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They go straight home – don't they? Using global positioning systems to assess adolescent school-travel patterns

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ABSTRACT

Background: Active travel to school is a potential source of physical activity for adolescents, but its assessments often rely on assumptions around travel patterns. Global positioning system (GPS) and accelerometry provide an objective assessment of physical activity from school-travel and the context in which it occurs (where, when, how long).
Purpose: To describe school-travel patterns of adolescents and to compare estimates of physical activity during the hour before/after school – a commonly used proxy for school-travel time – with physical activity accrued during school trips identified through GPS ('GPS-trips').
Methods: Adolescents ($n=49$, 13.3 ± 0.7 years, 37% female) from Downtown Vancouver wore an accelerometer (GT3X+) and GPS (Qstarz) for 7 days (October 2012). Minutes of moderate-to-vigorous physical activity (MVPA) during the hour before/after school and during GPS-trips were calculated for the $n=130$ school-trips made by 43 students. We used multilevel linear regression to assess the association between MVPA during GPS-trips and MVPA during the hour/before school.
Results: Only 55% of school-trips were from/to home and within the hour before/after school ('normal'). Estimates of MVPA during the hour before/after school were higher than during GPS-trips (12.0 vs. 8.0 min). On average, MVPA during GPS-trips was linearly associated with MVPA during the hour before/after school, suggesting that physical activity levels during the hour before/after school are broadly reflective of physical activity from school-travel.
Conclusion: GPS and accelerometry provide context-rich information relating to school-travel. The hour before/after school may – on average – provide a simple means to crudely estimate physical activity from school-travel when GPS are not available.

1. Introduction

Promoting walking and biking to school are among strategies identified as key to combat the physical inactivity pandemic in youth (GAPA, 2011) and one response to the call for global action to address this problem (Kohl et al., 2012). There is a compelling body of scientific evidence that youth who walk or bike are more physically active (Larouche et al., 2014). Historically, studies that objectively assessed physical activity from school-travel did so by first obtaining continuous measures of physical activity levels during the school day (accelerometry), then defining time 'windows' post hoc for a time of day when school-travel was *assumed*, for example the hour before or after school (or sometimes two hours after school), (Cooper et al., 2003; van Sluijs et al., 2009) and inferring that physical activity accrued during these times was attributable to school-travel. However, physical activity during the hour before/after school may not be exclusively from school-travel, which could question the validity as a proxy for physical activity from school-travel.

Combining accelerometry with global positioning systems (GPS) provides a great opportunity to improve objective assessments of physical activity from school-travel, because through GPS we can identify actual school-travel times. A handful of studies have started to

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employ this method to estimate physical activity from school-travel, (Klinker et al., 2014; Cooper et al., 2010; Southward et al., 2012) but none described teenagers' *actual* school-travel patterns in terms of travel time (i.e. do they travel when we assume they do?) and destinations (i.e. do they travel to/from home or elsewhere?). This contextual information is invaluable to planning and implementing effective physical activity promotion strategies that specifically target school-travel. In addition, it is unclear whether school-travel times (i.e. time of day) and destinations directly impact physical activity from school-travel, and whether the hour before/after school is a suitable proxy for physical activity from school-travel when no GPS (or travel diaries) are available.

Thus, the objectives were two-fold: (1) to describe adolescent school-travel patterns (from GPS) in terms of school-travel times (i.e. time of day) and destinations (i.e. home/not home); (2) to compare estimates of physical activity from school-travel during the hour before/after school (a commonly used proxy for school-travel time) with actual with physical activity accrued during school trips identified directly through GPS.

2. Methods

2.1. Participants and protocol

With parental consent and student assent, grade 8–10 students ($n=49$, 13.3 ± 0.7 years, 37% female) from the only public high school in Downtown Vancouver participated in this study. Measurements were conducted in the school setting in October 2012. The institutional ethics committee and school board approved the study.

2.2. Instruments

Physical activity was objectively assessed using accelerometers (GT3X+, ActiGraph LLC, FL; recording at 30 Hz) and concurrent location using GPS units (Qstarz BT-Q1000XT, Qstarz International Co. Ltd., Taiwan; recording at 1s). Participants were fitted with an elastic belt equipped with both monitors (accelerometer over the right hip) to be worn continuously for the next 7 days (except for water-based activities). Participants turned on the GPS unit on day one of the measurement period and were instructed not to turn them off for the remainder of the study period. We enabled the vibration sensor on the GPS unit so that the unit would go into battery-preserving sleep mode after 10 min of no movement.

2.3. Trip identification

School and home addresses (from parent/guardian) were geocoded and mapped in ArcGIS v. 10.1 (Esri Inc., CA), as were aerial images of the area (City of Vancouver Open Data) and a local street network shapefile (CanMap® Streetfiles, DMTI Spatial Inc., Markham, Canada). Using the Tracking Analyst tool, which visualises GPS points in a time series, a researcher with local knowledge identified school-trips from GPS points on weekdays that terminated at school before the end of the school day or that originated from school. Tracks had to be of ≥ 30 s duration and ≥ 100 m distance to be considered a trip. Trip start was identified as the first GPS point outside of home or school ground (combination of aerial image and geocoded addresses) where speed ≥ 1 km/h and distance > 0 m of movement, and changes from these criteria indicated trip stop time, allowing for pauses of < 5 min (e.g. at a stop light, bus stop). Trip mode was assigned based on the overall trip speed trajectory. Trips where speeds were predominantly ≥ 1 km/h and < 10 km/h were considered 'walking' trips (hereafter: 'active'). For the purposes of this analysis, trips where speeds were predominantly ≥ 10 km/h were considered 'passive' trips (including car and public transit trips). We are confident that no bicycle trips were mistaken for car trips, as only one student self-reported sometimes cycling to school, and the GPS-trips during the measurement period for this student were clearly walking trips. All GPS-trips in this analysis were coded by the same researcher; however, with this manual trip identification process in our lab we have found 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) – not a meaningful difference.

2.4. Data processing and statistical analyses

Raw accelerometry data were reintegrated into 1-s epochs using ActiLife v. 6.5.4. (ActiGraph LLC, FL), and merged with GPS-trip data (as.csv) using timestamps in Stata/MP 10.1 (StataCorp LP, TX). To visualise school-travel behaviour by time of day, we allocated the proportion of student-travel time into 5-minute time slots and plotted them (Fig. 2). GPS-trips were coded according to trip type (home to school, elsewhere to school, school to home, school to elsewhere), and grouped as 'normal' if they were to/from home and started and ended within the hour before or after school, or 'not-normal' if outside these parameters. From accelerometry, axis 1 (vertical) acceleration counts were converted into minutes spent in moderate-to-vigorous physical activity (MVPA) (Evenson et al., 2008) during GPS-trips and hour before/after school. Mean MVPA during the hour before/after school and during GPS-trips were calculated (Table 1) for all school-trips ($n=130$), and for 'normal' school-trips ($n=71$). Between trip-type comparisons of MVPA (outcome variable) were assessed via multilevel linear regression, using trip type as a categorical explanatory variable (referent: 'home to school') and with student as a random effect to account for clustering of trips by student (multiple school trips made by the same person are likely similar to each other). We used the same method to assess between-mode (referent: 'active') differences in MVPA, and we also used multilevel regression to explain how much of the MVPA during the hour before/after school (outcome variable) was explained by MVPA from the actual school trip (GPS-trip; explanatory variable, continuous).

3. Results and discussion

Forty-five students had GPS data for an average duration of 3 ± 1 days (range: 1–6). From 303 total trips, 130 were school-trips (hereafter: GPS-trips) made by 43 students (average GPS-trip rate per student: 3.0 ± 1.9 GPS-trips, range: 1–9).

3.1. They go straight home, don't they?

Almost all GPS-trips to school ($n=57/60$) originated from home, however, only two thirds of GPS-trips from school returned home ($n=46/70$). The most common (≥ 5 trips) after school destinations other than home were a community centre (12 trips by 12 students, separately) and a park (5 trips by 5 students, travelling together). Other destinations were other residential address/neighbourhood ($n=2$), elementary schools ($n=2$), restaurants ($n=2$), and a church ($n=1$).

The proportion of school trips that both started and finished within the hour before or after school is of interest, because this is a key assumption for using the hour before/after school as estimates of school travel PA. For trips to school, three-quarters of trips started and completed within the hour before school ($n=46/60$), whereas only 56% of trips from school did during the hour after school ($n=39/70$).

Overall, only 55% of the GPS-trips were considered 'normal' (i.e. from/to home, completed within the hour before/after school; $n=71/130$). This may have implications for estimating physical activity from school-travel when solely relying on using these time windows.

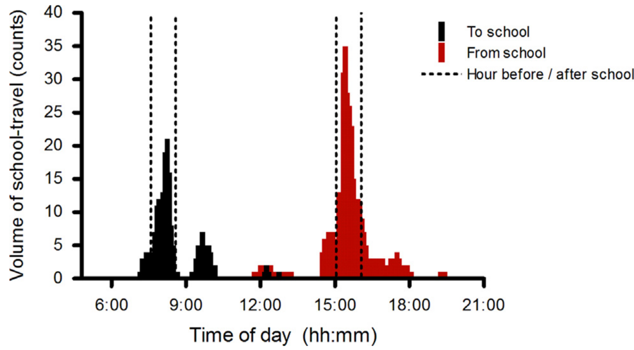

Fig. 1. Volume of school travel-time across the school day. Travel to and from school occurred most often during the hour before (77%) and after (64%) school. Note that the smaller cluster of travel time to school between 9–10 am was largely explained by a late school start on one measurement day (adjusted for in analyses). Also note the wider distribution of travel time from school across a 4-hour window. While some early trips from school were attributed to school sport competition, most travel times outside the hour before/after school remain unexplained. Based on $n=130$ school-trips by $n=42$ students from Vancouver, Canada (Oct 2012).

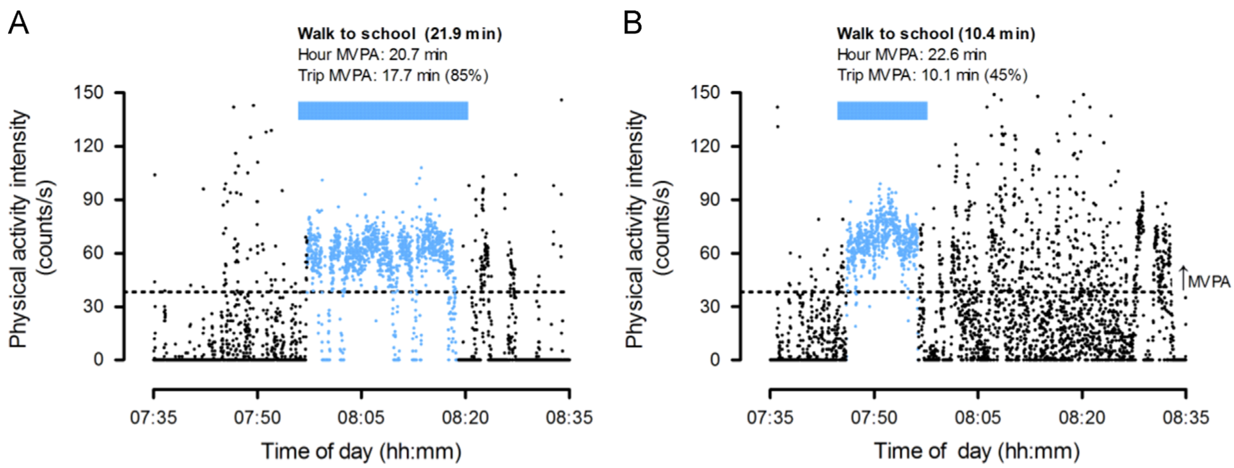

Fig. 2. Example of two students' physical activity patterns during the hour before school. Both students walked to school (light blue) and had comparable minutes of MVPA during the hour before school, but the relative contribution from actual school-travel and other PA (i.e. arriving at school and school start) differed between the students. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

For example, trips from school to community centres or parks may result in different amounts of physical activity compared with trips home, either because of different physical activity from transport (different travel modes, different trip times/distances), or because of physical activity at a destination (not during travel to it). Furthermore, 30% of GPS-trips home after school started ≥ 30 min after the final bell ($n=14/46$), providing additional opportunities for physical activity at school, which could also have impacted estimates of physical activity using the hour before/after school time window. We revisit between-trip type differences in physical activity from school-travel in Section 3.2.

Fig. 1 provides a visual representation of volume of school-travel time at any given time of day. Overall, school-travel volumes peak shortly before school start, and shortly after school ends. Furthermore, most (77%) of the travel-time volume to school occurred within the hour before school, and 64% of the volume of travel-time from school occurred within the hour after school.

3.2. *Assessing physical activity from school-travel: what GPS adds to current practice*

As previously outlined, physical activity from school-travel is commonly inferred from objectively measured physical activity during the hour before/ after school, because any physical activity accrued during these time windows is thought to be attributable to physical activity from school-travel. However, there is potential for error by this method. Specifically, we found that only 55% of the school trips were ‘normal’ (i.e. from/to home, completed within the hour before/after school). In some cases, there may be no school-travel at all taking place during the hour before/after school, whereas in other cases, trips to locations other than home may yield different transport-related physical activity (e.g. different travel modes) or capture physical activity at the destination that may differ from physical activity at home (in either direction). Fig. 2 shows examples of two students' physical activity levels during the hour before school. Both walked to school and had comparable overall physical activity (20.7 and 22.6 min of MVPA, respectively). In Panel A most of the student's physical activity during the hour was explained by the walk to school (85%); the student in Panel B, however, arrived at school more than half an hour before the start of instructional time and spent most of this time being physically active. Consequently, less than half of the physical activity during the hour before school was explained by school-travel (45%).

We estimated physical activity from school-travel during the hour before/after school and during GPS-trips for our whole trip sample (Table 1). On average, the hour before/after school yielded greater levels of physical activity than did the GPS-trips, which is intuitive given the longer duration. What is of interest, however, is that both methods were able to identify significant between-trip type differences in physical activity, with ‘school to elsewhere’ trips having higher physical activity compared with ‘home to school’ trips (referent; ‘all’ trips only). Similarly, both methods identified that physical activity was higher in trips by active modes compared with passive modes

Table 1
Physical activity from the school trip as measured during the hour before/after school (accelerometry only) or during the actual trip (accelerometry and GPS), stratified by trip type and travel mode.

	n	Moderate-to-vigorous physical activity (MVPA, min)[a]	
		Hour before/after school[b]	Actual trip (from GPS)[c]
All school trips			
All	130	12.0 ± 6.4	8.0 ± 5.1
Trip type[d]			
Home to school	57	10.9 ± 5.8	6.8 ± 4.0
Elsewhere to school	3	14.3 ± 10.5[e]	5.5 ± 2.6[e]
School to home	46	11.6 ± 6.1	8.4 ± 5.1
School to elsewhere	24	15.1 ± 7.2[†]	10.6 ± 6.5[†]
Travel mode[f]			
Active	51	13.4 ± 5.9	8.7 ± 4.3
Passive	79	11.1 ± 6.6	7.6 ± 5.5
'Normal' trips (based on trip type & time)[g]			
All	71	11.8 ± 4.5	6.5 ± 4.1
Trip type[d]			
Home to school	44	12.1 ± 4.5	6.5 ± 3.5
School to home	27	11.3 ± 4.6	6.6 ± 5.1
Travel mode[f]			
Active	34	13.3 ± 4.6	8.1 ± 4.1
Passive	37	10.4 ± 4.0[#]	5.0 ± 3.6[#]

Data are mean ± SD.
[a] ActiGraph (GT3X+, 1s epoch) acceleration counts converted to minutes of moderate-to-vigorous-physical-activity, MVPA (Evenson et al., 2008).
[b] Total minutes of MVPA between 7:35–8:35 (school start bell) or between 15:03 (school stop bell)–16:03.
[c] Total minutes of MVPA during the trip, identified from GPS tracks (Qstarz BT-Q1000XT, 1s epoch) mapped in a Geographic Information System (ArcGIS, v. 10.1, Esri Inc., CA).
[d] Trip type identified from mapped GPS tracks, using geocoded school- and home addresses (parent-reported).
[e] Excluded from between-trip-type comparison due to low number of trips; between-trip-type comparison (multi-level model, accounting for multiple trips per student).
[f] Travel mode identified from GPS tracks, primarily based on speed (see methods for details), active includes 'walk', passive includes 'car' and 'public transit'.
[g] 'Normal' trip is defined as a school trip that either originated or concluded at home based on mapped GPS tracks and that started and concluded within the hour before or after school.
[†] Significantly ($p < 0.05$) higher than 'home to school' (referent); between-mode comparison (multi-level model, accounting for multiple trips per student).
[#] Significantly ($p < 0.05$) lower than 'active' (referent).

('normal' trips only). The latter especially is an important observation, because assessing between-mode differences is often a focal point of studies that investigate physical activity from school-travel.

We illustrate the association between the two methods for the whole sample in Fig. 3 (includes the two examples from Fig. 2). We ran two models: one with all trips ($n=130$) and one with only 'normal' trips ($n=71$). In both models, trip-based physical activity was significantly and positively related to physical activity during the hour before/after school ($\beta=0.63$ min of MVPA, 95%CI 0.45–0.80, $p < 0.001$ and $\beta=0.75$ min of MVPA, 95%CI 0.59–0.91, $p < 0.001$, respectively). It is worth noting that the first model had more outliers than the second model, i.e. extreme cases that deviated notably from the simple regression line (and in both directions, see Fig. 3). These are likely instances where either after-school physical activity took place at school (high physical activity during hour before/after school, but low physical activity during GPS-trip), or active travel to/from school occurred outside of the hour before/after school (low physical activity during hour before/after school, but high physical activity during GPS-trip). It would appear as if both types of outliers occurred at comparable rates, thereby only marginally affecting the overall linear relationship between the two types of school-travel physical activity estimates (Fig. 3). In combination with the previously described ability of both methods to detect between trip type and mode differences in physical activity, it seems as if physical activity estimates from the hour before/after school hour may serve as crude estimates of school-travel MVPA overall when no GPS is available. However, it is worth noting that physical activity from school-travel was higher during the hour before/after school in most cases compared with physical activity during GPS-trips. We would therefore advise to identify (e.g. via questionnaire) any physical activity and/or travel patterns that may impact estimates of travel-related physical activity, for example after-school club participation which may lead to higher, non-travel related physical activity during the hour after school.

3.3. *Is GPS the holy grail for school-travel research?*

Through use of GPS, this study identified that only 55% of school-trips were 'normal', indicating that teenagers in our sample frequently travelled to destinations other than home or not during the hour before/after school. Although this did not seem to meaningfully impact overall estimates of physical activity from school-travel – in this sample at least – it highlights the value of GPS to provide context of travel (time, destination, route), in addition to providing objective estimates of physical activity from travel (Duncan et al., 2009). A recent study in Danish youth, using GPS and accelerometry, described gender-specific differences in physical activity from travel, school and leisure using these methods(Klinker et al., 2014); such context-specific information is invaluable for planning effective interventions to promote physical activity in youth.

Nevertheless, GPS has some limitations. 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. It is unknown how many days might be needed in order to capture individual student's habitual school-travel patterns, but future studies might incorporate protocols for charging to maximise GPS data acquisition during the typical 7 day study period. Signal loss or delay in acquisition is also a challenge for field-based GPS data collection. We measured the distance of missing

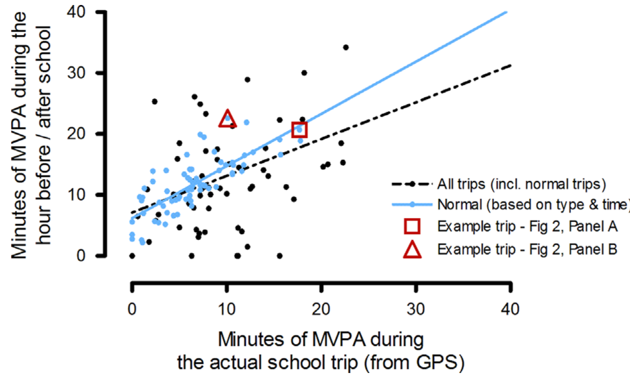

Fig. 3. Associations between physical activity during GPS-trips and during the hour before/after school. MVPA – moderate-to-vigorous physical activity; GPS – global positioning system; 'Normal' school-trip – to/from home, completely occurred within the hour before/after school. Note that the model with 'all trips' had more outliers (black dots) than the model with 'normal trips' only. These are likely instances where either after-school physical activity took place at school (high physical activity during hour before/after school, but low physical activity during GPS-trip), or active travel to/from school occurred outside of the hour before/after school (low physical activity during hour before/after school, but high physical activity during GPS-trip). Based on $n=130$ school-trips by $n=42$ students from Vancouver, Canada (Oct 2012).

trip segments along the street network by extending GPS track trajectories for 'home to school' and 'school to home' trips ($n=103$), because only for these trips could we be certain to know the correct trip origins and destinations. We found that on average, GPS-trips were missing $\approx 14\%$ of the trip distance in GPS points. This was mostly the result of a delayed signal fix at the trip start, which was markedly higher for 'home to school' trips (≈ 467 m) than for 'school to home' trips (≈ 71 m). This is likely the result of GPS units not having sufficient 'warm up' time in the morning, as well as the fact that GPS units typically require a longer time to first acquire a signal fix when they are in motion compared with when they are stationary (Stopher et al., 2008). We did not instruct participants to wait for a signal fix (e.g. a beep) before starting their trip, because we considered this an additional participant burden and consistent compliance to be unrealistic. Missing GPS data may result in underestimation of trip metrics like duration, distance and physical activity from travel. We repeated our analyses for trips who had $<15\%$ or $<1\%$ distance missing; although physical activity during GPS-trips was marginally higher when smaller proportions of the trips were missing, we found that the association between physical activity during the hour before/after school and during GPS-trips remained similar overall (not shown). Thus, we suggest that in this study, signal loss appears to have affected school-trips of low and high physical activity equally, on average. Finally, erratic GPS data were observed more frequently in urban canyons (clusters of high-rise buildings), and although a known phenomenon, (Schipperijn et al., 2014) this presents a real challenge for studies in urban centres.

3.4. Limitations

We acknowledge several additional limitations to this analysis. This study comprised of a convenience sample of grade 8–10 high school students from downtown Vancouver. Downtown Vancouver includes some of North America's most walkable neighbourhoods, which are also well-served by public transit. Furthermore, no students at this high school travelled by school bus as a result of the conservative local school bus eligibility criteria (≥ 4.8 km from nearest school) (Vancouver School Board, 2014) and the compact catchment area of this particular school (4.2 km^2; furthest distance to school along street network: 3.0 km). The unique local setting likely impacts the transferability of our findings to other communities. The current high school had an 'open gym' policy, meaning that students could autonomously use the school gym facilities between 8:00 am and 8:35 am (school start) on most school days. With no information on who made use of this, we cannot further explore the impact of this policy on school-travel patterns (i.e. do they purposely get to school earlier) and physical activity from school-travel (higher physical activity during the hour before school, see Fig. 2B). Likewise, provision of after school clubs – either at school or a different location, such as community centres – may impact school-travel patterns and related physical activity. Future studies should give consideration to these factors in their local contexts.

3.5. Implications for practice

GPS and accelerometry combined provide a context-rich insight into school-travel in terms of travel times (time of day and trip duration), destinations and physical activity from school-travel. Using GPS can also provide information on actual routes taken, which further enables the study of route characteristics that may influence school-travel behaviours. When no GPS is available, our findings suggest that the hour before/after school may serve as a crude proxy for physical activity from school-travel, on average. However, we identified that students frequently travelled outside of the hour before/after school, and that they commonly went to places other than home after school, which lead to outliers at the trip-level. Thus, we urge future studies to give consideration to these factors in their local contexts (for example via questionnaire), and explore whether they may impact their school-travel analyses.

4. Conclusion

Many environmental (neighbourhood, school) and individual factors (sex, age) likely contribute to complex school-travel behaviours in adolescents, particularly after school. GPS and accelerometry provide context-rich information relating to school-travel, but using the hour before/after school may provide a simple means to estimate physical activity from school-travel when GPS is not available. Further research examining adolescent school-travel behaviours should seek location- and school-specific information that likely impacts timing of school-travel, such as 'open door' policies for school gyms, as well as before- and after-school clubs and activities.

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References

Cooper, A.R., Page, A.S., Foster, L.J., Qahwaji, D., 2003. Commuting to school: are children who walk more physically active? Am. J. Prev. Med. 25 (4), 273–276.
Cooper, A.R., Page, A.S., Wheeler, B.W., Griew, P., Davis, L., Hillsdon, M., et al., 2010. Mapping the walk to school using accelerometry combined with a global positioning system. Am. J. Prev. Med. 38 (2), 178–183.
Duncan, M.J., Badland, H.M., Mummery, W.K., 2009. Applying GPS to enhance understanding of transport-related physical activity. J. Sci. Med. Sport 12 (5), 549–556.
Evenson, K.R., Catellier, D.J., Gill, K., Ondrak, K.S., McMurray, R.G., 2008. Calibration of two objective measures of physical activity for children. J. Sports Sci. 26 (14), 1557–1565.
GAPA. Global Advocacy for Physical Activity (GAPA) the Advocacy Council of the International Society for Physical Activity and Health (ISPAH), 2011. NCD Prevention: Investments that Work for Physical Activity. Available from: 〈www.globalpa.org.uk/investmentsthatwork〉 [28.03.14].
Klinker, C.D., Schipperijn, J., Christian, H., Kerr, J., Ersboll, A.K., Troelsen, J., 2014. Using accelerometers and global positioning system devices to assess gender and age differences in children's school, transport, leisure and home based physical activity. Int. J. Behav. Nutr. Phys. Act. 11, 8.
Klinker, C.D., Schipperjin, J., Christian, H., Kerr, J., Ersboll, A.K., Troelsen, J., 2014. Using accelerometers and global positioning system devices to assess gender and age differences in children's school, transport, leisure and home based physical activity. Int. J. Behav. Nutr. Phys. Act. 11, 8.
Kohl 3rd, H.W., Craig, C.L., Lambert, E.V., Inoue, S., Alkandari, J.R., Leetongin, G., et al., 2012. The pandemic of physical inactivity: global action for public health. Lancet 380 (9838), 294–305.
Larouche, R., Saunders, T.J., Faulkner, G., Colley, R., Tremblay, M., 2014. Associations between active school transport and physical activity, body composition, and cardiovascular fitness: a systematic review of 68 studies. J. Phys. Act. Health 11 (1), 206–227.
Schipperijn, J., Kerr, J., Duncan, S., Madsen, T., Klinker, C.D., Troelsen, J., 2014. Dynamic accuracy of GPS receivers for use in health research: a novel method to assess gps accuracy in real-world settings. Front. Public Health 2, 21.
van Sluijs, E.M., Fearne, V.A., Mattocks, C., Riddoch, C., Griffin, S.J., Ness, A., 2009. The contribution of active travel to children's physical activity levels: cross-sectional results from the ALSPAC study. Prev. Med. 48 (6), 519–524.
Southward, E.F., Page, A.S., Wheeler, B.W., Cooper, A.R., 2012. Contribution of the school journey to daily physical activity in children aged 11–12 years. Am. J. Prev. Med. 43 (2), 201–204.
Stopher, P., FitzGerald, C., Zhang, J., 2008. Search for a global positioning system device to measure person travel. Transp. Res. Part C 16, 350–369.
Vancouver School Board. EEA: Student Transportation Services, 1999. Available from: 〈http://www.vsb.bc.ca/district-policy/eea-student-transportation-services〉 [03.07.14].