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REVIEW

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Contribution of active commuting to and from school to device-measured physical activity levels in young people: A systematic review and meta-analysis

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Abstract

Objective: To analyze the contribution of active commuting to and from school (ACS) to device-measured light physical activity (LPA) and moderate-to-vigorous physical activity (MVPA) levels in young people aged 6 to 18 years old, as well as, in both trip directions (i.e., home-school, school-home).

Methods: This systematic review was conducted according to the PRISMA statement, and five different databases were used for the systematic search (PubMed, Web of Science, SPORTdiscuss, Cochrane Library, and National Transportation Library) using PECO strategy.

Results: A total of 14 studies met all the eligibility criteria, which compile 7127 participants. The overall ACS weighted LPA was 19.55 min (95% CI: 3.84-35.26; $I^2=99.9\%$, $p<0.001$) and 68.74 min (95% CI: 6.09-131.39; $z=2.15$, $p=0.030$) during the home-school and school-home trips, respectively. For MVPA, the overall ACS weighted MVPA was 8.98 min (95% CI: 5.33–12.62; $I^2=99.95\%$, $p<0.001$) during the home-school trip and 20.07 min (95% CI: 13.62-26.53; $I^2=99.62\%$, $p<0.001$) during the school-home trip.

Conclusion: ACS may contribute about 48% of the PA recommendations in young people on school days if both trip directions are actively performed. Therefore, future studies aimed at increasing daily PA levels in young population should focus on promoting students' ACS.

PROSPERO registration number: CRD42020162004A.

KEYWORDS
accelerometer, active transport, health promotion, physical activity, school, youth

1 | INTRODUCTION

Young people's compliance with at least an average of 60 min of moderate-to-vigorous physical activity (MVPA) per day is associated with social, psychological, and physical benefits.[1] However, according to the Global Matrix 4.0, less than the 30% of the world's children and adolescents meet PA guidelines.[2] Moreover, while most studies have focused on the association between MVPA and health indicators, light PA (LPA) levels have also been positively related to a wide range of benefits in children and adolescents.[3] Therefore, it is essential to promote regular PA (both LPA and MVPA) in the youth population, and every movement counts.[4]

An increase in daily PA levels could be achieved through different domains such as school, home, transport, or leisure locations.[5] Active commuting to/from school (ACS) by mainly walking and/or cycling has been recognized as a good source of increasing PA levels on school days for young students,[6,7] because they commute at least twice a day. In addition, a large body of research have shown that ACS not only increases daily PA levels, but could also provide many health benefits (e.g., physical fitness attributes[8] and well-being improvement[9]) and other non-health benefits (e.g., economic cost reduction[10]). Moreover, the World Health Organization (WHO) and the United Nations, through the Global Action Plan of Physical Activity 2018-2030[11] and the 2030 Agenda for Sustainable Development,[12] consider ACS as one of the main global policy priorities to create active societies.

Nevertheless, it is unclear to date how many minutes of LPA and MVPA derived from ACS contribute to total PA levels in the young population on school days. In the last years, the number of studies using device-measured PA for the analysis of ACS-related PA (hereinafter referred to as ACS-PA) have increased exponentially to answer this research question.[13] In addition to providing detailed information on PA performed in free-living conditions,[14] these devices overcome the limitations present in self-reported measures such as recognition, memory, or social desirability biases of the participants.[15] For example, as Adamo et al.[16] suggested, self-reported measures can overestimate device-measured PA levels by up to 70%, especially in the pediatric population. Therefore, for a correct assessment of the ACS-PA, device-measured PA such as accelerometers or pedometers seem to be the most appropriate devices, depending on the mode of commuting.

To best of our knowledge, only two systematic reviews (one of them with meta-analysis) have analyzed the association between ACS and PA levels on school-age children and adolescents.[6,7] Larouche et al.[6] showed that ACS was associated with higher daily PA levels (0–45 min of MVPA) and greater number of daily steps in most of the studies examined. While, the systematic review and meta-analysis by Martin et al.[7] indicated that walking to/from school could lead to achieve with PA recommendations of 23% in children and up to 36% in adolescents on school days. In order to make new contributions to the scientific literature, it is necessary to consider the limitations mentioned by these two studies.[6,7] First, considering the use of device-measured PA as an inclusion criterion overcomes the limitations associated with self-reported measures. In addition, it is important to consider not only walking, but also, cycling, since it has been shown that depending on the active mode of commuting to/from school may have different benefits,[17,18] where cycling provides higher physical health benefits than walking.[8] In addition, analyzing both trip directions (i.e., home-school and school-home) separately could be necessary since they may have different PA benefits.[19] Bearing in mind that all movement counts, it is necessary to analyze not only MVPA levels, but also LPA.[3,20] In addition, it seems appropriate to update these data because it has been 8 years since the last search (i.e., February 2015) of the last systematic review and meta-analysis.[7]

Therefore, considering the gaps and limitations of the previous studies, the current systematic review and meta-analysis aimed to analyze the contribution of ACS to device-measured LPA and MVPA levels in young people, as well as, in both trip directions (i.e., home-school and school-home).

2 | METHODS

Several types of reviews have emerged in the recent years.[21] The type of review that best answers our research question in the current study is the systematic review, because it makes the methods explicit, systematic, and reproducible, thus capturing all studies that meet the inclusion and exclusion criteria established to answer the proposed research question.[22] In addition, the complementary use of meta-analysis makes it possible to quantitatively synthesize research effect sizes across studies.[21,23] This systematic review and meta-analysis was registered in the PROSPERO International Prospective Register of Systematic review (Registration number: CRD42020162004). In addition, for more information about the methodological process of this systematic review, further details can be found in the protocol.[24] The current study was conducting according to the checklist "Preferred Reporting Items for Systematic Reviews and Meta-analysis: The PRISMA Statement"[22] (see Tables S1 and S2 in Additional File 1).

2.1 | Inclusion criteria

Studies were included if they had met the following criteria: (1) study design had to be a cross-sectional, longitudinal, or intervention (i.e., randomized and non-randomized trials) assessing ACS-PA with device-measured PA; (2) apparently healthy children and adolescents, aged 6 to 18 years old, who were actively commuting to and/or from school by walking, and/or cycling in free-living conditions; (3) ACS-PA had to be reported as LPA and/or MVPA in minutes during ACS; and (4) peer-reviewed studies whose title and abstract were written in English and/or Spanish language were included.

On the contrary, exclusion criteria were (1) populations with any physical disorder; (2) populations outside the 6-18 age range; (3) studies that assessed ACS-PA using self-reported tools; (4) studies that analyzed active modes of commuting to and/or from school different from walking/cycling or unspecified (i.e., ACS), as these are the most examined in the scientific literature[13]; (5) studies that did not specify the trip direction; (6) studies that did not report a dispersion value (e.g., standard error, standard deviation, and confidence interval) associated with the mean number of minutes of MVPA during ACS; and (7) gray literature (e.g., abstracts and congress communications).

2.2 | Search strategy

The keyword combination formula for the systematic search was created following: (1) the indications of Gusenbauer & Haddaway[25]; (2) based on different systematic reviews published on this topic[6,7,26]; and (3) according to the "PECO" (i.e., population, exposure, comparison, and outcomes) strategy.[27] Lastly, given the lack of criteria for which databases to use,[23,25] those used by previous systematic reviews on this topic were used.[6,7,24,26,28] Therefore, the literature search was conducted in five different databases (Pubmed, Web of Science, SPORTdiscuss, Cochrane Library, and National Transportation Library) up to the November 4, 2022.

2.3 | Study selection

EndNote citation manager was used to manage, import, and remove duplicates studies. According to the recommendations of Gunnell et al.,[23] the study selection was split into three steps: (1) abstract and titles were screened by P.C.-G. paired with J.S.-S., Y.B.-R., and P.Ch. according to the inclusion criteria; (2) the same pairs reviewed the full text of the potential studies to be included; and (3) P.C.-G. also analyzed the references of the included studies to identify potential studies ignored during the systematic search (see Figure 1). The agreement percentage of the authors in the first step was 78%, 83% during the screening of full text, and 100% after resolving the discrepancies.

2.4 | Data extraction

Data collection process was carried out by one author (P.C.-G). In addition, each of the authors (J.S.-S., Y.B.-R., and P.Ch.) analyzed a random 10% of the included studies.[29] Data extracted from the studies were as follows: (1) author(s), year, and country; (2) sociodemographic variables/information (e.g., residence place or gender); (3) sample and age; (4) study design; (5) ACS mode (i.e., walking, cycling, or ACS [when the study specified or did not specify the ACS mode]); (6) trip direction (i.e., home-school and/or school-home); (7) identification of the ACS trip start/end points/times (methodology used to define the time frame where and when ACS took place, using GPS or predefined time intervals); (8) mean MVPA in minutes during ACS; and (9) mean LPA in minutes during ACS. In case that the included studies reported multiple measurement times (e.g., pre–post data after an intervention program), the information included was for the first measurement (i.e., baseline). It should be noted that the age and sample of each study are of the participants who actively commutes to and/or from school. Finally, in case an item was not reported or was not clear in the study, it was rated as "not reported" or "not clear," respectively. Discrepancies were resolved by discussion between the authors who carried out the data collection process. In addition, the data necessary for the risk of bias and quality assessment were extracted.

2.5 | Data synthesis

Following previous systematic reviews with meta-analysis[30–32] and the results by Campos-Garzón et al.[13] which pointed out the existence of different methodologies that may influence the results of ACS-PA, a random-effects model was used to pool the PA results of the included studies (DerSimonian and Laird method)[33] using Stata (version 17.0; StataCorpo.) and the *admetan* procedure.[34] Through a random-effects model, the heterogeneity among included studies, their generalizability, their wider applicability in different situations, and conservative approach in estimations were taken into account. The DerSimonian and Laird method was used in the meta-analysis to estimate the pooled variance and weighted average effect of the included studies, because it was expected variability among the results of the studies. In addition, this method was used to display the results as forest plots. The confidence intervals were set at 95% and the pooled PA[35] calculated. Heterogeneity across effect sizes was calculated using the inconsistency index (I^2).

LPA and MVPA were expressed in minutes in all included studies. A pooled global estimate was calculated according to the trip direction (i.e., home-school and/or school-home). Moreover, in the case that the studies did not differentiate both trip directions (i.e., unspecified), the LPA and MVPA contributions of each study were averaged. In addition, studies were also separated according to the mode of ACS reported, as well as whether special conditions were followed in their study (e.g., children and adolescents were assessed separately, or estimation of different PA intensities was used). A weighting factor, based on the study sample size, was used to weight the proportional LPA and MVPA in the pooled estimate. Finally, a random-effects meta-regression analysis was used to determine whether the amount of PA differed from the predefined time interval used in the study.

Meta-analysis results were reported differentiating by PA intensity (LPA or MVPA), differentiating by trip direction (home-school trips, school-home trips, or unspecified), and within each trip direction differentiating by mode of commuting (ACS, walking, cycling, or unspecified). Furthermore, the same analyses were replicated by including only those studies that used GPS or used a time interval up to 60 minutes, as these are the most used methodologies in the scientific literature for the trip identification[13] (see Figures S1 and S2 in Additional File 2).

3 | RESULTS

3.1 | Study selection

The PRISMA 2020 flow diagram is presented in Figure 1. Initially, the systematic search yielded 7908 original

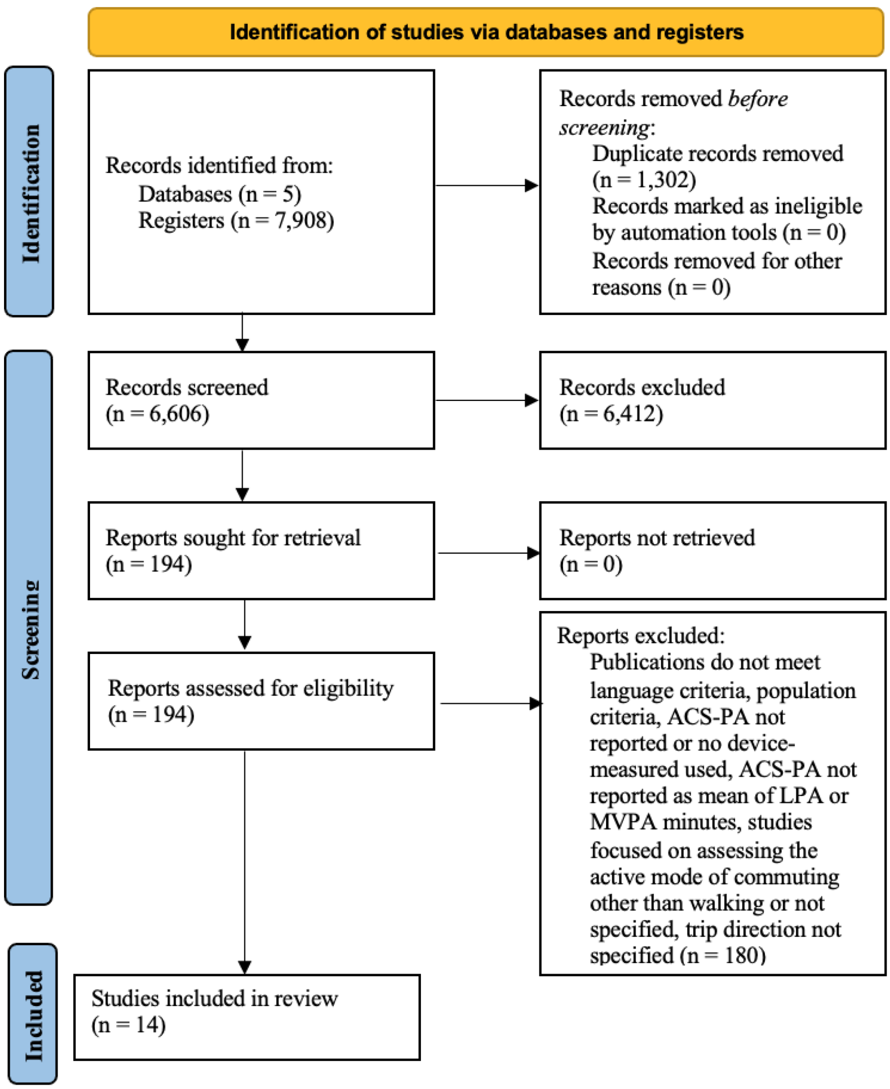

FIGURE 1 PRISMA flow diagram of the study selection process.

studies from five databases. After discarding duplicates, 6606 were screened by title and abstract. Then, 201 articles were reviewed in full text and based on the inclusion and exclusion criteria, 14 studies were included in the current systematic review and meta-analysis.

3.2 | Study characteristics

Of these 14 studies ($n = 7127$ participants), 11 had a cross-sectional design, two had a longitudinal design, and one study had an intervention design. Regarding the country where these studies were conducted, four were carried out in the United Kingdom,[36–39] two each in the United States,[40,41] Canada,[42,43] Spain,[44,45] and in New Zealand,[46,47] and one study in The Netherlands.[48] Furthermore, one of the included studies was carried out in 12 different countries (Australia, Brazil, Canada, China, Colombia, Finland, India, Kenya, Portugal, South Africa, United Kingdom, and United States).[49]

A total of 42.9% ($n = 6$) of the included studies were conducted in children ($n = 3525$)[36–39,44,49] and 57.1% ($n = 8$) in adolescents ($n = 3602$).[40–43,45–48] Regarding trip direction, eight of the included studies only assessed the home-school trip,[36–39,42–45] and six of the included studies assessed both trips direction (i.e., home-school and school-home)[40,41,46–49] (see Table 1 for more details). The device used to measure PA in all included studies was the accelerometer.

3.3 | Meta-analysis

3.3.1 | Contribution of ACS to LPA levels

Only one study assessed walking LPA during the home-school trip, reporting a mean of 5.90 min/day (95% CI: 3.77–8.03).[26] On the contrary, studies that did not report the specific active mode of commuting to/from school ($n = 4$) showed a mean LPA of 22.28 min/day during the home-school trip (95% CI: 4.71–39.86; $I^2 = 99.9\%$, $p < 0.001$). Weighted LPA in the home-school trips across the five studies (there were six samples, because the study of Denstel et al.[49] had two different samples) was 19.55 min/day (CI 95%: 3.84–35.26; $I^2 = 99.9\%$, $p < 0.001$) (Figure 2). Regarding the school-home trip, the mean LPA accumulated while actively commuting from school ranged from 13.40 to 148.90 min/day. Weighted LPA in the school-home trips across the five studies (the study of Denstel et al.[49] had two different samples) was 68.74 min/day (95% CI: 6.09–131.39; $z = 2.15$, $p = 0.03$; Figure 3).

3.3.2 | Contribution of ACS to MVPA levels

The home-school trip mean daily MVPA of the included studies that did not specify the active mode of commuting to/from school ranged from 0.70 to 13.40 min/day. In this case, weighted MVPA in the home-school trips across the eight samples (although there were six studies, the studies of Voss et al.[43] and Denstel et al.[49] had two different samples) was 8.03 min/day (95% CI: 4.48–11.59; $I^2 = 99.79\%$, $p < 0.001$). For those six studies which specify walking as the active mode of commuting in the home-school trips, the mean daily MVPA ranged from 4.03 to 15.40 min/day. Weighted MVPA in the home-school trips across the eight studies was 9.88 min/day (95% CI: 6.51–13.25; $I^2 = 99.73\%$, $p < 0.001$). The overall weighted MVPA of both ACS and walking was 8.98 min/day (95% CI: 5.33–12.62; $I^2 = 99.95\%$, $p < 0.001$). There were no differences between groups (i.e., studies which did not report the active mode of commuting to school and studies which reported walking as mode of commuting to school; $p = 0.46$; Figure 4).

Regarding the school-home trips MVPA of those studies which did not report the specific active mode of commuting from school, the results ranged from 5.10 min/day to 36.20 min/day. Weighted MVPA in the school-home trips across the five samples (although there were four studies, the study of Denstel et al.[49] had two different samples) was 18.80 min/day (95% CI: 6.68–30.91; $I^2 = 99.74\%$, $p < 0.001$). For the two studies which reported walking as the active mode of commuting from school, the results ranged from 22.50 to 23.90 min/day. Weighted MVPA in the school-home trips was 23.89 min/day (95% CI: 23.71–24.08; $I^2 = 0.00\%$, $p < 0.001$). Finally, the overall MVPA in the school-home trips of both ACS and walking was 20.07 min/day (95% CI: 13.62–23.53; $I^2 = 99.62\%$, $p < 0.001$). There were no differences between groups (i.e., studies which did not report the active mode of commuting from school and studies which reported walking as mode of commuting from school; $p = 0.41$; Figure 5).

4 | DISCUSSION

The aim of this systematic review and meta-analysis was to analyze the contribution of ACS to device-measured LPA and MVPA levels in young people, considering both trip directions (i.e., home-school and/or school-home) together and separately. The main findings of the meta-analysis were the following: (1) ACS could contribute about the 48% of the daily PA recommendations for health in young people on school days; (2) higher levels of LPA and MVPA were found in the school-home trips compared to home-school trips. Therefore, these findings

TABLE 1 Characteristics of the studies that assessed ACS-PA[a]

Author (s) year, country	Sociodemographic variables/ information	Sample; age (years)	Study design	ACS mode	Trip direction	Start/end times of the ACS-PA	Mean MVPA during ACS	Mean LPA during ACS
Cooper et al. 2003, United Kingdom[36]	N/A	74 children; 10.4 (0.8)	Cross-sectional	Walking	Home-school	Predefined time interval of 60 min	15.4 min	Not reported
Saksvig et al. 2007, United States[41]	N/A	120 adolescents; 12.0 (0.5)	Cross-sectional	Walking	Home-school	Predefined time interval from 6:00 am to school start bell time	13.0 min	Not reported
	N/A	190 adolescents; 12.0 (0.5)	Cross-sectional	Walking	School-home	Predefined time interval from school end bell time to 5:00 pm	10.1 min	Not reported
Cooper et al. 2010, United Kingdom[37]	N/A	179 Children; 11.3 (0.3)	Cross-sectional	Walking	Home-school	Predefined time interval of 60 min and GPS	5.4 min	Not reported
Cooper et al. 2012, United Kingdom[38]	N/A	435 children; 11.0 (0.4)	Longitudinal	Walking	Home-school	Predefined time interval of 60 min	7.2 min	Not reported
Saksvig et al. 2012, United states[40]	N/A	944 adolescents; 14.0 (0.5)	Cross-sectional	Walking	Home-school and school-home	Predefined time interval from 6:00 am- school start bell time and school end bell time-5:00 pm	Home-school: 13.2 min School-home: 22.5 min	Not reported
Voss et al. 2014, Canada[43]	N/A	51 adolescents; 13.3 (0.7)	Cross-sectional	ACS	Home-school	Predefined time interval of 60 min	13.3 min	Not reported
	N/A	51 adolescents; 13.3 (0.7)	Cross-sectional	ACS	Home-school	GPS	8.7 min	Not reported
Denstel et al. 2015, 12 countries[49]	Gender (Boys)	1222 children; 10.4 (0.6)	Cross-sectional	ACS	Home-school and school-home	Barreira et al. algorithm[50]	Home-school: 8.8 min School-home: 36.2 min	Home-school: 35.9 min School-home: 147.9 min
	Gender (Girls)	1417 children; 10.4 (0.6)	Cross-sectional	ACS	Home-school and school-home	Barreira et al. algorithm[50]	Home-school: 7.1 min School-home: 29.0 min	Home-school: 36.1 min School-home: 148.9 min
Voss et al. 2015, Canada[42]	N/A	49 adolescents; 13.3 (0.7)	Cross-sectional	ACS	Home-school	GPS	9.4 min	Not reported
Ginja et al. 2017, United Kingdom[39]	N/A	26 children; 9.0	Cluster randomized trial	ACS	Home-school	Predefined time interval of 59 min	4.9 min	Not reported
Kek et al. 2019, New Zealand[47]	N/A	73 adolescents; 14.7 (1.2)	Cross-sectional	ACS	Home-school and school-home	Predefined time interval of 60 min	Home-school: 12.7 min School-home: 13.3 min	Home-school: 15.7 min School-home: 16.3 min

TABLE 1 (Continued)

Author (s) year, country	Sociodemographic variables/ information	Sample; age (years)	Study design	ACS mode	Trip direction	Start/end times of the ACS-PA	Mean MVPA during ACS	Mean LPA during ACS
Martinez-Martinez et al. 2019, Spain[44]	N/A	172 children; 9.25 (0.59)	Cross-sectional	Walking	Home-school	Predefined time interval of 60 min	4.0 min	Not reported
Villa-González et al. 2019, Spain[45]	N/A	18 adolescents; 15.0 (0.1)	Cross-sectional	Walking	Home-school	GPS	11.4 min	5.9 min
Remmers et al. 2020, Netherland[48]	N/A	Adolescents; 12.1 (0.4)	Longitudinal	ACS	Home-school and school-home	Predefined time interval from 6:00 a.m. to start school time and GPS	Home-school: 0.7 min School-home: 5.1 min	Home-school: 2.8 min School-home: 13.4 min
Gale et al. 2021, New Zealand[46]	N/A	25 adolescents; 16.7 (0.9)	Cross-sectional	ACS	Home-school and school-home	Predefined time interval of 60 min	Home-school: 8.1 min School-home: 10.3 min	Home-school: 20.9 min School-home: 17.2 min

Abbreviations: ACS, active commuting to/from school; ACS-PA, active commuting to/from school related physical activity; GPS, global positioning system; LPA, light physical activity; min, minutes; MVPA, Moderate to vigorous physical activity; N/A, not applicable.

[a]Only the information and data of the first measurement time (i.e., baseline) were considered and when the same article uses different ACS-PA quantification methodologies, these will be presented in different lines within the same article.

suggest that ACS may be a good and feasible strategy to increase students LPA and MVPA levels on school days. Actively perform both trip directions (i.e., home-school or school-home) could help young people to accumulate up to almost half of the daily PA recommendations. The results suggest that both home-school and school-home trips should be measured because different LPA and MVPA levels are accumulated during these ACS trips. According to Campos-Garzón et al.,[13] it is also needed to create a standardized protocol for measuring ACS to facilitate comparison of results across studies. In this regard, a series of recommendations are provided for researchers throughout the discussion of the present study.

First, the results of this systematic review and meta-analysis suggest that ACS can result in up to 19.55 min/day LPA in the home-school trips and 68.74 min/day LPA in the school-home trips. These results would be promising given ACS may help to achieve several health benefits associated with LPA.[3] However, it is necessary to point out some issues: (1) the small number of studies that analyze the contribution of LPA to ACS on both home-school and school-home trips. ACS studies have tended to focus on MVPA minutes rather than LPA minutes. Indeed, the two systematic reviews with meta-analyses conducted to our knowledge have not examined ACS-LPA.[6,7] Nowadays, because the WHO in the latest recommendations states that any movement counts, LPA is beginning to be analyzed in more studies linked to ACS[51]; (2) the high LPA minutes are closely related to studies that did not use GPS to identify trips. The two studies that used GPS[45,48] reported less than 14 minutes of LPA in the analyzed trips, but studies that used time intervals report a range from 15.70 to 148.90 min of LPA. The use of time intervals precludes to obtain information at the individual level[52] and ACS will largely depend on the distance the participants live from the school.[53] Seeing that the time intervals used in these studies are at least 60 min, this time differs greatly from the estimated walkable distance for children and adolescents in Spain[54] and Belgium,[55,56] for adolescents in Ireland,[57] or children in Australia,[58] which would be completed in approximately 15 min. Therefore, the LPA results of this meta-analysis seem to be not only related to ACS but may also include activities at home or other extracurricular activities, particularly in the home-school trips. This could be because, unlike on the home-school trip, many young people after school could play or do extracurricular activities instead of going home. Nevertheless, it is important to note that, as can be seen in the Figures S1 and S2, when excluding the study by Denstel et al.,[49] the range of LPA minutes for the home-school trip was 14.06 min and for the school-home trip was 16.51 min, results that may be considered more in line with a more walkable distance for an ACS trip. This mentioned study[49] did not identify

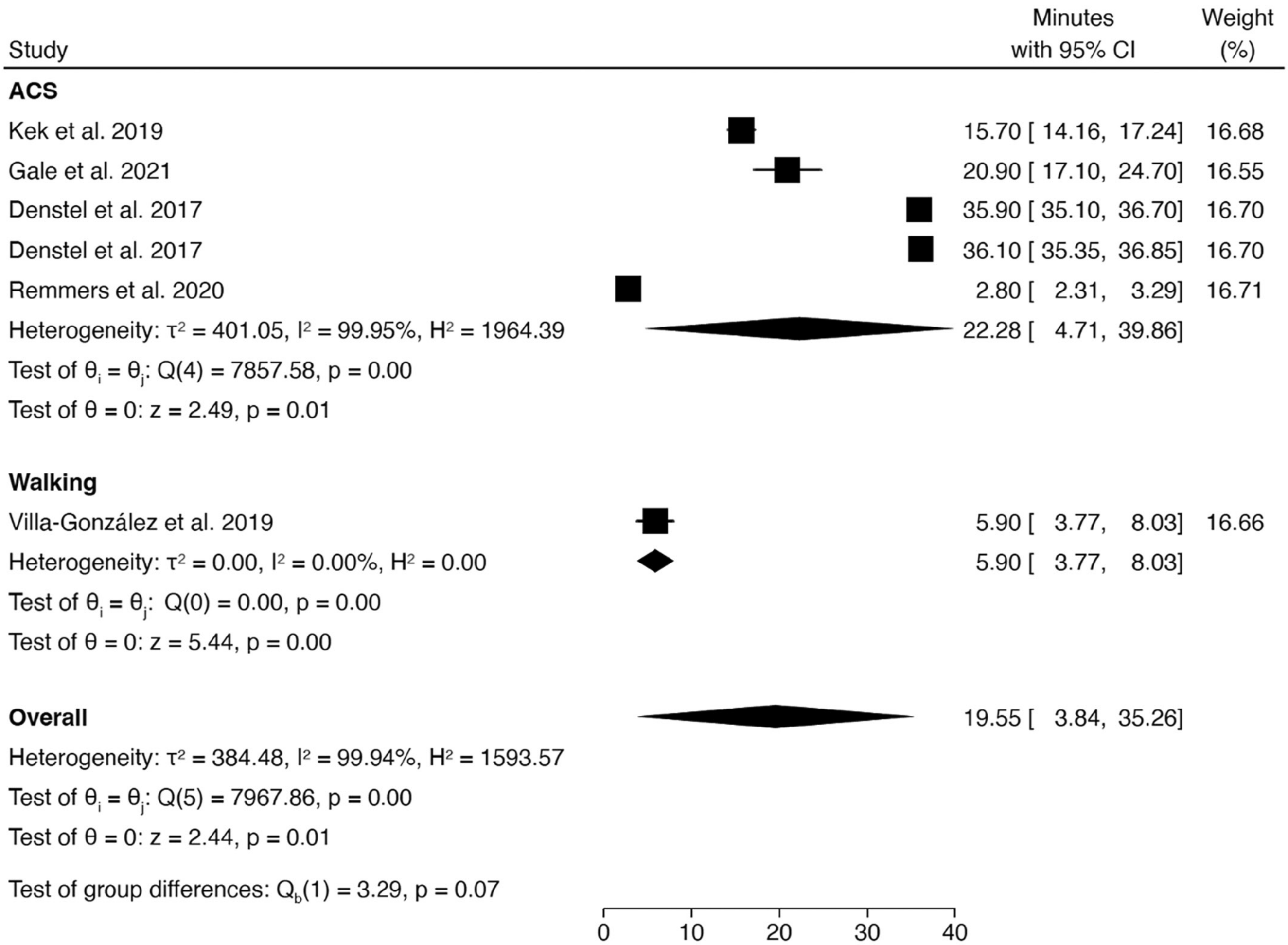

FIGURE 2 Pooled estimated light physical activity minutes/day during the home-school trip by walking and ACS. Note: 95% CI, 95% confidence interval; ACS, active mode of commuting to school not specified; τ2, tau-squared; I2, inconsistency index; H2, H2 index; Test of θ, likelihood-ratio test; Q, assesses the heterogeneity by measuring the discrepancy between individual study results and the overall effect size; z, z-score.

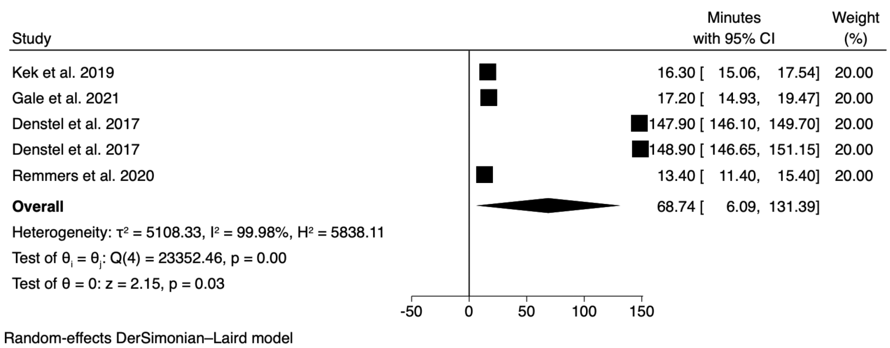

FIGURE 3 Pooled estimated light physical activity minutes/day during the school-home trip of studies that did not specify the active mode of commuting. Note: 95% CI, 95% confidence interval; *z*, *z*-score; Test of θ: likelihood-ratio test.

a time interval but used an algorithm to determine the time before and after school. Therefore, caution should be taken when extrapolating these results to those that could be provided by ACS. Future studies should compare the most frequent methodologies used for the identification of the start/end times of the trip (i.e., GPS or time intervals) to clarify the possible ACS-PA overestimation in the results. In addition, the use of GPS will ensure a more accurate estimation of home-school and school-home trips, and if GPS is not available, self-reported measures such as activity diaries maybe be also a good option.[59] In case of using a time interval, the home-school distance should be considered to try to individualize the time interval applied to each participant.

Regarding MVPA levels, walking or ACS in the home-school trip could provide 14.96% of the daily PA recommendations, while in the school-home trip this percentage goes up to 33.45% on school days. If these results are

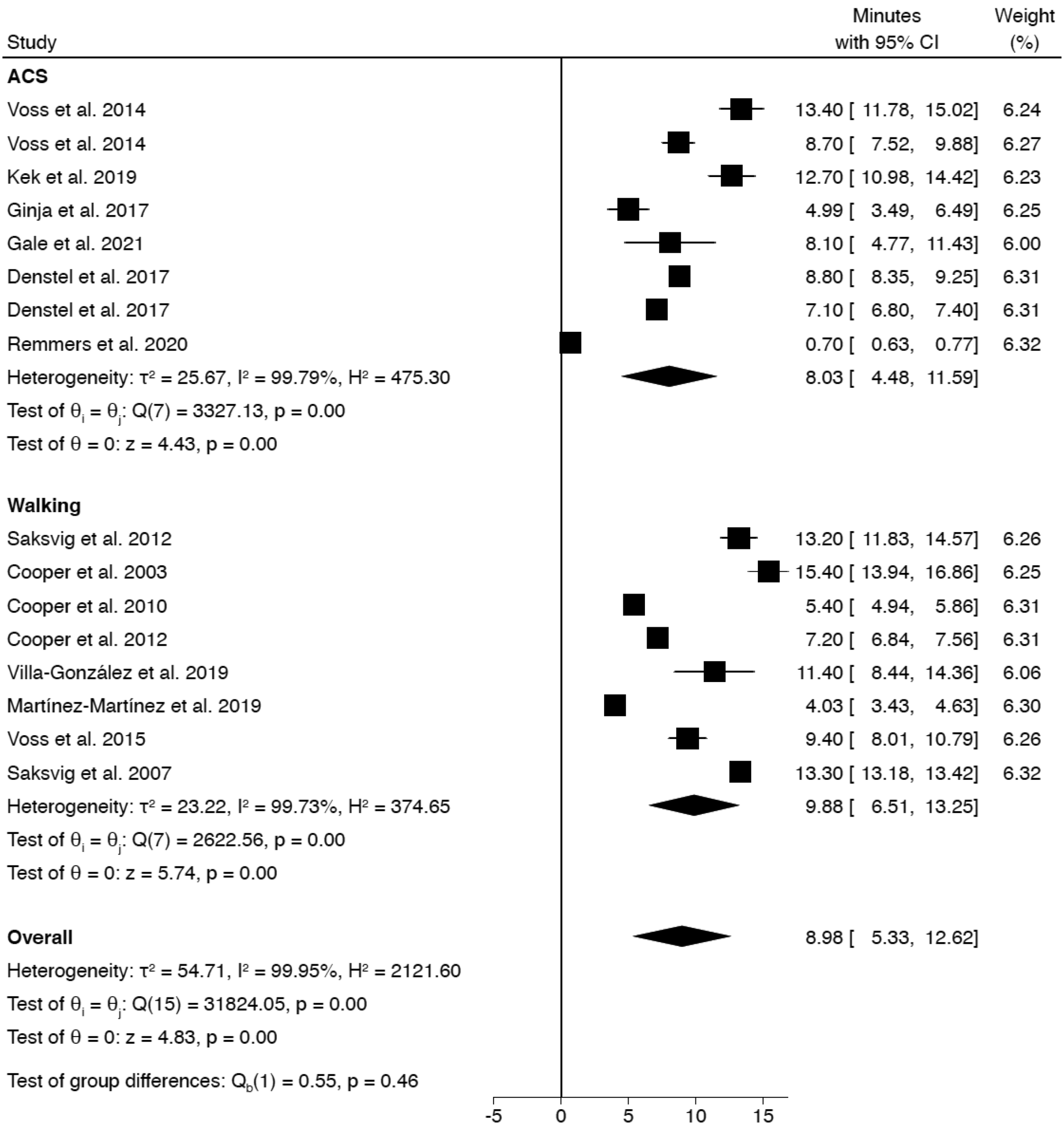

FIGURE 4 Pooled estimated moderate-to-vigorous physical activity minutes during the home-school trip. Note: 95% CI, 95% confidence interval; ACS, active mode of commuting to school not specified; τ^2, tau-squared; I^2, inconsistency index; H^2, H^2 index; Test of θ: likelihood-ratio test; Q, assesses the heterogeneity by measuring the discrepancy between individual study results and the overall effect size; *z*: *z*-score.

analyzed separately, they are below those reported by Martin et al.[7] in their meta-analysis (i.e., 23% for children and 36% for adolescents). However, in the study conducted by Martin et al.,[7] they did not report whether their percentages were the sum of the two directions or just one direction. Thus, the results obtained in this meta-analysis suggest that a single active trip may account for between 14.96%–33.45% of the PA recommendations for health in young people, since one single active trip supposes between 8.98 and 20.07 min of MVPA. Moreover, if the two trips (i.e., home-school and school-home) are actively commuted, almost 48% of the daily PA recommendations could be achieved on school days (home-school trip: 8.98 min and school-home trip: 20.07 min). Supporting

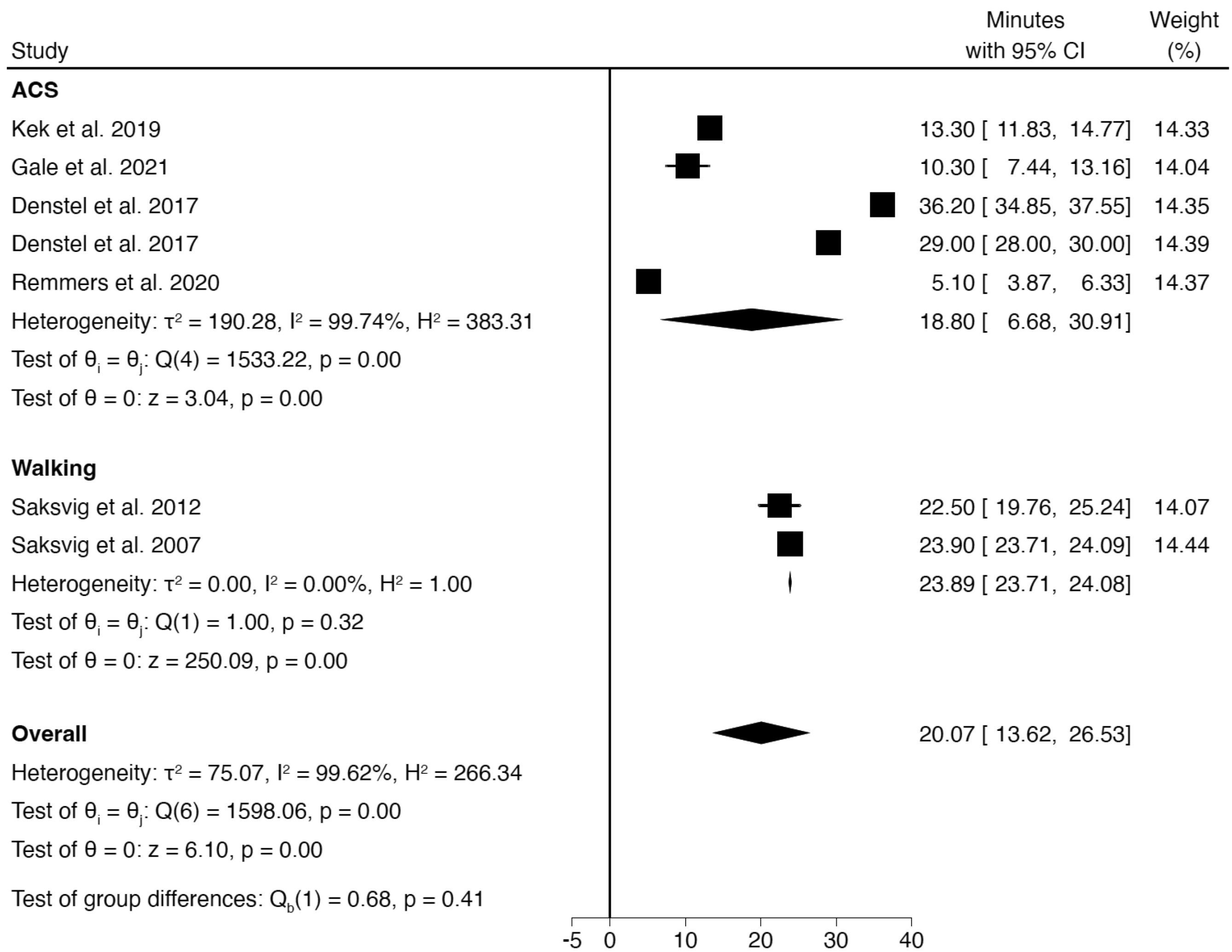

FIGURE 5 Pooled estimated moderate-to-vigorous physical activity minutes during the school-home trip. Notes: 95% CI, 95% confidence interval; ACS, active mode of commuting to school not specified; τ^2, tau-squared; I^2, inconsistency index; H^2, H^2 index; Test of θ: likelihood-ratio test; Q, assesses the heterogeneity by measuring the discrepancy between individual study results and the overall effect size; *z*: *z*-score.

these results, the study carried out by Khan et al.[60] in 80 countries found that young people who actively commute to/from school have 2.4 possibilities in low-income countries, the double possibilities in middle-income countries, and 1.8 possibilities in high-income countries of meeting PA recommendations than those who passively commute to/from school. Therefore, given that the results of the present meta-analysis are consistent with other studies[6,7,60] and that scientific literature shows that only 27%–33% of young people meet PA recommendations,[2] future interventions should focus on promoting ACS, because of its great and feasible contribution to daily MVPA levels. Moreover, this is especially important because ACS-PA in childhood might contribute to PA in adulthood.[61]

It is also important to note that higher MVPA minutes were obtained on the school-home trip than on the home-school trips. Similar to LPA results, MVPA related to the school-home trips may be influenced by after-school activities due to the time intervals used for its measurement. In fact, after carrying out the meta-analysis only with studies that used GPS or time intervals up to 60 min, the weighted MVPA is reduced especially for the school-home direction (i.e., home-school: 9.08 95% CI: 7.36–10.79; school-home: 12.06 min, 95% CI: 9.17–14.96). Thus, more studies are needed to clarify these differences. In addition, despite these results are very encouraging in terms of ACS-PA, it should take into account that depending on the distance the young people live from the school, they may obtain higher or lower PA levels. Nevertheless, not all the included studies provided data on the distance that participants actively commute in home-school or school-home directions, which meant that distance could not be taken into account as a covariable in the meta-analysis. Therefore, future studies, focusing on the analysis of ACS-PA, should identify the ACS-related trip individually and the distance from home to school to obtain more accuracy results, as well as methodological studies are needed to test the extent of these differences in methods (e.g., comparing the PA levels of the trip identified by GPS with the PA levels of the trip identified by time interval, knowing the potential levels of MVPA that young people can obtain according to his/her commuting speed and the distance he/she lives from the school).

Based on the main findings of this systematic review and meta-analysis, there are practical implications for researchers, public health practitioners, policymakers, teachers, and parents to promote this PA-related behavior. Firstly, it is crucial for all these agents to actively promote and encourage ACS as a promising strategy to increase PA levels in young people, as our results and those of previous studies show.[6,7] Emphasizing the health and environment benefits of ACS and its potential to help students achieve recommended PA levels is important.[62] Researchers should collaborate closely with schools and municipalities to advocate for initiatives that support ACS, such as implementing bike racks, creating pedestrian-friendly routes, organizing Walking School Bus or walking groups[63–65] or e conducting Safe Routes to School.[66,67] In addition, the school curricula may include this ACS promotion. For example, Physical Education teachers could design cycling learning sessions to improve confidence, knowledge, skills, and attitudes in their students.[68] Moreover, these results reinforce the objectives of organizations such as the WHO and the United Nations, which through the Global Action Plan on Physical Activity 2018-2030[11] and the 2030 Agenda for Sustainable Development,[12] consider ACS as one of the main priorities of global policies. Therefore, promoting school ACS policies can increase the use of active modes of transport.[69]

The authors recommend that future studies focus on analyzing device-measured LPA or MVPA during the ACS, should consider the following considerations: (1) to identify the start/end times of the trips. The use of GPS is convenient, but if it is not possible to use it, an activity diary could also be a good option. If neither of these two instruments are available, a time interval per participant should be adapted according to the distance they live from the school[13]; (2) for the quantification of ACS-PA, it is necessary to report the active mode of commuting to/from school used, since walking and cycling are both active modes of commuting, but they provide different PA intensities and benefits. For the assessment of PA, the most recommended device is the accelerometer, although in case the study population predominantly walks, pedometers might be used.[13] In addition, caution should be taken in measuring the levels of PA provided by cycling, as studies may underestimate the PA associated with this mode of commuting. Methodological studies are necessary for the correct evaluation of cycling trips; (3) finally, given the results of the meta-analysis, it is necessary to indicate the trip direction assessed (i.e., home-school or school-home), as these could provide different levels of LPA or MVPA and, in addition, trying to assess both trip directions to have a better measurement of the total daily PA.

4.1 | Limitations and strengths

The current study is not without limitations that should be mentioned: (1) Although the contribution of PA to ACS is provided, it will depend on the distance the children or adolescents live from school. In the current meta-analysis, considering that the methodology used by each study may influence the results, meet the 48% of the PA recommendations could be equivalent to actively commuting both trip directions, with the distance commuted between the two trips (i.e., home-school and school-home) being around two kilometers[70]; (2) no gray literature and studies that were not in English or Spanish were not included, and although the literature search was conducted in five databases, some eligible studies from other databases may have been missed; (3) in line with the meta-analysis conducted by Martin et al.,[7] it was not possible to examine the contribution of cycling to/from school to LPA and MVPA levels. Cycling is often underestimated due to the processing of accelerometry data and/or the placement of devices, among other factors; (4) many studies did not differentiate the mode of active commuting (i.e., walking or cycling) and, therefore, it is not possible to know which mode the results refer to; (5) dividing the studies by mode of active commuting and by trip direction did not allow to divide the results by age group (i.e., children and adolescents), gender, or country/geographic location; (6) the fact that there is no consensus on how to measure ACS-PA using devices can lead to limitations in interpreting the results, as in the case of MVPA and LPA.[13]

The present study also shows several strengths: (1) last PRISMA guidelines were followed to ensure that the systematic review was conducted with adequate rigor. In addition, it was registered in PROSPERO and the systematic review protocol was also published[24]; (2) the quality and risk of bias of the included studies were assessed, as they are different concepts, following the recommendations of Gunnell et al.[23] Most studies had a low risk of bias (see Figures S3 and S4 in Additional File 3) and medium quality (see Tables S3 and S4 in Additional File 3); (3) a meta-analysis was conducted to contribute to the scientific literature on how much device-measured LPA and MVPA is related to ACS; (4) to best of our knowledge, it is the first systematic review and meta-analysis that separates the home-school and school-home trips, suggesting that they should be evaluated separately.

5 | CONCLUSION

ACS may contribute up to almost half of the daily PA recommendations in young people on school days if both trip directions are actively performed. In addition, the contribution of ACS to LPA could have important health implications as it could be associated with a reduction in sedentary time. Moreover, given that the contribution of LPA and MVPA to ACS-related to trip direction (i.e., home-school or school-home) may be different, it would be appropriate to examine both directions. Therefore, future studies aimed at increasing young's daily PA levels should focus on promoting ACS on school days.

6 | PERSPECTIVES

Less than 30% of young people meet the daily PA recommendations proposed by the WHO.[2] ACS has been recognized as a good strategy to increase daily PA levels during school days.[6,7] However, it is not clear how many minutes of device-measured LPA and MVPA can be related to ACS and according to the trip direction (i.e., home-school or school-home), as they could provide different levels of PA.[19] To best of our knowledge, this is the first systematic review with meta-analysis that separately analyses trips direction and device-measured ACS-PA by for each. Observational evidence shows that ACS can contribute to around 48% of the daily PA recommendations for young people on school days, if both trip directions are actively performed. These results support that ACS has a large impact on both LPA and MVPA of young people. Nevertheless, future studies should address certain limitations, such as the development of a standardized protocol for device-measured ACS-PA. Facilitating the comparison and interpretation of results between different studies.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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