

Quantifying physical activity during active commuting to school: A comparison of methodologies

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ABSTRACT

The current study aims to detect walking trips to/from school with different methodologies (GPS, self-reported, fixed windows [w30 and w60], and distance-based time), and to compare the start/end times for the trips, and the time accumulated in sedentary time, light physical activity (LPA), and moderate-to-vigorous physical activity (MVPA). A total of 93 Spanish adolescents wore an accelerometer and GPS during school days, and the start/end times of walking trips to/from school were determined using five different methodologies. Mixed-effects limits of agreement analyses were used to determine the level of agreement between the start/end times of the walking trips identified by the five methodologies mentioned. Moreover, methodologies were determined to be equivalent if the mean difference with the GPS was within the proposed equivalence zone of ± 5.0 min. Self-reported measures showed a good level of agreement for estimating start times of walking trips to school compared to GPS, 0.0 (LoA95%:-0.3–0.2) hours. Self-reported measures were deemed equivalent to GPS for measuring sedentary time, LPA, and MVPA. W30 and distance-based time were equivalent to GPS for LPA and MVPA, but not for sedentary time. W60 was only deemed equivalent to GPS for MVPA accumulated during walking trips to and from school. Self-reported measures showed the most precise approach for estimating start times to school, as well as it deemed equivalent to GPS for quantifying sedentary time, LPA, and MVPA. Moreover, estimating the time to complete the trip based on the distance between home and school could be more appropriate than fixed windows.

1. Introduction

Physical activity (PA) is an extensively researched and recognized behavior that has been shown to have significant health-promoting effects among children and adolescents (Bull et al., 2020; Chaput et al., 2020). These benefits include improved cardiovascular health, improved body composition, improved cognitive health, improved psychological well-being, among many others (Poitras et al., 2016; Rodriguez-Ayllon et al., 2019). In fact, the World Health Organization recommends achieving 60 daily minutes of moderate-to-vigorous PA

(MVPA) to obtain these benefits in children and adolescents (Chaput et al., 2020). Nevertheless, reported PA measures estimate that around the 80 % of children and adolescents worldwide do not achieve these recommendations (Aubert et al., 2022). Given the numerous health benefits of PA and the high prevalence of physical inactivity among children and adolescents, there is a need to promote effective interventions and strategies to reverse the current situation.

The school environment is considered an ideal setting to promote an active lifestyle, and the active commuting to and from school (ACS) offers a significant opportunity to add up some minutes to the daily

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MVPA volume for all children and adolescents (Larouche et al., 2014; Campos-Garzón et al., 2023a). In recent years, the scientific literature has examined ACS and its associated health (Larouche et al., 2014) and community (Gössling et al., 2019) benefits, as well as the factors that influence being an active commuter, such as socio-demographic characteristics (Esmaeli et al., 2024), barriers (Huertas-Delgado et al., 2018), or built environment (Olsen et al., 2021). Numerous interventions promoting ACS have also been carried out (Aranda-Balboa et al., 2022; Molina-García et al., 2024; Villa-Gonzalez et al., 2016). However, despite its significant individual benefit of increasing daily PA levels, the methods used so far to identify the occurrence of the trips to/from school and how they might affect the quantification of PA during the commuting have been barely evaluated.

In the meta-analysis conducted by Campos-Garzón et al. (2023a) on the contribution of device-measured ACS-PA, one of the limitations highlighted is the high heterogeneity among the included studies due to the varying methodologies used to define when ACS occurs. This issue may have led to an overestimation of sedentary time, light PA (LPA), or MVPA that does not correspond to the actual time frame in which commuting to school occurs (e.g., household chores or afterschool activities) (Campos-Garzón et al., 2023b). To date, no study has analyzed how the methodology used to identify the start and end times of the trip to and from school might influence results when compared to geolocation devices (e.g., Global Positioning System [GPS]).

The occurrence of ACS is inherently linked to the time and space frames when and where the trip occurs. To reduce the measurement error in the assessment of PA during the trips to/from school, it is crucial to accurately define the start/end times and locations of the trips (Campos-Garzón et al., 2023b). To date, several methods to identify the occurrence of ACS have been proposed. GPS-based identification is arguably the most objective and accurate method, although it is not exempt from limitations, including short battery life, signal loss, low compliance and high cost of the devices, and the lack of automated tools to match and process GPS and accelerometer data (Campos-Garzón et al., 2023b). Investigating alternatives to GPS is therefore warranted, and previous studies have already proposed some approaches, such as predefining fixed time windows using accelerometry (e.g., the 30- or 60-minute window preceding and/or following school time; [Chillon et al., 2017; Ginja et al., 2017]), or using child-reported information on the times they left/arrived home every day. Additionally, since the location of home and school is known, it would be possible to estimate the trip duration based on the trip distance and use that information to identify the PA related to ACS trips. However, to the authors' knowledge, this approach has not been tested and documented thus far. The use of distance from home to school as a variable to establish a more individualized time interval would improve the accuracy of analysis of PA related to ACS (Campos-Garzón et al., 2023b). This fact would improve the definition of the space-time where ACS takes place, avoiding the over- or underestimation of PA not related to ACS.

Therefore, the aims of the current study were: (1) to detect walking trips to/from school with different methodologies (GPS, self-reported, fixed windows [w30 and w60], and distance-based time), and (2) to compare the start/end times for the trips, and the time accumulated in sedentary time, LPA, and MVPA. We hypothesized that self-reported measures, the 30-minute window, and distance-based time could be as good option as GPS to identify the start and end times of walking trips to/from school, and thus the sedentary time, LPA, and MVPA levels accumulated during these trips. On the other hand, the 60-minute window will show the largest differences in determining the start and end times of walking trips as well as the accumulated sedentary time, LPA and MVPA during these trips compared to GPS, due to the large amount of time considered in this interval time.

2. Methods

2.1. Study design

The present study was conducted under the framework of the "Cycling and Walk to School" project (PACO, by its Spanish acronym) (<https://profith.ugr.es/paco>). The PACO project aimed to analyze the commuting patterns of Spanish children and adolescents and to promote cycling to and from school through a school-based intervention in the adolescent population. Information on the participant recruitment process, methodology, and inclusion/exclusion criteria have been previously published elsewhere (Chillón et al., 2021). The PACO Study was reviewed and approved by the Review Committee for Research Involving Human Subjects at the University of Granada (Reference: 162/CEIH/2016).

The data used in this study were from the baseline assessment of the PACO study and were collected from ten schools in four different Spanish cities (Almeria, Granada, Jaen, and Valencia). The data collection process took place from January 2019 to June 2021 and included two different visits to the school eight days apart. Briefly, during the first visit to the school, participants' height was measured using a measuring tape (Seca 2013, Seca Ltd., Hamburg, Germany) and weight using a digital scale (Seca 876, Seca Ltd., Hamburg, Germany). These measurements were used to calculate the Body Mass Index (BMI) as weight in kilograms divided by squared height in meters. Moreover, participants were instructed to wear an accelerometer and a GPS device for seven consecutive days. However, the COVID-19 pandemic affected the usual routines in the Spanish schools, so that the adolescents did not go to school every day (i.e., adolescents only went to school two days a week). Thus, participants were instructed to wear GPS for at least two consecutive schooldays (instead of seven as initially planned). Regarding the accelerometer device, it was worn for seven days. In addition, participants filled in an activity diary during the seven days of recording and answered a paper-based questionnaire during the second visit to the school (seven days after the first visit), as well as returned the devices and the activity diary.

2.2. Participants

In the PACO Study, a total of 317 adolescents wore the accelerometer and GPS devices. Of this total, 181 participants presented valid accelerometry and GPS data, as well as at least one trip to or from school. Nevertheless, to be included in the current analysis, participants needed to have: (1) valid data from accelerometry and GPS from at least one walking trip to or from school; (2) filled in the activity diary with the time of departure from home to school; and (3) walking trips to/from school with speeds inside the range of 2 km/h to 6.5 km/h. Therefore, the final sample of the current study was 93 participants (51.6 % girls) aged 14.6 ± 0.8 years, who performed 272 walking trips to or from school. More information about the recruitment process and sample size justification can be found elsewhere (Chillón et al., 2021).

2.3. Socio-demographic data

Sociodemographic variables, such as age, gender, and postal address, were self-reported by participants using a paper-based student questionnaire (<https://profith.ugr.es/pages/investigacion/recursos/cuestionario-alumnos-v4>).

2.4. Identification of the start and end times of the trip

2.4.1. Gps-based detection

Geolocation data were obtained using the Qstartz BT-Q1000XT GPS (International Co., Ltd. Taipei, Taiwan). The GPS devices were programmed with a 15-second epoch to record time, longitude, latitude, elevation, speed, and distance. Qstartz data viewer software was used

for the device initialization and GPS raw data download.

For cleaning GPS data and trip identification, the software HABITUS (<https://www.sdu.dk/en/habitus>) was used. A trip was determined with the following criteria: a) the minimum distance travelled over one minute was 25 m; b) trips less than 100 m were not considered trips; c) trips less than 120 s were not considered trips; d) pauses were considered less than two minutes without any movement; e) the end of a trip was considered more than three minutes without any movement; f) a walking trip was defined as a trip with a speed equal to or greater than 1 km/hour but lower than 10 km/hour (Pizarro et al., 2016; Stewart et al., 2017).

Once this step was completed, the direction of the walking trips identified by GPS (i.e., to and from school) were determined using the PALMSplusR R package (<https://thets.github.io/palmsplusr/index.html>). Firstly, ArcGIS 10.3 (ESRI, Redlands, CA, USA) software was used to geocode home and school postal addresses (Pizarro et al., 2016). After this step, by combining the output of HABITUS and this Geographic Information System in the PALMSplusR R package, every trip that started within home and ended at the school was considered a trip to school, and vice versa for a trip from school. The output file of this process also contained data about the trip characteristics (i.e., speed, distance, and duration) of each walking trip to/from school.

2.4.2. Self-reported start times

Participants received an activity diary in which they were asked to record the time they left home to go to school in the mornings. The end time of the trip to school was set based on the official school start time.

2.4.3. Predefined time windows: w30 and w60

For the choice of time intervals, we followed the recommendations of the systematic review by Campos-Garzón et al., 2023b were followed, which identified a minimum time interval of 30 min (Chillón et al., 2017) and commonly used intervals of 60 min (Cooper et al., 2012; Martínez-Martínez et al., 2019; Pabayo et al., 2012). Therefore, both w30 and 60-minute w60 intervals preceding and following the school start/end times were utilized to determine the start and end times of the trips.

2.4.4. Distance-based time

For study protocols lacking self-reported information, we propose a novel method to personalize the start and end times of trips to and from school. This method relies on the distance between home and school, leveraging the common availability of student address data held by schools. To estimate the duration of these trips, we employed quantile regressions, specifically targeting the 90th percentile to determine the time within which at least 90 % of participants would complete their walking trips. The resulting equation derived from our analysis is: duration = 3.77126 + 0.01633 * distance (from home to school). Detailed model residual analyses and error metrics are provided in the supplementary material (Fig. S2, Fig. S3, and Table S1). Predicted durations for specific distances were rounded to the nearest minute to maintain practical accuracy (see Table 1). Subsequently, start and end

Table 1
Proposed time for each interval distance in the distance-based time method.

Distance from home to school in meters	Time in minutes
0 to ≤ 250	8
>250 to ≤ 500	12
>500 to ≤ 1000	20
>1000 to ≤ 1500	28
>1500 to ≤ 2000	36
>2000 to ≤ 2500	44
>2500 to ≤ 3000	53
>3000 to ≤ 3500	61
>3500 to ≤ 4000	69
>4000 to ≤ 4500	77

times of the trips were established by adjusting the official school start and end times based on these distance-based duration estimates.

2.5. Quantification of sedentary time, LPA, and MVPA during walking trips to/from school

The MVPA levels were estimated using data collected from accelerometers (GT3X+, Actigraph, Pensacola, FL, USA), initialized to collect data at a sampling frequency of 90 Hz. The accelerometers were initialized and data were downloaded using Actilife software (v.6).

A database was created for each methodology, containing reported or estimated start and end times of the trips. Accelerometer data were processed using the open-source R package GGIR v.2.8–4 (Migueles et al., 2019). The GGIR pipeline included: (1) auto-calibration of raw accelerometer data based on local gravitational acceleration (Migueles et al., 2019), (2) detection and imputation of non-wear time (van Hees et al., 2011), (3) calculation of activity counts over 15-second epochs using the algorithm described by Neishabouri et al. (2022), facilitated by the open-source R package actilifecounts, and classification of MVPA with epochs above the established cut-point for MVPA of 574 counts/15 s (Evenson et al., 2008).

2.6. Statistical analysis

Participant data were presented as mean and standard deviation (SD), or frequencies and percentages as appropriate. Given that each participant had varying numbers of walking trips to/from school, mixed effects limits of agreement analyses were conducted using the *RMBA* package to assess the agreement between methodologies (Parker et al., 2016). The *RMBA* package provides information on mean bias and limits of agreement, thus Bland-Altman plots (Bland & Altman, 1986) were generated to visualize agreement between start to school and end times from school of walking trips identified by GPS compared with self-report, w30, w60, and distance-based time. Supplementary Bland-Altman plots for sedentary time, LPA, and MVPA accumulated during walking trips can be found (Fig. S4, Fig. S5, and Fig. S6 respectively).

Equivalence of sedentary time, LPA, and MVPA accumulated during walking trips, identified by GPS and other methodologies, was assessed. Methodologies were considered equivalent to GPS if the mean differences and 95 % confidence intervals between GPS and each methodology were within a proposed equivalence zone. To do this, a mixed model was fitted to compare the minutes identified by GPS with the rest of the methodologies, and an equivalence test was then performed, following Isager's (2019) recommendations, to determine whether the output of the model fell within the proposed equivalence zone. This method assesses whether the differences between two methods, along with their corresponding 90 % confidence interval, fall entirely within a pre-defined equivalence range, indicating that the methods can be considered effectively equivalent to no difference (Williams et al., 2022). Given the absence of a standardized threshold to define equivalence zones (O'Brien, 2021), the equivalence zone in this study was set at ± 5.0 min. This threshold was based on the minimum clinically significant difference in physical activity (PA), as variations smaller than this value are unlikely to lead to meaningful changes in health outcomes or clinical relevance (Chudasama et al., 2019; Piercy et al., 2018). All statistical analyses were performed using R software version 4.3.3 (R Core Team; Auckland, New Zealand), with a p-value < 0.05 considered statistically significant.

3. Results

Descriptive data on demographic characteristics, anthropometric measurements, trip direction, and characteristics of walking trips for all participants, stratified by sex, are presented in Table 2. The study included 93 participants (51 % girls) aged 14.6 ± 0.8 years old who collectively accumulated 272 walking trips to and from school, with 63

Table 2
Descriptive data of the participants and walking trips (mean ± SD).

	All (n = 93)	Boys (n = 43)	Girls (n = 48)
Participant characteristics			
Age (years)	14.6 ± 0.8	14.4 ± 0.8	14.5 ± 0.7
BMI	21.7 ± 3.9	21.8 ± 4.3	21.9 ± 3.6
FAS	3.1 ± 0.9	3.0 ± 0.9	3.1 ± 1.0
Walking trips characteristics*			
Trip direction n (%)			
To school	100 (36.7)	48 (39.0)	52 (34.9)
From school	172 (63.3)	75 (61.0)	97 (65.1)
Speed (km/h)	3.9 ± 0.9	4.1 ± 0.9	3.7 ± 0.8
Distance (m)	1275 ± 775	1567 ± 852	1046 ± 640
Duration (min)	19.6 ± 10.7	23.0 ± 11.8	16.9 ± 9.3

SD= Standard deviation; BMI = body mass index; kg = kilogram; h = hour; m = meter; min = minutes.

*Trip characteristics measured by GPS.

% originating from school and 37 % directed to school. Table 3 shows the start and end times of walking trips to and from school, as well as accumulated sedentary time, LPA, and MVPA during these trips, according to each methodology.

Fig. 1 shows the Bland-Altman plots for the agreement between the start and end times of walking trips to and from school identified by GPS and the rest of methodologies. Start times of walking trips to school identified by self-reported measures differed from GPS by -0.0 h (LoA_{95%}: -0.3 - 0.2 h). On the other hand, differences between w30 and GPS were -0.2 h (LoA_{95%}: -0.6 - 0.1 h), between w60 and GPS were -0.7 h (LoA_{95%}: -1.1 - -0.3 h), and between distance-based time and GPS were -0.2 h (LoA_{95%}: -0.5 - 0.0 h). Regarding end times from school, results showed differences between w30, and GPS were 0.2 h (LoA_{95%}: -0.2 - 0.6 h), between w60 and GPS were 0.7 h (LoA_{95%}: 0.3 - 1.1 h), and between distance-based time and GPS were 0.1 h (LoA_{95%}: -0.1 - 0.4 h).

The equivalency between the sedentary time accumulated during walking trips to and from school for each methodology used to identify the start and end times of these trips are shown in Fig. 2. Self-reported measures were the only methodology which fell within the proposed equivalence zone. Regarding the LPA accumulated during these walking trips, self-reported measures, w30, and distance-based time were considered equivalents to GPS, while w60 did not fall within the proposed equivalence zone (Fig. 3). Fig. 4 illustrates the MVPA accumulated

Table 3
Start and end times of walking trips to and from school, along with sedentary time, LPA, and MVPA during these trips, as identified by five different methodologies.

	GPS (mean ± SD)	Self- reported (mean ± SD)	w30 (mean ± SD)	w60 (mean ± SD)	Distance- based time (mean ± SD)
Start times of trips to school (hh:mm)	07:54 ± 00:18	07:48 ± 00:12	07:42 ± 00:06	07:12 ± 00:06	07.42 ± 00:12
End times of trips from school (hh: mm)	15:12 ± 00:24	NA	15:06 ± 00:18	15:36 ± 00:18	15:06 ± 00:18
Sedentary time to/from school (min)	4.9 ± 6.3	5.2 ± 6.7	12.9 ± 7.2	36.9 ± 9.5	11.5 ± 7.9
LPA to/from school (min)	4.8 ± 3.9	4.6 ± 3.5	7.8 ± 3.9	12.7 ± 5.6	7.3 ± 4.4
MVPA to/from school (min)	9.9 ± 7.7	7.9 ± 7.6*	8.9 ± 6.9	10.0 ± 7.9	9.3 ± 8.0

SD= Standard deviation; GPS = global positioning system; w30 = window of 30 min; w60 = window of 60 min; h = hours; min = minutes; LPA = light physical activity; MVPA = moderate-to-vigorous physical activity; NA: not applicable.

during walking trips to and from school, all the methodologies were considered equivalent to GPS, as the 95 % confidence intervals of the differences fell within the proposed equivalence zone.

4. Discussion

The aims of the current study were: (1) to detect walking trips to/ from school with different methodologies (GPS, self-reported, fixed windows [w30 and w60], and distance-based time), and (2) to compare the start/end times for the trips, and the time accumulated in sedentary time, LPA, and MVPA. Our main findings suggest that: (1) Self-reported measures showed the highest levels of agreement for defining start times of walking trips to school compared to GPS. Moreover, distance-based time exhibited a good level of agreement for both start and end times of walking trips to and from school identification; (2) the other methodologies for identifying the start and end times of walking trips to and from school compared to GPS differed between -1.0 to 0.4 min for trips to school and -2.6 to 0.5 for trips from school; (3) Self-reported measures were the only ones shown to be equivalent to GPS for determining sedentary time, LPA, and MVPA accumulated during walking trips to/ from school; (4) On the other hand, w30 and distance-based time were considered equivalent to GPS when analyzing LPA and MVPA accumulated during walking to and from school. W60 was only deemed equivalent to GPS when analyzing MVPA related to walking to and from school. Our findings underline the need to standardize the identification of start and end times of walking trips to and from school, as the identification may vary depending on the method used, which could lead to overestimations of LPA, MVPA, and sedentary time. Wherever feasible, GPS devices and self-report measures are the next best option. Distance-based time or w30 may still be viable solutions when the outcomes of interest are LPA or MVPA.

In terms of identifying the start and end times of walking trips to and from school, self-reported measures demonstrated the highest level of agreement for start times to school. Our findings align with previous studies comparing trip times using GPS and activity diaries (Bachu et al., 2001; Gálvez-Fernández et al., 2022; Stopher et al., 2007). For instance, the study by Galvez-Fernandez et al. (2022) reported that adolescents self-reported 0.8-1.0 min more time than GPS during commuting to school, suggesting that self-reported measures are nearly as effective as GPS devices. In contrast, w30 and w60 showed differences of approximately ± 12 min and ± 42 min, respectively, compared to GPS detection for start and end times. The use of time intervals may limit obtaining detailed individual-level information (Kelso et al., 2021). Galvez-Fernandez et al. (2022) noted that 90 % of trips fell within 30 min, yet some participants completed their commute in significantly shorter times, such as eight, 11, or 15 min, indicating that fixed time intervals may not accurately capture the variability in start and end times of walking trips to/from school. Conversely, the proposed distance-based time interval considers the actual distance from home to school, a key predictor of active commuting (Nordbø et al., 2020), thereby improving results compared to w30 or w60 and reducing variability among participants. Hence, in the absence of GPS, self-reported measures offer the best option for defining start times of walking trips to school, followed by distance-based time, which proved effective in identifying end times from school during walking trips. However, further studies are needed to assess differences in the end times from school using self-reported measures and to confirm the accuracy of this methodology for both directions.

Furthermore, our results suggest that failure to accurately identify the start and end times of trips can influence the levels of PA or sedentary time associated with this behavior. Specifically, our findings indicate that only self-reported measures were equivalent to GPS when analyzing sedentary time, LPA, and MVPA accumulated during walking trips to/from school. In contrast, methodologies using w30, w60, and distance-based time did not show equivalence to GPS in analyzing sedentary time during these trips. This discrepancy may explain why

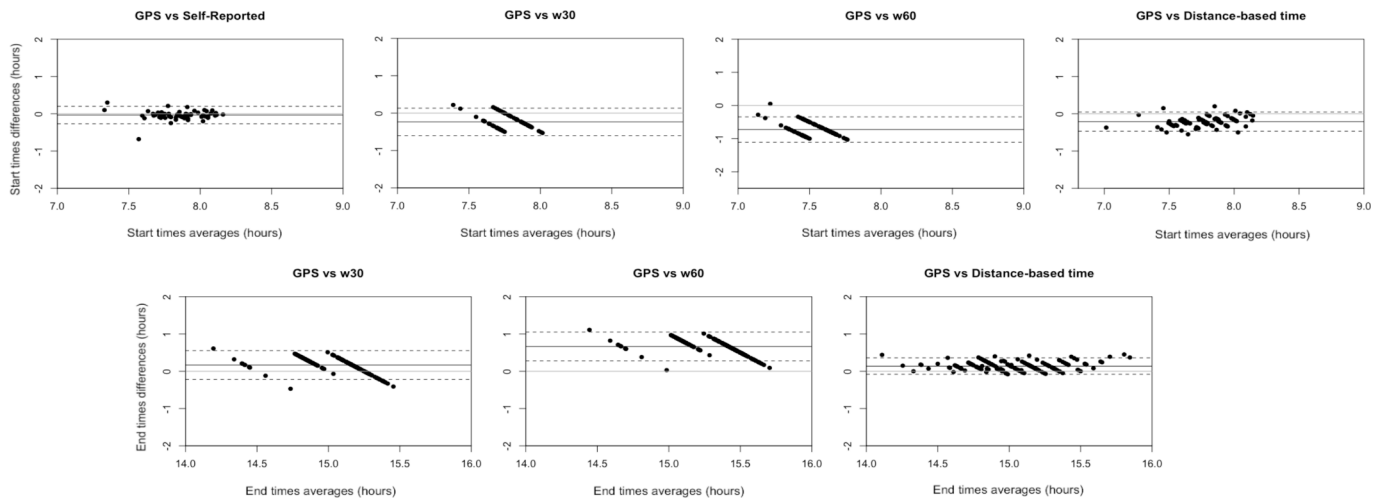


Fig. 1. Bland-Altman plots for the agreement between start and end times of walking trips to and from school identified by GPS and the rest of methodologies. The solid line represents the mean difference (bias) between the GPS and the corresponding method; points close to the grey horizontal line (perfect agreement) suggest good agreement between methods, while points outside the dashed lines indicate larger discrepancies; and the dashed lines represent the 95 % limits of agreement, which indicate the range within which most differences are expected to fall. Interpretation: The focus should be on whether the points are evenly distributed around the mean bias and within the limits of agreement. For instance, a clustering of points within the limits indicates better agreement. **GPS** = global positioning system; **SR** = self-reported measures; **w30** = window of 30 min; **w60** = window of 60 min. Hours from the previous midnight.

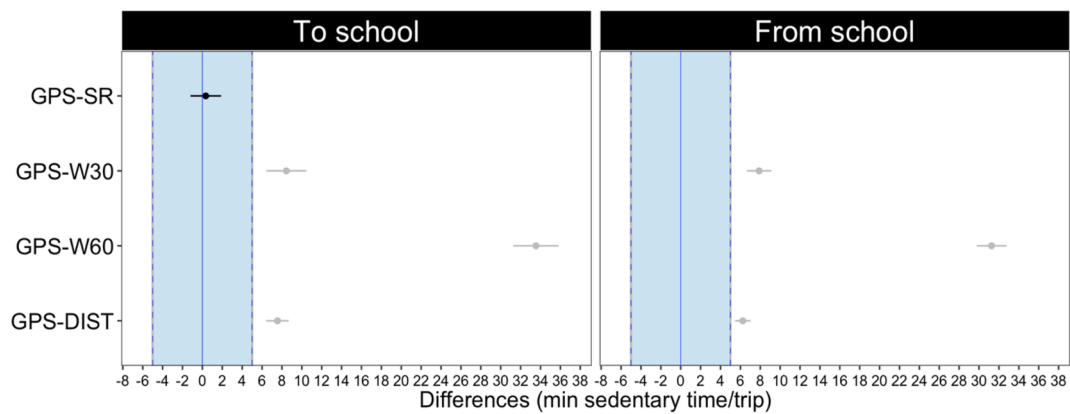


Fig. 2. Equivalence between methodologies for identifying the start and end times of walking trips to and from school and the accumulated sedentary time. The blue solid line represents perfect equivalence (zero difference) between the GPS and the corresponding method; points within the dashed lines (the proposed equivalence zone of ± 5.0 min) indicate negligible differences, while points outside the dashed lines suggest larger discrepancies. Black markers represent cases where the 95 % CI lies entirely within the equivalence zone, showing strong agreement, whereas grey markers indicate that the CI extends beyond the equivalence zone, signalling potential inconsistencies. Interpretation: The focus should be on whether the error bars (95 % CI) lie entirely within the equivalence zone. For instance, black markers suggest agreement between the GPS and the alternative method, while grey markers highlight differences that may not meet the equivalence criteria. **CI** = confidence intervals; **GPS** = global positioning system; **min** = minutes; **SR** = self-reported measures; **w30** = window of 30 min; **w60** = window of 60 min. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

previous studies using w60 to analyze sedentary time and PA levels during school commutes found no association between ACS and sedentary time (Owen et al., 2012). Regarding LPA, only w60 was not equivalent to GPS. This might be due to its wider window capturing activities outside ACS, such as housework or personal grooming, which are not related to school commuting (Butte et al., 2018). On the other hand, all methods were considered equivalent in identifying start time of walking trips to school and end times of walking trips from school when analyzing accumulated MVPA. Indeed, several studies have reported associations between ACS and MVPA (Gale et al., 2021; Khan et al., 2021; Larouche et al., 2014). However, these associations may vary depending on population characteristics and cultural settings; for example, adolescents participating in extracurricular activities after school may overestimate their PA levels (Kek et al., 2019; Mota et al., 2008). For example, studies conducted by Saksvig et al. (2007) and Saksvig et al. (2012) using time intervals reported nearly ten minutes

more MVPA during school-to-home than home-to-school trips. Future studies should investigate both arrival and departure times at school and home, as trip direction (home-to-school vs. school-to-home) has been shown to affect PA levels differently (Campos-Garzón et al., 2023c). Improving the accuracy of start and end times identification of walking trips to and from school will enhance the measurement tool, consistent with findings from previous studies comparing self-reported and GPS measures (Bachu et al., 2001; Gálvez-Fernández et al., 2022; Stophor et al., 2007).

When interpreting the findings of this study, several limitations should be considered: (1) The actual arrival and departure times from school were not directly observed; instead, official school timetables were used, which may differ from GPS-identified times. (2) GPS, although the gold standard for geolocation, may still have inaccuracies due to satellite signal disruptions, potentially affecting trip identification accuracy. (3) Walking trips to/from school that included pauses

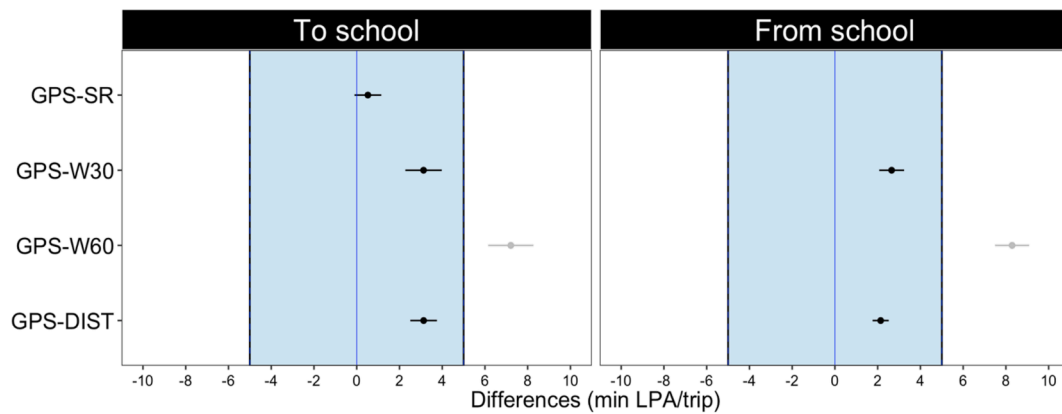


Fig. 3. Equivalence between methodologies for identifying the start and end times of walking trips to and from school and the accumulated LPA time. The blue solid line represents perfect equivalence (zero difference) between the GPS and the corresponding method; points within the dashed lines (the proposed equivalence zone of ± 5.0 min) indicate negligible differences, while points outside the dashed lines suggest larger discrepancies. Black markers represent cases where the 95 % CI lies entirely within the equivalence zone, showing strong agreement, whereas grey markers indicate that the CI extends beyond the equivalence zone, signalling potential inconsistencies. Interpretation: The focus should be on whether the error bars (95 % CI) lie entirely within the equivalence zone. For instance, black markers suggest agreement between the GPS and the alternative method, while grey markers highlight differences that may not meet the equivalence criteria. CI = confidence intervals; GPS = global positioning system; min = minutes; LPA: light physical activity; SR = self-reported measures; w30 = window of 30 min; w60 = window of 60 min. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

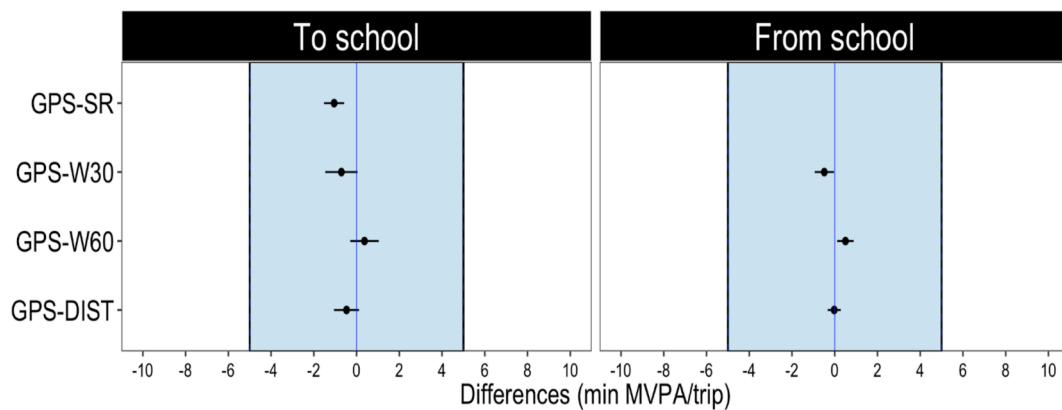


Fig. 4. Equivalence between methodologies for identifying the start and end times of walking trips to and from school and the accumulated MVPA time. The blue solid line represents perfect equivalence (zero difference) between the GPS and the corresponding method; points within the dashed lines (the proposed equivalence zone of ± 5.0 min) indicate negligible differences, while points outside the dashed lines suggest larger discrepancies. Black markers represent cases where the 95 % CI lies entirely within the equivalence zone, showing strong agreement, whereas grey markers indicate that the CI extends beyond the equivalence zone, signalling potential inconsistencies. Interpretation: The focus should be on whether the error bars (95 % CI) lie entirely within the equivalence zone. For instance, black markers suggest agreement between the GPS and the alternative method, while grey markers highlight differences that may not meet the equivalence criteria. CI = confidence intervals; GPS = global positioning system; min = minutes; MVPA = moderate-to-vigorous physical activity; SR = self-reported measures; w30 = window of 30 min; w60 = window of 60 min. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

longer than 10 min were not captured. (4) Trips with speeds outside the range of 2 km/h to 6.5 km/h were excluded from the analysis. (5) The findings may primarily apply to adolescents, and cultural factors could limit generalizability, particularly if adolescents engage in immediate post-school activities. (6) The study focused exclusively on walking trips to/from school; therefore, results may differ for other commuting modes like cycling or passive modes. (7) End times from school for self-reported measures were not assessed, as participants were not queried on this. (8) While the proposed distance-based time interval showed good agreement and equivalence with GPS, it remains a time interval method with inherent limitations. Otherwise, the current study shows some strengths that should be noted: (1) It integrated accelerometry and GPS data using HABITUS and PALMSplus R. (2) It compared the most commonly used methodologies in the literature for identifying active school trips (Campos-Garzón et al., 2023b); (3) It proposed a distance-based time interval method to enhance individualization of w30 and w60 per participant. (4) MVPA during walking trips to/from school was

quantified using the open-source software GGIR (Migueles et al., 2019).

The main findings of the present study represent only a first step toward addressing how to device-measured ACS-PA. Future studies should examine whether the self-reported measures also show an adequate level of agreement with GPS for trips from school to home. Moreover, it is essential to focus on assessing the level of agreement and equivalence between these methodologies in other modes of commuting, such as cycling or passive transportation. It is also important to note that this study was conducted with adolescents, making it necessary to carry out studies with children or even preschoolers to determine whether the results are consistent across different age groups. Lastly, future studies should refine the distance-based time estimates. For instance, there may be interactions by gender or by trip direction that we have not been able to observe in this study. Before recommending its implementation, future studies should try to improve this method with a larger and more varied sample.

In conclusion, this study suggests that in the absence of GPS, self-

reported measures can identify the start times of walking trips to school with a high level of agreement compared to GPS. Our novel proposed method, distance-based time, showed the second-best level of agreement for detecting start times of walking trips to school and was the best for detecting end times of walking trips from school compared to GPS. Moreover, self-reported measures were considered equivalent to GPS for measuring sedentary time, LPA, and MVPA. On the other hand, w30 and distance-based time were deemed equivalent to GPS for detecting LPA and MVPA, while w60 was shown to be only equivalent to MVPA accumulated during walking trips to and from school. Therefore, in the absence of GPS devices and self-report measures, estimating the time to complete the trip based on the distance between home and school could be more appropriate than pre-defining fixed windows. The findings of this study hold significant relevance for researchers seeking to determine the most accurate and suitable methodology for detecting the start and end times of walking trips to and from school, and how it can affect sedentary time, LPA, and MVPA accumulated during these behaviors.

CRedit authorship contribution statement

P. Campos-Garzón: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **A.J. Lara-Sánchez:** Writing – review & editing, Investigation. **A. Queralt:** Writing – review & editing, Investigation. **J. Schipperijn:** Writing – review & editing, Visualization, Supervision, Methodology. **T. Stewart:** Writing – review & editing, Supervision, Methodology, Formal analysis. **Y. Barranco-Ruiz:** Writing – review & editing, Visualization, Supervision. **P. Chillón:** Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **J.H. Migueles:** Writing – review & editing, Visualization, Supervision, Methodology, Formal analysis, Conceptualization.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.tbs.2025.100996>.

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