.

Figure 1. Study area – City of Toronto

Data: Environment Canada,¹⁴ City of Toronto.¹⁵

Seasonal climate and weather conditions may have received less attention in the current literature because these natural conditions are non-modifiable. However, there are two important reasons why their effects on school travel outcome should be explored. First, if climate and weather conditions have an important influence on school travel behaviour, then expensive public investments leading to improvements in the built environment can only produce limited benefits, perhaps only by improving walking rates in months when weather conditions are generally good. This should be an important consideration before making such investments. Second, if climate and weather conditions do not have an important influence, then there is a need for more focused interventions that target households situated within a walkable distance from school throughout the school year and that are tailored appropriately for each season.

Within this context, this study explored the effects of seasonal climate and objectively measured weather conditions on children's AST uptake in the City of Toronto. The potential role of snow-clearing policy was also taken into account. To our knowledge, this is the first study to rigorously examine climate-related effects on children's school travel mode in a large North American city with marked seasonal variation in climatic conditions.

Study design

The school transportation behaviour of children 11-12 years old in the City of Toronto was examined. The primary hypothesis of the paper was that once the variations in household socio-economic characteristics and the travel distance are taken into account, the effect of seasonal climate and related weather conditions on active school travel, particularly walking, would be minimal.

Study area

Toronto is the largest city in Canada, with a population of over 2.5 million.¹² The city is situated in a continental climate zone (Köppen climate classification: Dfa).¹³ In 2006, the mean February tempera-

ture in Toronto was -2.4°C (minimum temperature recorded in 2006 was -13.1°C). In contrast, the mean temperatures in July and October were 23.4°C and 9.7°C respectively.¹⁴ Total precipitation in 2006 was 957.1 mm, which occurred mostly in the summer and winter months. The city also has different snow management policies for its inner-city and inner-suburban neighbourhoods, thanks to the legacy of a political and geographic amalgamation in 1998 (Figure 1). The 2000 Snow Plan requires owners of inner-city properties to clear sidewalks of snow and ice within 12 hours after a snowfall. In contrast, inner-suburban residents of Toronto continue to enjoy publicly funded, mechanical sidewalk clearing services, as they did before the amalgamation.¹⁵

Travel data

This study uses school travel data from the 2006 Transportation Tomorrow Survey (TTS). The TTS is a repeated cross-sectional survey of travel behaviour in southern Ontario and covers a 5% sample of all households in the study area.¹⁶ The 2006 TTS data were collected for a randomly selected weekday in fall or winter; an adult household member proxy reported travel data (e.g., origin/destination of trips, trip start time, purpose, primary travel mode) for all trips by household members aged 11 years and older, associated with the day before the interview. For this study, all home-to-school trips between the 6h00-9h30 time interval ($n=2,520$) were extracted. Only the students who travelled to public and Catholic schools were included; these students are expected to attend schools that are closest to their residential locations. The school trips were made between September 2006 and January 2007. School travel mode was determined on the basis of the proxy reported data on primary mode of travel.

Socio-economic and travel distance data

Household socio-demographic information and the distance between home and school locations were used as control variables

Table 1. Description of Variables and Summary Statistics

	% (n=1992)	Mean (SD)
Control Variables		
Age: The child was 12 years old (reference: 11 years).	52.2	
Sex: The child was a male (reference: female).	52.8	
Number of Children: Number of school-age children below driving age (4-15 years) in the household.		1.92 (0.84)
Single-adult Household: There was only one adult household member (>17 yrs) in the household (reference: >1 adults in a household).	12.4	
Vehicles per Licensed Driver: Number of vehicles in the household per licensed driver.		0.72 (0.42)
Distance: Minimum travel distance (i.e., shortest path using a street network) between home and school (km).		1.05 (0.69)
Low-income Neighbourhood:* The child's residential neighbourhood was a low-income neighbourhood, i.e., median household income was <CAD \$39,400. Median household income was estimated by taking a median of the census dissemination area median household incomes (reference: not a low-income neighbourhood).	16.3	
Climate and Weather Variables		
Seasonal Climate:† (reference: Fall AND outside of the sidewalk snow-plough zone).		
Winter AND outside of the sidewalk snow-plough zone.	8.9	
Fall AND inside of the sidewalk snow-plough zone.	54.8	
Winter AND inside of the sidewalk snow-plough zone.	12.9	
Temperature (6-9:30 am):‡ Weekly average of hourly temperatures (°C) between the 06h00-09h30 time interval.		5.08 (5.64)
Max Temperature: Weekly average of daily maximum temperatures (°C).‡	9.70 (5.91)	
Min Temperature: Weekly average of daily minimum temperatures (°C).‡		2.52 (5.66)
Mean Temperature: Weekly average of daily mean temperatures (°C).‡		6.13 (5.73)
Precipitation Days:‡ Number of days in a week with precipitation.		2.16 (1.20)
Average Precipitation:‡ Average precipitation in a week (mm).‡		2.30 (3.11)
Snow Days:‡ (reference: residence located outside of the sidewalk snow-plough zone AND no snow during the week).		
Residence located outside of the sidewalk snow-plough zone AND ≥1 days of snow during the week.	9.1	
Residence located within the sidewalk snow-plough zone AND no snow during the week.	58.7	
Residence located within the sidewalk snow-plough zone AND ≥1 days of snow during the week.	8.9	

Note: Variables in italics were excluded from the multivariate logistic regression specifications.

* Individual household income data were not available. Median household income was calculated using 2006 population census data from Statistics Canada. Average household size for the sample was 4.3 (SD=1.28). In a large metropolitan area such as Toronto (i.e., population >500,000), the low income cut-off, defined by Statistics Canada, was CAD \$39,399 for a four-member household.¹⁷

† Fall: Travel data were collected between September 10 and December 17, 2006; Winter: Travel data were collected in January 2007.

‡ Weather data were averaged/aggregated for weekdays only; holidays and weekends were excluded.¹⁴

(Table 1). The socio-demographic data were taken from the 2006 TTS. However, the TTS did not provide information on household income. As a result, the median household income data from the population census of Canada were aggregated to identify the low-income neighbourhoods. Shortest path network distance (i.e., minimum travel distance) between home and school locations of a child was computed using Toronto's street network file (DMTI Can-Map® RouteLogistics file, version 2007.3).

Climate and weather data

School trip data were collected between September 2006 and January 2007. These data were categorized into fall (78.2% of total trips; data collected between September 10 and December 17, 2006) and winter (21.8% of total trips; data collected in January 2007) trips, in order to capture potentially climatically moderated differences in travel behaviour. In addition, seven objectively measured weather-related variables were computed for three weather stations located inside and near the City of Toronto (Toronto City, Toronto Lester B. Pearson Airport and Toronto Buttonville Airport), using data from Environment Canada customized climate search (Figure 1).¹⁴ Weekly average for each weather variable was used, computed from an average of all school days in the week of data collection (Table 1). The 2006 TTS did not provide information on the date of travel. For each household, the nearest weather station (straight line distance) was identified to determine the weekly weather condition for that household. In order to account for Toronto's snow management policy, households located inside and outside of the sidewalk snow-plough zone were identified.

Statistical analysis

Binomial logistic regressions were estimated to explore the correlates of active (i.e., walking) versus non-active (i.e., private auto-

mobile, public transit or school bus) mode choice for school trips. The effect of weather on walking and cycling are potentially different; these two modes also have different costs of access (i.e., equipment, safety) and infrastructure requirements. In our sample, only 16 children cycled to school and, because of this, cycling trips were excluded from further statistical analysis. In addition, we assumed that beyond a distance of 3.2 km (2 miles) the transportation choices become primarily limited to motorized modes.¹⁸ As a result, this study only explored the travel behaviour of children living within 3.2 km from their schools. Adjusting for missing data and outliers, the final dataset included 1,992 home-to-school trips. The results are presented in terms of odds ratios ($OR = \exp(\hat{\beta}_i)$), which demonstrates the relation between a variable i and the odds of active travel. Statistical analyses were performed with R® version 2.9.0.

The bivariate association between active travel and each of the climate and weather-related variables was first examined; effect plots were generated for the variables that demonstrated statistically significant associations. The degree of multi-collinearity across the climate and weather variables was also explored before the multivariate analysis. Not surprisingly, weather conditions (e.g., temperature, precipitation) were highly correlated with seasonal climate (i.e., fall and winter). To overcome this collinearity problem, separate models were estimated to explore the effects of seasonal climate and weekly weather conditions. Some of the weather variables were also highly correlated ($r > 0.9$). Those correlated variables (e.g., Temperature 6-9:30 am, Max temperature, Min temperature, Mean temperature; and Precipitation days, Average precipitation) were entered into the multivariate (i.e., adjusted) model one at a time, and only the ones with strongest association (e.g., Temperature 6-9:30 am; Precipitation days) were included in the final model specification.

Figure 2. Rates of walking and car (i.e., private automobile) trips by distance

RESULTS

Logistic regression models of mode choice were estimated using travel data for 1,992 students aged 11-12 years. The majority (62.7%) walked to school; the other 37.3% travelled by private automobile, school bus or transit (Table 2). Most students (79.8%) lived within 1.6 km (1 mile) of their schools. Of these students, 72.7% walked to school, 17.6% were driven, and 9.7% used school bus or transit as their travel mode.

Table 2 also demonstrates that school transportation mode shares (percentage of total school trips) were not different between fall and winter seasons, suggesting that seasonal climate does not have an influence on mode choice. The rates of walking and car (i.e., private automobile) trips at different travel distances were also compared (Figure 2). Figure 2 indicates that in both fall and winter, more children (with or without caregivers) walked than were driven to school when the household locations were within 1.4 km of school. Not surprisingly, walking rates declined with increased distance, but no systematic variation across seasons was evident. This result suggests that the perception of a “walkable distance” was not different between fall and winter seasons. The model results further confirmed these observations (Table 3). Children in general were less likely to walk within the sidewalk snow-plough zone (i.e., in the inner-suburban neighbourhoods) compared with the areas outside of the zone (i.e., in the inner-city neighbourhoods); seasonal climate (i.e., fall versus winter conditions) was not associated with the likelihood of walking within any of these urban locations.

With regard to weekly weather conditions, the probability of walking was inversely correlated (bivariate) with the number of weekdays with precipitation and the average weekly precipitation (mm) (Figure 3). There was also an association between walking and snow days across the two snow-plough zones. However, most of these correlations disappeared in the multivariate (i.e., adjusted) model. Table 3 suggests that objective measures of weather were not associated with mode choice when household socio-economic characteristics and school travel distance were taken into account.

Table 2. School Travel Mode Share (Percentage of Total School Trips)

	All Seasons (n=1992)	Fall (n=1558)	Winter (n=434)	Chi-square*
Walk	62.7	62.6	62.9	0.06 (p=0.807)
Private automobile	20.5	20.7	19.8	
School bus	9.6	9.5	9.9	
Transit	7.2	7.2	7.4	

* Difference in mode choice distribution between fall and winter seasons; calculated on the basis of the total number of trips.

The only statistically significant variable was “Snow Days”. However, the observed effect relates entirely to the geographic location of the households, similar to our earlier observation related to seasonal climate. The amount of snowfall was not associated with the likelihood of walking.

In addition to children living outside of the sidewalk snow-plough zone (i.e., in the inner-city neighbourhoods), older students and males were more likely to walk to school than the younger students and females (Table 3). The propensity of walking decreased with an increased distance between home and school locations, and with an increased number of vehicles in the households per licensed driver.

DISCUSSION

Our findings indicate that seasonal climate and weekly weather conditions do not appear to be major influencing factors on choice of school travel mode in Toronto. Distance between home and school remained the strongest correlate of travel mode, supporting what has been reported elsewhere.^{19,20} Students living in inner-suburban neighbourhoods walked to school less. Even with the removal of a potential barrier to walking in the winter in the inner-suburban neighbourhoods (i.e., sidewalk snow removal by the City of Toronto), students were still less likely to walk, suggesting consistency in travel mode regardless of season. While the city-run, sidewalk snow plough service remains a political legacy in Toronto’s inner-suburban neighbourhoods, this policy does not facilitate children’s AST uptake.

Table 3. Correlates of Walking to School

	Base Model		Seasonal Climate Model		Weather Conditions Model	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Age						
11 years	1.00		1.00		1.00	
12 years	1.60 (1.28-1.99)	0.000	1.58 (1.26-1.97)	0.000	1.58 (1.26-1.97)	0.000
Sex						
Female	1.00		1.00		1.00	
Male	1.34 (1.08-1.67)	0.008	1.38 (1.11-1.72)	0.004	1.37 (1.10-1.70)	0.005
Number of children	1.08 (0.95-1.24)	0.241	1.09 (0.95-1.25)	0.208	1.09 (0.95-1.25)	0.209
Single-adult household	1.07 (0.77-1.50)	0.681	1.03 (0.74-1.44)	0.865	1.03 (0.73-1.43)	0.879
Vehicles per licensed driver	0.62 (0.48-0.81)	0.000	0.64 (0.49-0.83)	0.000	0.65 (0.50-0.85)	0.001
Distance	0.13 (0.11-0.16)	0.000	0.13 (0.10-0.15)	0.000	0.13 (0.11-0.16)	0.000
Low-income neighbourhood						
No	1.00		1.00		1.00	
Yes	1.24 (0.91-1.68)	0.166	1.23 (0.91-1.67)	0.159	1.21 (0.89-1.65)	0.213
Seasonal climate						
Fall AND outside of the sidewalk snow-plough zone			1.00			
Winter AND outside of the sidewalk snow-plough zone			0.73 (0.46-1.16)	0.183		
Fall AND inside of the sidewalk snow-plough zone			0.57 (0.43-0.75)	0.000		
Winter AND inside of the sidewalk snow-plough zone			0.56 (0.38-0.82)	0.003		
Precipitation days					0.94 (0.84-1.07)	0.362
Temperature (6-9:30 am)					1.03 (0.97-1.09)	0.342
Precipitation days × Temperature (6-9:30 am)					0.99 (0.97-1.01)	0.441
Snow days						
Outside of the sidewalk snow-plough zone AND no snow during the week					1.00	
Outside of the sidewalk snow-plough zone AND ≥1 days of snow during the week					1.06 (0.62-1.82)	0.828
Within the sidewalk snow-plough zone AND no snow during the week					0.64 (0.48-0.86)	0.003
Within the sidewalk snow-plough zone AND ≥1 days of snow during the week					0.71 (0.42-1.20)	0.203
Intercept	12.18 (7.93-18.72)	0.000	17.82 (10.99-28.88)	0.000	16.94 (9.64-29.75)	0.000
-2 [L(0) - L(B)]	646.6		964.0		665.9	
McFadden's ρ^2 (adjusted)	0.24 (0.24)		0.25 (0.25)		0.25 (0.25)	
AIC†	2002.0		1990.6		1994.7	

Note: Variables in **bold** are significant at $\alpha=0.01$.

OR= odds ratios, CI=confidence interval.

† Akaike information criterion.

Figure 3. Effect of weekly weather on walk to school (bivariate logistic regression results)

Note: The dotted lines represent the 95% percentile brackets around the fitted lines.

* Snow Days: A = Outside the sidewalk snow-plough zone and no snow; B = Outside the sidewalk snow-plough zone and ≥1 days of snow during the week; C = Inside the sidewalk snow-plough zone and no snow; D = Inside the sidewalk snow-plough zone and ≥1 days of snow during the week.

In this study, weather variables were based on weekly averages rather than the weather on the day of the school trip. In other words, the variables explored in this study capture the prevalent weekly weather conditions and their potential contribution to the formation of individual travel patterns. We could not examine responses to extreme weather conditions on any given day. Extreme weather may produce short-term changes in mode choice anywhere on the planet for that matter, and for any activity. However,

given the utilitarian necessity of the school trip, it may be that choice of transportation modes for travelling to elementary schools is largely habitual in nature and less influenced by external factors such as the climate and weather unless in those extreme conditions where walking becomes dangerous or extremely difficult. Developed from a qualitative study of parent/child interviews focused on AST in Toronto, a two-stage AST decision-making process was described by Faulkner et al.,²¹ one decision being whether or not the

child needs escorting to/from school and a second decision about mode choice, which is largely influenced by perceptions as to the easiest and most convenient way to travel. Importantly, these initial decisions had developed into routinized behaviour that no longer required a conscious decision-making process. For example, for the parents of children who walked to school, walking remained the most convenient option even in the winter months.²¹ Additionally, others have reported that adults who enjoy exercise²² or who walk for any reasons in and around their neighbourhoods²³ are less likely to mention weather as a barrier. Overall, this again points to the potential stability of choice of school travel mode based on preferences and perceptions of convenience rather than weather per se.

With more extensive sampling during winter and a more rigorous exploration of climate and weather conditions at different travel distances and across different built and policy environments, this study significantly extends existing research on the relation of climate and weather conditions with school travel. However, further research is required to confirm the absence of an association given some limitations of this study. First, there may be some variability between weather conditions at the weather stations and those conditions in close vicinity to the household, although the majority of households were within 10 km of a weather station (mean 8.96±4.03 km). Second, our findings also require replication in other geographic locations in Canada where there is more extreme seasonal variation. Yet local policy should be based upon local evidence, and our results have important implications for promoting active school travel within the Greater Toronto Area, Canada's largest and most culturally diverse metropolitan region. In terms of policy, our results suggest that climate and weather conditions do not have any significant effect on AST in this study location. The results are encouraging for policies directed toward improvements in the built environment to increase rates of walking and physical activity among children. Given that seasonality and short-term weather conditions appear not to limit AST uptake in general, the potentially enormous capital cost of built environment interventions designed to facilitate AST could have benefits that spill over across the entire year rather than being limited to a particular season.

In terms of practice, there is growing interest in initiatives targeting drivers of children from households located within a walkable distance from school.^{8,24} Our findings suggest that seasonal climate and weather should not be actual barriers to AST in Toronto and, moreover, that parents are likely driving their children to school even when the climate is most conducive to supporting AST (e.g., in the spring and fall). For example, in the fall of 2006 (between September and December), 17.6% of all students who lived within 1.6 km of their schools were driven to school, and in the winter of 2007, 17.5% were driven. Educational campaigns to promote winter walking with strategies for overcoming barriers and parental safety concerns, making the trip fun, and ensuring that clothing choices are appropriate, are also warranted in complementing built environment modifications that facilitate active school travel.

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RÉSUMÉ

Objectif : Les conditions climatiques pourraient favoriser ou entraver le transport scolaire actif dans de nombreuses villes d'Amérique du Nord, mais ce sujet est en grande partie inexploré dans la recherche existante. Notre étude porte sur l'effet du climat saisonnier (p. ex., automnal ou hivernal) et des conditions atmosphériques hebdomadaires (température, précipitations) sur le transport scolaire actif dans différents milieux bâtis et environnements politiques.

Méthode : Nous avons examiné les trajets de la maison à l'école d'enfants de 11 et 12 ans vivant à Toronto à l'aide des données du Sondage pour le système de transports de demain de 2006. Des régressions logistiques binomiales ont été estimées pour explorer les

corrélats du choix d'un mode de transport actif (comme la marche) ou non actif (voiture privée, transports en commun, autobus scolaire) pour se rendre à l'école.

Résultats : Les variables liées au climat et à la météo n'étaient pas associées au choix du mode de transport scolaire. Les enfants vivant à l'intérieur de la zone de déneigement des trottoirs (c.-à-d. dans les quartiers de la proche banlieue) étaient moins susceptibles de se rendre à l'école en marchant que les enfants vivant hors de cette zone (c.-à-d. dans les quartiers du centre-ville).

Conclusion : Étant donné que les cycles saisonniers et les conditions atmosphériques de courte durée ne semblent pas limiter le transport scolaire actif en général, les interventions sur le milieu bâti conçues pour faciliter les déplacements actifs pourraient avoir des répercussions positives toute l'année plutôt que de se limiter à une saison particulière. On devrait aussi envisager, pour compléter des modifications au milieu bâti, des campagnes de sensibilisation comportant des stratégies pour rendre le trajet amusant et pour aider les enfants à choisir des vêtements appropriés.

Mots clés : climat; temps; transport scolaire; marche; milieu bâti