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School-travel by public transit: Rethinking active transportation

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ABSTRACT

Background. Walking and cycling to school is a source of physical activity (PA). Little is known about public transit use for travel to school and whether it is a physically active alternative to car use for those who live too far to walk.
Purpose. To describe school-trip characteristics, including PA, across travel modes and to assess the association between PA with walk distance.
Methods. High school students (13.3 ± 0.7 years, 37% female) from Downtown Vancouver wore accelerometers (GT3X+) and global positioning systems (GPS) (QStarz BT-Q1000XT) for 7 days in October 2012. We included students with valid school-trip data ($n = 100$ trips made by $n = 42$ students). We manually identified school-trips and mode from GPS and calculated trip duration, distance, speed, and trip-based moderate-to-vigorous PA (MVPA; min). We assessed between-mode differences and associations using multilevel regression analyses (spring 2014).
Results. Students accrued 9.1 min (±5.1) of trip-based MVPA, which was no different between walk and transit trips ($p = 0.961$). Walking portions of transit trips were similar to walking trips in terms of distance ($p = 0.265$) and duration ($p = 0.493$). Walk distance was associated with MVPA in a dose–response manner.
Conclusions. Public transit use can contribute meaningfully toward daily PA. Thus, school policies that promote active school-travel should consider including public transit.

Introduction

The global physical inactivity crisis is a serious public health concern (Kohl et al., 2012). In Canada, fewer than 1 in 10 children and youth are sufficiently active to enjoy health benefits (Colley et al., 2011). Children and youth who use active travel to school, such as walking and biking, engage in more physical activity (PA) overall than those using motorized modes (Larouche et al., 2014). To inform policy and practice, it is important to quantify PA from the school-trip and to better understand specific trip characteristics (length, duration, route, speed) that may influence PA. A few studies utilized global positioning systems (GPS) and accelerometry to quantify PA during school-travel (Cooper et al., 2010; Klinker et al., 2014; Southward et al., 2012). However, no study has applied these methods to characterize school-trips by public transit (hereafter: 'transit'), despite a handful of previous studies identifying potentially meaningful PA from transit use in this population (Owen et al., 2012; Pabayo et al., 2012). Using transit for school-travel is rare overall in North America (McDonald, 2012), but may be as common as 40% of trips in urban centers such as Toronto (Buliung et al., 2009). Distance to school is the single most consistent barrier to active travel across settings (Wong et al., 2011); therefore, there is a need to identify and characterize alternatives to car travel.

Therefore, the purpose of our paper was two-fold; first, to describe trip characteristics and trip-based PA across different school-travel modes in high school students from Downtown Vancouver (known for excellent walkability and transit access); second, to assess the association between health-related PA with walk distance.

Methods

Sample

We drew data from the ongoing *Active Streets*, *Active People–Junior* study, collected in October 2012 at the only public high school in Downtown Vancouver. We invited students in grades 8–10 to participate;

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$n = 49$ students provided written parental consent and student assent (19% response; 13.3 ± 0.7 years, 37% female). Institutional- and school board ethics committees approved the study.

Protocol and instruments

Trained researchers measured stature (0.1 cm) and body mass (0.1 kg) during physical education classes. We expressed BMI ($kg \cdot m^{-2}$) as age–sex specific percentiles based on World Health Organization (2011) norms (de Onis et al., 2007); we categorized BMI into 'normal-', 'over-weight' or 'obese' based on age–sex specific International Obesity Task Force criteria (Cole et al., 2000).

We fitted each participant with an elastic belt equipped with an accelerometer (GT3X+, ActiGraph LLC, FL; worn over right hip) and GPS unit (QStarz BT-Q1000XT, QStarz International Co. Ltd., Taiwan; recording at 1 s). We provided uniform instructions to wear the belt for the next 7 days and to remove it only for water-based activities (shower, swim) or sleep. We did not ask participants to charge the GPS units in this study.

GPS data processing

We downloaded GPS data (as.csv; QStarz Data Viewer v. 1.1) and removed units (e.g. km/h) and data points with indicators of poor signal ("No Fix") (<0.1%). We created point shapefiles from GPS data in geographic information system software (ArcGIS v. 10.1; Esri Inc., CA)., Using an address locator in GIS based on the *CanMap* street network file (DMTI Spatial) we geocoded home locations based on parent-reported addresses (provided with written informed consent). The geocoded school location, as well as parcel polygons (i.e. property lines), were obtained from the City of Vancouver Open Data catalogue.

School-trip identification

We restricted analyses to school-trips (hereafter: 'trips'), identified as GPS tracks on weekdays that terminated at school before the end of the school day ('to school'), or that originated from school ('from school'). A schematic overview of the manual trip identification method we employed for the current analyses is visualized in Fig. 1. A researcher with local knowledge assessed second-by-second GPS points using the tracking analyst tool (ArcGIS) and coded trips that were ≥30 s duration and ≥100 m. Speeds of ≥1 km/h and distance >0 m of linear movement indicated trip start time; changes from these criteria indicated trip stop time. Trip pauses were identified when speed was <1 km/h and trajectory was no longer linear for ≥1 min. Pauses ≥5 min resulted in two separate trips; in transit trips, longer pauses at transit stops were permitted. Start and stop locations were identified as GPS tracks crossing parcel lines of origins or destinations (i.e. home, school).

Trip mode is typically identified by speed, but there is currently no consensus on criteria. For example, previous studies in young people employed a variety of average speeds to identify walking (1.6–9.6 km/h (Rodriguez et al., 2012), <10 km/h (Dessing et al., 2014), or 1–10 km/h (Klinker et al., 2014)). Our manual method allowed for a more tailored approach and we assigned trip mode based on the overall trip speed trajectory. When GPS points' speeds predominantly were ≥1 km/h and <10 km/h, the mode was coded as 'walking'. If speeds predominantly were ≥10 km/h, the mode was defined as 'car', unless the following criteria would identify a transit trip: some walking at the beginning and/or end of the trip (to a transit stop), a pause (>30 s) between walking and motorized trip segments, the motorized trip segment followed a transit route (verified against shapefile) with frequent pauses during the motorized segment resembling transit stops. Within-trip segments (e.g. walk to bus) were coded by mode and a main mode was assigned

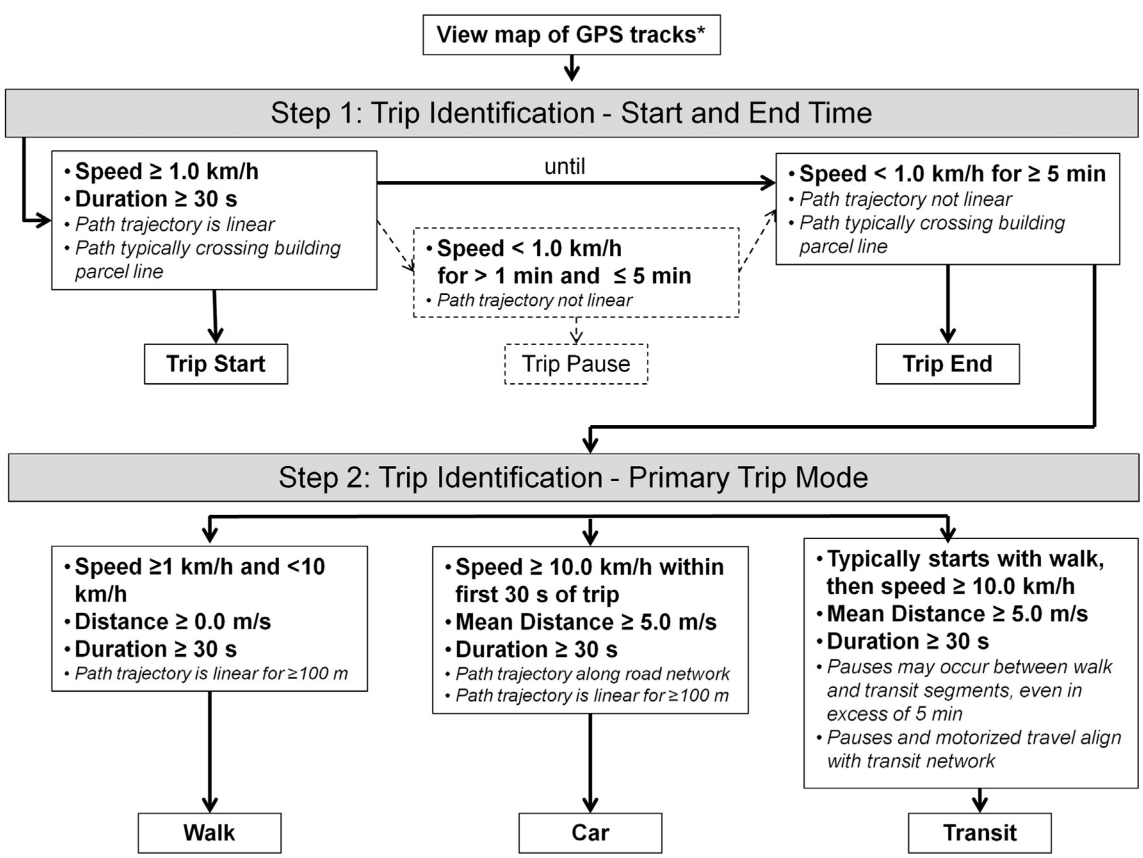

Fig. 1. Flow chart of the manual trip identification method. *We used the 'tracking analyst' tool in ArcGIS (v. 10.1) to map the GPS coordinates in the context of time. Text in italics highlights complimentary verification criteria used by the researcher during the manual trip identification process.

based on the greatest distance traveled. There is potential to misclassify bicycle trips as car trips; however, only one of our research participants indicated that they sometimes cycle to school, but their GPS-trips during the measurement period were clearly all walking trips. The same researcher coded all GPS-trips in this study, but the manual trip identification process in our lab (Fig. 1) yielded 100% inter-rater agreement for trip mode, and an inter-rater difference (bias) for trip-based physical activity of 0.11 min (95% CI 0.01, 0.2).

Daily and trip-based physical activity

We generated a 1 s epoch accelerometry files from the raw.gt3x files using ActiLife v. 6.5.4. (ActiGraph LLC, FL). To describe mean daily PA levels, we scored participants' accelerometry files who met common wear-time criteria (≥3 days (weekday or weekend) with ≥600 min/day wear time, permitting 60 min of ≤2 min of zeros), and then calculated mean daily minutes spent in MVPA (≥2296 CPM; Evenson et al., 2008; all done in ActiLife). A recent study identified the Evenson cut-points' most accurately estimated PA intensities in this age group (Trost et al., 2011).

For trip-based PA estimates, we assumed 100% valid accelerometry data during GPS trips because both monitors were attached to one belt. We created.csv files of 1 s accelerometry data (axis1 or vertical axis) and merged them with GPS trips (trip start and stop, speed, distance, mode) using timestamps (Stata/MP 10.1; StataCorp, LP, TX). We then manually calculated trip duration and estimated trip-based MVPA (Evenson et al., 2008; all done in Stata). We excluded $n = 30$ trips with >15% of the trip distance missing in GPS points between home and school, as this might bias estimates of trip characteristics (missing data due primarily to signal acquisition delay at the beginning of trips).

Statistical analyses

Descriptive sample statistics (individual or trip-based) were calculated as frequencies, means (±SD) or medians (interquartile ranges). We used independent t-tests, chi-square or Mann–Whitney U tests to assess between-sex differences in sample characteristics. We assessed between-mode differences (referent: walk) for trip variables of interests (duration, speed, distance, MVPA) and associations between walk distance and MVPA using multi-level (mixed) regression models to account for multiple trips by students. All analyses were carried out in Stata/MP 10.1 ($p < 0.05$) in spring 2014.

Results

Of 49 students who participated, four had no GPS data (refused or hardware error) and three did not have sufficient GPS data during school-travel, likely a result of the GPS monitors' limited battery life in the current study. Thus, our sample for analysis was 100 school-trips made by 42 students (average rate per student: 2.4 ± 1.7 trips, range: 1–8). There were no differences in sex, age or BMI (all $p > 0.05$) between included and excluded students.

We provide participant characteristics in Table 1. Overall, approximately 1 in 4 students were overweight or obese, comparable to national estimates (Colley et al., 2011). We provide two detailed examples of PA patterns during school-trips in Fig. 2. Panel A shows a continuous bout of PA during a walking trip, whereas Panel B shows the walk-interrupted during transit travel, with bouts of walking bordering the predominantly sedentary wait time and bus travel (Fig. 2). We summarize trip characteristics by mode in Table 2. The few car trips were excluded from further analyses. Compared with walk trips, transit trips were, on average, significantly longer in distance ($\beta = 5.8$ km, 95% CI 4.5–7.1, $p < 0.001$) and duration ($\beta = 19.3$ min, 95% CI 11.9–26.7, $p < 0.001$), but with similar amounts of MVPA ($\beta = -0.1$ min, 95% CI −2.2–2.1, $p = 0.961$). This was due to walking

Table 1
Sample descriptive statistics.

	All	Male	Female
n	42	27 (64%)	15 (36%)
Age (years)	13.8 ± 0.6	13.8 ± 0.6	13.8 ± 0.6
BMI percentile[a]	54.5 ± 34.3	56.6 ± 35.1	50.6 ± 33.8
IOTF weight category[b]			
Normal (incl. under)	30 (71%)	18 (67%)	12 (80%)
Overweight (incl. obese)	12 (29%)	9 (33%)	3 (20%)
Distance to school (km)[c]	1.3 (1.0–2.4)	1.5 (1.0–2.6)	1.2 (0.7–2.1)
Home within school catchment area[d]			
Yes	39 (93%)	24 (89%)	15 (100%)
No	3 (7%)	3 (11%)	0 (0%)
Physical activity[e]			
Intensity (CPM/day)[f]	476.5 ± 207.0	556.6 ± 214.6	327.6 ± 61.3**
Total activity (counts/day)[g]	375,290 ± 142,520	427,627 ± 150,367	278,093 ± 46,309**
MVPA (min/day)[h]	64.3 ± 21.8	72.2 ± 23.0	49.6 ± 7.6**
Meet PA guidelines[i]			
Yes	7 (35%)	7 (54%)	0 (0%)*
No	13 (65%)	6 (46%)	7 (100%)

Data are: mean ± SD, *n* (%), or median (IQR); significant between-sex differences: *$p < 0.05$, **$p < 0.01$; participants were public high school students from Downtown Vancouver, sampled in October 2012.
[a] Body Mass Index (kg·m^{-2}); percentiles calculated based on age–sex specific WHO 2007 reference charts (de Onis et al., 2007).
[b] International Obesity Task Force age–sex specific BMI weight categorisation (Cole et al., 2000).
[c] Shortest distance between residential address (parent-reported) and school along the street network, calculated using geographic information systems software (ArcGIS v. 10.1; Esri Inc., CA).
[d] 4.2 km^2 catchment area, furthest distance to school along street network: 3.0 km.
[e] ActiGraph accelerometry (GT3X+, 1 s epoch), based on ≥3 days with ≥600 min valid wear time ($n = 20$).
[f] Counts (axis1 or vertical axis) Per Minute.
[g] Total activity (sum of axis1 (or vertical axis) counts/day).
[h] Moderate-to-vigorous Physical Activity (≥2296 CPM) (Evenson et al., 2008).
[i] ≥60 min of MVPA/day; missing data: $n = 22$ had insufficient accelerometry data to calculate daily CPM, counts, min of MVPA or meeting of PA guidelines.

portions of transit trips being no different from trips that were solely completed by walking in terms of distance ($\beta = -0.1$ km, 95% CI −0.3–0.01, $p = 0.265$) and duration ($\beta = -1.0$ min, 95% CI −3.8–1.8, $p = 0.493$). Walk distance was positively associated with trip-based MVPA. For every additional ~100 m walked, students accrued an additional one minute of MVPA from school-travel ($\beta = 101.8$ m, 95% CI 92.3–113.4, $p < 0.001$; model based on whole trips, including pauses and trip segments where PA was of light intensity).

Discussion

Our main novel finding was that students who used transit covered a similar distance on foot as students who walked, which resulted in similar and meaningful trip-based PA in both groups. Students accrued on average nine minutes of MVPA during a school-trip. In light of the low levels of PA among young Canadians (Colley et al., 2011), it is noteworthy that walking or using transit twice a day may contribute more than 30% toward recommended daily PA (60 min of MVPA) (World Health Organization, 2011).

Our study is one of only a handful of studies that have combined GPS and accelerometry to objectively quantify trip characteristics and PA specifically from the school-trip (Cooper et al., 2010; Klinker et al., 2014; Southward et al., 2012). A recent similar study in Copenhagen, Denmark, found that students (12 to 14-year-olds) accrued approximately 9–10 min of MVPA during active school-travel (Klinker et al., 2014), similar to our findings. However, they did not report MVPA during transit use. Two related papers (Cooper et al., 2010; Southward et al., 2012) utilized GPS for mapping purposes of school-trips and they reported total MVPA during school-travel windows (8–9 am & 3–5 pm). One study (Bristol, UK) (Southward et al., 2012) reported

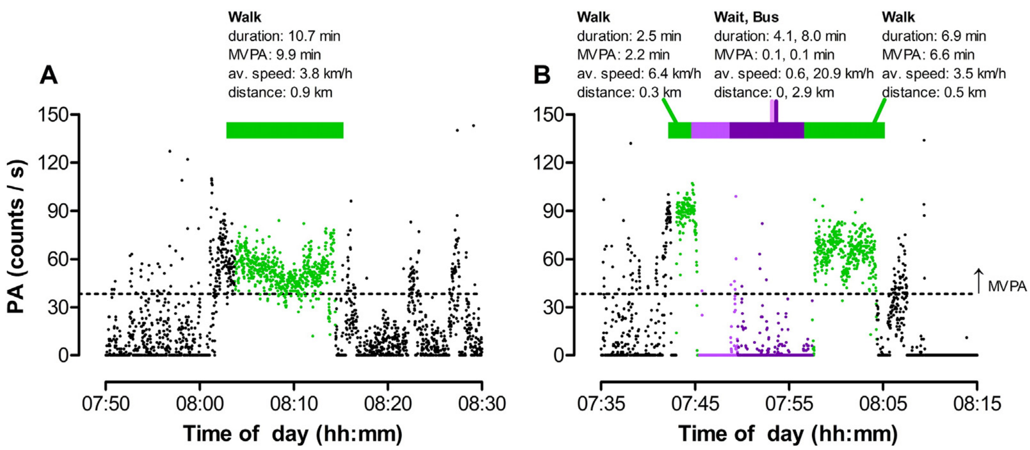

Fig. 2. Sample physical activity patterns in walking and public transit school-trips. Physical activity (PA) intensity (GT3X+, 1 s epoch) during a walking trip to school (Panel A) and a transit trip to school (Panel B) as identified by GPS (QStarz, 1 s). Note the sustained bout of PA of predominantly moderate-to-vigorous intensity (MVPA) (Evenson et al., 2008) during walking portions of both the walk and transit trip. Motorized travel during the transit trip (including the wait time at the transit stop) was predominantly sedentary time; however, accelerometry data during motorized travel should be interpreted with caution. Participants were public high school students from Downtown Vancouver, sampled in October 2012.

approximately 10–12 min of MVPA during school-travel (11 to 12-year-olds). The other study (11-year-olds; London, UK) (Cooper et al., 2010) reported only ~5–6 min of MVPA during the 8–9 am window. Distances to school were comparable to our sample, but a much higher MVPA cut-point was used (≥3200 vs. ≥2296 counts per minute) and this may explain the lower levels of MVPA reported in that study.

Table 2
School trip characteristics by travel mode.

	All	Walk	Transit	Car[†]
n (trips)	100	36	56	8
Type: to/from school	38/62	12/24	24/32	2/6
Complete trip				
Trip characteristics[a]				
Distance (km)	3.0 (1.1, 3.7)	0.9 (0.6, 1.2)	3.4 (3.1, 10.8)*	3.5 (2.4, 6.1)
Duration (min)	25.7 ± 18.0	14.4 ± 9.6	33.2 ± 17.9*	23.4 ± 22.0
Speed (km/h)	6.9 ± 3.9	3.4 ± 0.7	8.2 ± 2.5*	13.9 ± 5.7
Physical activity[b]				
Intensity (CPM/trip)[c]	2087 ± 1279	3351 ± 1141	1416 ± 474*	1094 ± 1383
Total activity (counts/trip)[d]	41,605 ± 23,560	42,366 ± 20,015	44,113 ± 24,181	20,626 ± 26,394
MVPA (min/trip)[e]	9.1 ± 5.1	9.5 ± 4.6	9.5 ± 5.1	4.2 ± 5.6
Walking portions of trip				
Trip characteristics[a]				
Distance (km)	0.7 (0.5, 1.1)	0.9 (0.6, 1.2)	0.7 (0.5, 0.9)	0.1 (0.0, 0.4)
Duration (min)	11.3 ± 6.7	12.6 ± 6.5	11.6 ± 6.4	3.2 ± 3.8
Speed (km/h)	3.5 ± 1.4	3.5 ± 0.6	3.4 ± 0.8	2.4 ± 2.0
Physical activity[b]				
Intensity (CPM/trip)[c]	3372 ± 1043	3486 ± 1043	3469 ± 0784	2177 ± 1824
Total activity (counts/trip)[d]	37,564 ± 21,380	41,406 ± 18,859	38,912 ± 21,451	10,835 ± 12,805
MVPA (min/trip)[e]	8.4 ± 4.7	9.4 ± 4.4	8.6 ± 4.5	2.6 ± 3.1

Data are: mean ± SD, or median (IQR); [†]car trips not included in analyses of between-mode differences because 4 out of 8 car trips were part of a trip chain and unlikely resembling habitual school-travel trips; *$p < 0.001$ significantly different from walk trips (multi-level regression analyses; adjusted for multiple trips per person); participants were public high school students from Downtown Vancouver, sampled in October 2012.

[a] Global positioning systems (QStarz BT-Q1000XT, 1 s).

[b] ActiGraph accelerometry (GT3X+, 1 s epoch).

[c] Counts (axis1 or vertical axis) Per Minute.

[d] Total activity (sum of axis1 (or vertical axis) counts/trip).

[e] *M*oderate-to-vigorous *P*hysical *A*ctivity (≥2296 CPM) (Evenson et al., 2008); Data not shown: public transit trips and car trips accrued almost a minute of MVPA, on average, during trip pauses; these pauses lasted on average 10 and 6 min, respectively.

Physical activity from public transit to school: rethinking active transportation

It is intriguing that transit users accrued similar levels of trip-based PA compared with walkers. In adults, the association between transit use and PA from walking to/from transit stops is reasonably well documented (Rissel et al., 2012). Few studies however described PA during transit use for school-travel (none used GPS). This is not surprising given that the wealth of previous studies (Larouche et al., 2014) primarily focused on establishing the more intuitive association between PA (and/or health-related fitness) with walking or cycling to school. In addition, prevalence of transit use for school-travel is location-specific. For example, transit is the most common school-travel mode in London, UK (46%; 2010) (Department for Education, 2010), is common in urban Toronto (37%–45%; 2006) (Buliung et al., 2009), but is rare (~2%; 2009) across the US, where car use and provision of school buses are common (McDonald, 2012).

Few studies documented PA during transit travel to school. One large study of elementary school children (10-year-olds) in London, UK objectively assessed PA during school-travel windows (8–9 am & 3–5 pm). Transit users and walkers had similar school-travel PA, both groups being significantly more active than car users (Owen et al., 2012). Another large study from Bristol, UK (11 to 12-year-olds) found no differences in school-travel PA between car- and transit users during a travel window (8–9 am & 3–4 pm), likely because transit users in this study rarely walked as part of their trip (van Sluijs et al., 2009). We found only one North American study (Alberta, Canada) (Pabayo et al., 2012) that reported PA during transit travel (10 to 11-year-olds). Transit users were rare (<1%), but accumulated more steps than walkers (26–30%) during school-travel windows (8–9 am & 3–4 pm). None of these studies had GPS or diaries to identify the exact amount of PA attributable to the school-trip.

Distance to school is the single most consistent barrier for active school-travel (Wong et al., 2011). The near absence of data related to transit use and PA represents a missed opportunity to identify PA-supporting types of motorized travel for students who live too far to walk. Specifically, the typical multi-modal nature of transit use appears to present an opportunity for PA. However, this may differ by location (i.e. transit stop location/density). Trip-based PA is likely of smaller magnitude in school bus users, although depending on local policies around pick up/drop off, it may still offer some opportunity for walking. We had no school bus users in our study and were unable to assess this. Car travel likely offers the least opportunity for PA. As parents' decisions regarding school-travel are largely influenced by safety concerns and convenience (Faulkner et al., 2010), it seems unlikely that most routine car trips accommodate purposeful PA.

A variety of factors likely influence transit travel. Parental concerns over safety is one important consideration (Faulkner et al., 2010). However, the relatively high prevalence of transit use for school-travel in Europe and urban centers in North America (i.e. Toronto (Buliung et al., 2009) (and in our Vancouver study), indicate that transit can be an accepted school-travel mode. Access to transit, including area coverage and frequency of stops and service, is essential to provide a convenient alternative to car travel. However, there may be such a thing as 'too much' provision of transit. For example, the dense bus network in London, UK, which is free of charge for school-aged children, may result in bus journeys replacing even short walking trips in some students (Jones et al., 2012). Regardless, the frequent use of transit in urban centers suggests that *if we provide it, they will use it*.

Trip-based physical activity: dose–response relationships with distance

We found that for every additional ~100 m walked – irrespective of travel mode – students accrued an additional one minute of MVPA, which is broadly in line with what others previously reported (Faulkner et al., 2013; Panter et al., 2011; Southward et al., 2012; van Sluijs et al., 2009). The dose–response relationship between walking distance and PA may have important policy implications regarding school sitings, catchment sizes and school bus policy (Faulkner et al., 2013). Our findings also hold relevance for transportation planners: transit users had meaningful levels of PA because most (but not all) transit connections were located approximately 500 m from the school — a meaningful walking distance.

However, the key question is whether active travel is ultimately associated with improved health outcomes. Students who cycle to school have better cardiovascular fitness than those traveling by other modes (Larouche et al., 2014) — a powerful marker of health in this population (Ortega et al., 2008). This is likely a response to the greater exercise intensity associated with cycling versus walking. Future studies that explore the composite effect of volume (frequency, distance, duration) and intensity (speed) of walking on PA behaviors and objective health outcomes would be an asset to the literature.

Limitations

This study comprised of a relatively small sample of grades 8–10 high school students from Downtown Vancouver, which includes some of North America's most walkable neighborhoods that are also well-served by public transit. As a result, we did not have enough car trips and no school bus trips to assess trip-based PA by those modes, which potentially limit the transferability of our findings to other settings. Use of GPS and accelerometry in combination enhances our understanding of travel behaviors as they relate to PA. However, the practical application of GPS for person-based health research is limited by battery life and data memory constraints, signal loss or delay in acquisition, and power buttons that can be switched off by participants. Specifically in the current study, the availability of GPS data was a function of battery life, which limited the number of school trips. Future studies should explore how many school trips and/or days are required to capture habitual school-travel (and associated PA). Furthermore, there is currently no consensus in this still emerging field regarding data collection and processing of GPS data, including sampling intervals and speed thresholds, which hinder comparability between studies.

Conclusions

The 'walk-interrupted' experienced during public transit use can contribute meaningfully toward youth meeting recommended daily guidelines for PA. A better understanding of barriers to, and facilitators of, transit use for school-travel would inform school-travel planning, that we perceive likely requires a local community-specific approach. School policies that promote active school-travel by any mode – including public transit – may be warranted.

Conflict of interest statement

The authors have no financial disclosures or conflicts of interest to declare.

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