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Does activity space size influence physical activity levels of adolescents?—A GPS study of an urban environment

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ABSTRACT

Background. Physical activity (PA) is closely linked with child and youth health, and active travel may be a solution to enhancing PA levels. Activity spaces depict the geographic coverage of one's travel. Little is known about activity spaces and PA in adolescents.

Objective. To explore the relation between adolescent travel (using a spatial measure of activity space size) and daily moderate-to-vigorous PA (MVPA), with a focus on school days.

Methods. We used Global Positioning Systems to manually identify trips and generate activity spaces for each person-day; quantified by area for 39 students (13.8 ± 0.6 years, 38% female) attending high school in urban Downtown Vancouver, Canada. We assessed the association between activity space area and MVPA using multi-level regression. We calculated total, school-day and trip-based MVPA for each valid person-day (accelerometry; ≥ 600 min wear time).

Results. On school days, students accrued 68.2 min/day (95% CI 60.4–76.0) of MVPA. Daily activity spaces averaged 2.2 km^2 (95% CI 1.3–3.0). There was no association between activity space size and school-day MVPA. Students accrued 21.8 min/day (95% CI 19.2–24.4) of MVPA during school hours, 19.4 min/day (95% CI 15.1–23.7) during travel, and 28.3 min/day (95% CI 22.3–34.3) elsewhere.

Conclusion. School and school travel are important sources of PA in Vancouver adolescents, irrespective of activity space area covered.

Introduction

Physical activity (PA) is a powerful determinant of health. It is also an effective means to prevent a host of chronic diseases across ages and populations (Warburton et al., 2006). Thus, it is alarming that fewer than 1 in 10 young Canadians meet national PA guidelines (Colley et al., 2011).

Solutions are needed to offset the decline in PA in young people. There is a growing body of evidence that links the built environment to adolescent PA (Ding et al., 2011; Tucker et al., 2009); well-designed neighbourhoods offer adolescents more opportunities to be physically active outdoors or choose active travel modes (e.g. walk, cycle).

Activity spaces are defined as the geographic coverage of an individual's travel by measuring the places people visit and the routes people take to get there (Hirsch et al., 2014), and provide a realistic and accurate definition of the spatial environment that individuals are exposed to and interact with (Zenk et al., 2011). In our study context of downtown Vancouver—a highly walkable setting with good access to public transit—we assume that adolescents' activity spaces are largely reflective of their active travel behaviours, and hypothesize that larger activity spaces are positively associated with PA. We are aware of only one previous study that has directly investigated the association between activity space size and children's PA, and they found no association (Villanueva et al., 2012). Their study defined activity spaces from a mapping exercise, where children self-identified their neighbourhoods (home, destinations) on maps.

Combining accelerometer, global positioning systems (GPS) and geographic information systems (GIS) provides sensitive and accurate measures of context-specific behaviour relative to space and time (Jankowska et al., 2015). The aim of this paper was to employ these state-of-the-art measures to explore the association between the size

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of activity spaces (geographic coverage of daily travel) and moderate-to-vigorous PA (MVPA; min/day) amongst adolescents residing in downtown Vancouver.

Methods

Sample

In Fall 2012, we invited grade 8–10 students who were attending a high school in downtown Vancouver to participate in the *Active Streets, Active People-Junior* study. Of the 49 students who assented and provided parental consent, 39 (13.8 ± 0.6 years, 38% female) had sufficient data to include in the analysis. The Vancouver School Board and the University of British Columbia Behavioural Research Ethics Board approved the study.

Protocol and data processing

Trained research assistants assessed stature (0.1 cm) and body mass (0.1 kg) in schools during physical education classes. Concurrently, students self-reported usual modes of travel to and from school via questionnaire. To better understand our sample in relation to the school's student population, and to illustrate the close proximity between home and school in our sample of urban youth, we used ArcGIS[TM] (v.10.1, ESRI®, Redlands, CA) to calculate the shortest distance along the street network between a student's residential address (parent-reported) and their school, and to determine whether students resided within the defined school catchment area. We fitted students with Global Positioning Systems (GPS; QStarz BT-Q1000XT, QStarz International Co. Ltd., Taipei, Taiwan) and accelerometers (GT3X+; ActiGraph LLC, Pensacola, FL) and instructed them to wear units over the right hip. Data were collected using 1 second epochs for both GPS and accelerometry.

We manually identified GPS trips using the tracking analyst tool in ArcGIS[TM]. We describe these methods in detail elsewhere (Voss et al., 2015). In brief, accelerometry and GPS data were merged for each participant. Then, trained researchers used the tracking analyst tool (ArcGIS) to evaluate second-by-second data and code trips. Trip start, end, and pause times were determined, and trip mode was identified by looking at speed, MVPA intensity, and the actual path the student was taking. Trip-based MVPA was defined as any MVPA accrued while the student was in transit (moving between two discreet locations), regardless of the mode. Trips containing multiple modes (e.g. walk to bus) were coded by mode and were also assigned a main mode (based on the greatest distance travelled) (Voss et al., 2015). We included days for participants with ≥10 h accelerometer wear-time and ≥1 GPS trip for each person-day. From accelerometry, we estimated MVPA (min/day) as total/day, school-day (weekdays between 8:35 and 15:03, based on school schedule) and trip-based (during travel only) for each person-day (ActiLife v.6.5.4; Evenson et al., 2008). We had 74 valid person-days (range 1–4 days/person); most were school days ($n = 54$, 73%). For the remainder of this analysis, we focused on school days only, given the routine nature of school travel and common destinations (home, school).

Activity space generation

Using a previously published python script (Python 2.7.2, Python Software Foundation, www.python.org) (Hirsch et al., 2014) and ArcPy for ArcGIS 10.1 (ESRI, Redlands, CA, USA) we analysed trip-related GPS point data, aggregated by individual to create activity spaces from GPS points for each person-day. In brief, we generated Daily Path Area (DPA) activity spaces by buffering each individual's GPS trips 200-m, dissolving all buffered trips into one polygon, and removing bodies of water. We included GPS points for all trips in a day for each person-day, and used ArcGIS[TM] to quantify activity space area for each person-day (km^2). On a theoretical level, this method may more closely represent the environments these adolescents passed through during the time they wore their GPS units than other types of activity spaces, such as Standard Deviation Ellipses or Minimum Convex Polygons, which may capture large regions not encountered by the wearer of the GPS.

Data analysis

We generated sex-specific descriptives as frequencies or means (SD/95% CI). To account for multiple person-days per adolescent, we used multi-level regression models that evaluated associations between daily activity space area and daily MVPA (total, school-day, and trip-based). We visually inspected the distribution of residuals to confirm the appropriateness of parametric methods. We used Stata (v. 13, StataCorp LP, College Station, TX) to perform our analyses. Results from linear models without clustering produced almost identical estimates (not shown).

Table 1
Characteristics of adolescents and their physical activity.

	All	Boys	Girls	*p*
n participants	39	24	15	
Sample characteristics				
Age (years)	13.8 (0.6)	13.8 (0.6)	13.7 (0.6)	0.619
BMI percentile[a]	53.4 (33.7)	57.4 (34.8)	46.9 (32.1)	0.345
WHO weight category, n (%)[b]				
Normal	29 (74%)	16 (67%)	13 (87%)	0.164
Overweight (incl. obese)	10 (26%)	8 (33%)	2 (13%)	
Distance to school (km)[c]	2.0 (1.8)	2.3 (2.2)	1.3 (0.7)	**0.046**
Proportion living in school catchment, *n* (%)[d]	36 (92%)	21 (88%)	15 (100%)	0.154
Main mode of travel to and from school, n (%)[e]				
Walk	19 (49%)	11	8	0.600
Transit	14 (36%)	10	4	
Other (incl. car)	6 (15%)	3	3	
School day statistics				
n person-days (participants)	54 (37)	36 (23)	18 (14)	
Activity spaces (km^2)[f]				
Activity space size	2.2 (1.3–3.0)	2.5 (1.2–3.8)	1.5 (0.9–2.2)	0.265
Physical activity (min/day)				
Total MVPA[g]	68.2 (60.4–76.0)	75.9 (65.9–85.9)	53.2 (46.7–59.8)	**0.003**
School-day MVPA[g]	21.8 (19.2–24.4)	23.9 (20.7–27.0)	18.1 (14.6–21.6)	**0.020**
Trip-based MVPA[g]	19.4 (15.1–23.7)	20.8 (14.7–26.9)	17.2 (11.7–22.6)	0.442
Other MVPA[g]	28.3 (22.3–34.3)	33.0 (24.9–41.1)	18.9 (12.8–24.9)	**0.024**

Data are *n*, mean (SD), or mean (95% CI) unless otherwise specified. Significant between-group differences were estimated via Pearson's Chi-Square test for frequency data or independent t-tests for continuous data; significance set at $p < 0.05$ (unadjusted for multiple comparisons), indicated in boldface text. Participants were public high school students from Downtown Vancouver, sampled in October 2012.

[a] BMI—body mass index ($kg\ m^{-2}$); percentiles calculated based on age-sex specific WHO 2007 reference charts (De Onis et al., 2007).

[b] World Health Organization age-sex specific BMI weight categorization (De Onis et al., 2007).

[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] Main mode (≥6 trips/week); based on students' self-report.

[f] Daily Path Area Activity Spaces (Hirsch et al., 2014). Area of 200 m buffer around total daily GPS tracks with water bodies removed, calculated using Python v. 2.7 and geographic information systems software (ArcGIS v. 10.1; ESRI Inc., CA).

[g] Moderate-to-vigorous physical activity (≥2296 CPM) (Evenson et al., 2008).

Results and discussion

There were no differences for sex, age, body mass index (BMI) percentile, school travel mode or distance to school between our sample and students excluded from analysis. Approximately 25% of participants were overweight or obese (Table 1), similar to national estimates (Colley et al., 2011). Almost half of students walked to school; one third travelled by public transit.

Associations between MVPA and activity space

On average, students accrued 68.2 min/day (95% CI 60.4–76.0) of MVPA on school days (Table 1). PA levels were higher than previously reported for Canadian adolescents (47.9 min/day, on average) (Larouche et al., 2014). This may be due to our focus on the school day and downtown Vancouver's pedestrian-friendly (mean Street Smart Walk Score®: 96; www.walkscore.com) and transit-rich environment (Transit Score®: 98). This neighbourhood offers increased opportunities for youth to use active modes of travel to different locations (hereafter "domains"). One quarter of daily MVPA was trip-based; the remaining MVPA was accrued in discrete domains. Similarly, previous reports of Danish adolescents also found that one quarter of daily MVPA was accrued through travel (Klinker et al., 2014)—a meaningful contribution to daily MVPA.

We hypothesized that larger activity spaces are positively associated with PA. We illustrate a typical activity space for one day of one participant (Fig. 1); the day is comprised of two school trips, and a short trip home from the community centre.

On average, daily activity space size was 2.2 km^2 (95% CI 2.2–7.4)—significantly smaller than the school catchment area (4.2 km^2). There was no association between activity space size (km^2) and total MVPA (min/day) on school days ($\beta = -1.32$, 95%CI -4.05, 1.36; $p = 0.321$). One previous study also found no association between PA and activity space size, where active spaces were operationalized as

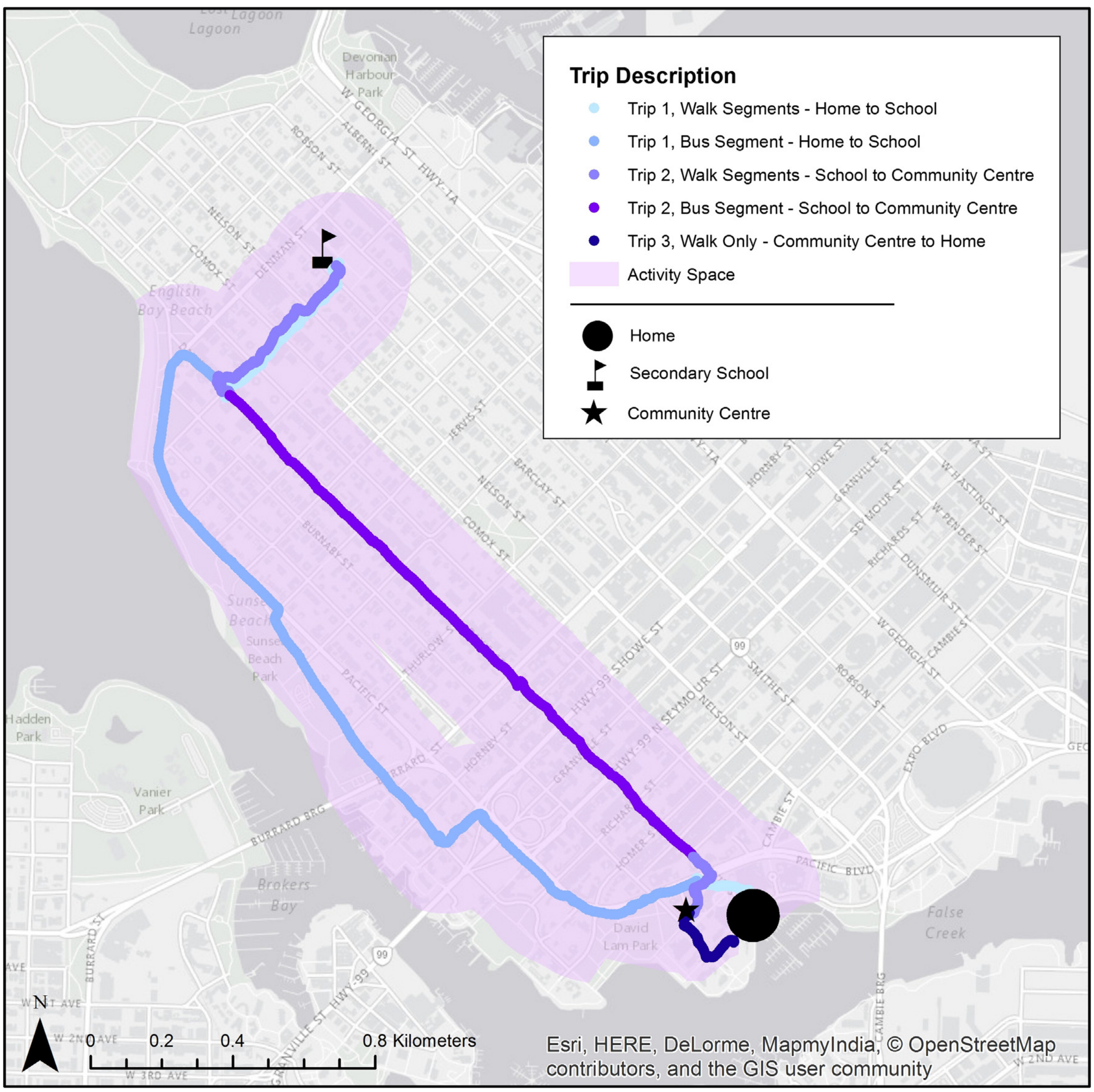

Fig. 1. Example of GPS data and the resulting activity space on a typical school day of one participant. On this day, the participant accrued 54.4 min of total MVPA: 22.5 min of school MVPA, 15.6 min of trip MVPA, and 16.2 min of other MVPA. Total travel duration was 50.7 min. For privacy, the student's residence has been masked with a black circle which portrays the approximate location of their home; the circle intersects with three Census Dissemination Areas (DA) representing 2664 residents in 2006 (DAs not shown). Trips are depicted as coloured lines. The activity space creates a 200 m buffer around these lines (bodies of water are excluded as they are likely not part of an activity space when someone travels between locations on land, even if travel is within 200 m of water). This figure illustrates the participant's use of different transportation modes within the same trip; Trips 1 and 2 comprise of a transit segment flanked by two walking segments. A good example of a School Day Activity Space, this figure contains complete GPS tracks denoting the participant's trips, and an activity space which successfully buffers the trips. The participant was a public high school student from Downtown Vancouver, sampled in October 2012.

minimum convex polygons derived from children's self-report of routes and destinations (Villanueva et al., 2012). Others also utilized adolescent self-reported definitions of their 'neighbourhood', but did not directly relate area size to their PA (Colabianchi et al., 2014). We advance our understanding through use of objectively measured MVPA (accelerometers) and activity space size (GPS)—which provides more sensitive and accurate measures of adolescents' actual spatial behaviour (Jankowska et al., 2015).

Almost two-thirds (63%) of school days ($n = 34/54$) involved two school trips (assessed using GPS). Students accrued 2.7 trips/day (95% CI 2.3–3.2) on school days, on average; most (59%) were school trips. The size of daily activity space was largely determined by school trips. Of note, these trips were mostly conducted on foot and/or by transit. Transit users typically had larger activity spaces than walkers (due to longer overall distances), but it is of note that we previously reported transit users walked similar amounts as part of their trips as did walkers, and therefore accrued similar amounts of trip-based MVPA (Voss et al., 2015).

Domains that encourage physical activity in youth

Importantly, travel to school and in-school PA combined, comprised most of our participants' daily MVPA. Approximately 30% of total daily PA was accrued at school (21.8 min/day), a further 30% during travel (19.4 min/day), and 40% elsewhere (28.3 min/day). Our findings align with previous work that objectively measured children's MVPA—opportunities for MVPA arise during the school-day, such as during lunchtime and physical education classes (Fairclough et al., 2012). Thus, MVPA during and to and from school contributes meaningfully to daily MVPA on school days (Long et al., 2013) and contributes significantly to adolescents meeting recommended PA guidelines. In future, it seems important to identify specific domains where MVPA is accumulated outside of school and travel in a North American setting. One such study has been done in a European context, reporting that Danish adolescents accrued significant amounts of MVPA at playgrounds and in urban greenspace (Klinker et al., 2014). PA patterns are likely highly context- and location-specific which warrants investigation of local settings.

Strengths and limitations

Our study has a number of strengths. It is the first to assess the relation between objectively measured activity space and adolescents' objectively measured school day PA. Further, Vancouver's downtown core is a highly walkable setting which may not be reflective of other settings. It supports active travel, not possible in settings where school travel patterns (distance, mode) may differ. We also note some limitations. We had a relatively small sample size. The battery life of the GPS units (without a recharge at home) resulted in only 3 days on average of GPS data in our study, some of these days were weekend days, lacked matching accelerometry data and/or did not sufficiently capture school trips on schooldays—factors which collectively hampered the number of valid days we were able to include in our analyses. Additionally, GPS technology may be affected by signal loss and/or delays in signal acquisition, especially in urban centres. Missing GPS data may produce smaller activity spaces and/or underestimate MVPA from travel (Voss et al., 2015). To counter this, we repeated activity space and MVPA analyses with a subset of days deemed to have 'good' GPS tracks. There was still no association between daily activity space size and MVPA using these data.

Conclusion

Although approximately a quarter of adolescents' PA is accrued during travel, the overall activity space size—or total geographic area they visited or travelled through—was not related to total daily PA. The majority of adolescent PA appears to be accrued in discrete locations, such as at school.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

Transparency document

The Transparency document associated with this article can be found, in the online version.

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