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Effects of school-based interventions on all 24-hour movement behaviours in young people: a systematic review and meta-analysis of randomised controlled trials

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ABSTRACT

Objective This systematic review and meta-analysis examined the effects of school-based interventions on all 24-hour movement behaviours.

Design Systematic review and meta-analysis.

Data sources Studies published in English, French, and Spanish from four databases from inception to February 2024 were identified.

Eligibility criteria for selecting studies Eligible articles were randomised controlled trials (RCTs) that targeted and assessed physical activity (PA), sedentary behaviour (SB) and sleep duration among school-aged youth (3–17 years). Risk of bias and quality assessment were assessed using the Risk of Bias Tool 2 and Quality Assessment of Controlled Intervention Studies tool, respectively. Grading of Recommendations, Assessment, Development and Evaluation (GRADE) tool evaluated the certainty of evidence. The study was registered in International Prospective Register of Systematic Reviews (PROSPERO) (ID: removed for peer review).

Results Of the 5141 records initially identified, 41 studies remained for full-text review. After full reading, 7 RCTs, comprising 8234 participants (49% girls), were included. Results indicated no effect in PA-related outcomes (Hedge's *g*=0.12, –0.05 to 0.28), a small reduction in SB-related outcomes (g=–0.33, –0.51 to –0.16) and a small increase in sleep duration (g=0.30, 0.16 to 0.43) according to Hedges' g (small effects (0≤g ≤0.50)). The GRADE, risk of bias and quality assessment tools indicated that most of the studies have a low risk of bias and are of good quality.

Conclusions More school-based interventions promoting all movement behaviours are needed to determine if schools are optimal for encouraging 24-hour movement behaviours among young people.

WHAT IS ALREADY KNOWN

⇒ Most school-based interventions focused on single-movement behaviours have shown non-significant or meaningful effects.
⇒ An overflow but small effect on non-targeted behaviours was found in interventions targeting physical activity and sedentary behaviour.
⇒ No previous systematic reviews and meta-analyses analysed the effects of school-based interventions on all three 24-hour movement behaviours.

WHAT ARE THE NEW FINDINGS

⇒ School-based interventions targeting 24-hour movement behaviours did not increase physical activity levels.
⇒ School-based interventions targeting 24-hour movement behaviours reduced sedentary behaviour-related outcomes and increased sleep duration.
⇒ More school-based interventions promoting all movement behaviours are needed.

INTRODUCTION

A wide body of research has shown that high physical activity (PA) levels,[1] low sedentary behaviour (SB)[1] and optimal sleep duration[2] are independently and positively related to a wide range of health benefits in young people. However, most do not engage in regular PA,[3] spend many hours sitting[4] and do not get enough sleep duration.[5]

Considering that movement behaviours are codependent throughout the day (ie, if one or two increase, the others decrease and vice versa), different studies have suggested the importance of examining them together.[6] Indeed, Canadian 24-Hour Movement Guidelines for PA, recreational screen time and sleep duration were released for preschoolers (aged 3–4 years),[7] children and adolescents (aged 5–17 years).[6] To date, these recommendations have been extended to Australia, South Africa, New Zealand, the Asia-Pacific region, the UK and Saudi Arabia.[8] An optimal time allocation of these three movement-related behaviours during the whole day or meeting 24-Hour Movement Guidelines has been associated with additional health

benefits for young people.[9] Nevertheless, despite these recommendations, a recent meta-analysis involving 387 437 young people aged 3–17 years revealed that only 7.12% met the overall 24-Hour Movement Guidelines.[10] Therefore, promoting adherence to these 24-hour movement behaviours among young people should be considered a public health priority worldwide.

Schools have been identified as an ideal setting for promoting these movement behaviours for several reasons: (1) the broad audience of young people they reach during a significant portion of their childhood; (2) the involvement of the whole school community (eg, families, teachers and students); (3) the training of in-service teachers in health education; (4) the opportunities provided to be active (eg, recess, physical education, physically active lessons, classroom PA breaks and active commuting to/from school) and (5) the emphasis in educational curricula worldwide on promoting PA in schools.[11] However, most school-based interventions focused on single movement behaviours such as PA,[12–14] sedentary time (ST) or screen time[12 13 15] and sleep duration[16 17] have shown non-significant or meaningful effects at postintervention that decrease or even disappear by long-term follow-ups.

Previous studies have also shown that the intervention characteristics can influence their overall effects. Multicomponent school-based interventions (ie, involve two or more agents or components designed to address a particular issue or goal) seem to provide more favourable results than single-component interventions.[12 18] Although the evidence is still limited, multiple health behaviour change interventions (ie, targeting two or more behaviours at the same time) may also have greater effects on certain health-related behaviours compared with single-behaviour interventions.[19 20] A recent systematic review and meta-analysis found that movement behaviour change interventions aimed at increasing PA or reducing SB in young people had spillover effects on non-targeted behaviours, although the effect sizes (ESs) were small.[21] Therefore, it could be assumed that school-based interventions targeting all 24-hour movement behaviours might have a greater effect on these three behaviours because an increase in one of these movement behaviours (eg, PA) might be related to a decrease in other behaviours (eg, ST) and vice versa. Moreover, a carry-over effect between movement behaviours may take place (eg, PA may facilitate sleep duration/quality and vice versa).[22] Theory-based interventions (ie, interventions designed and implemented based on established behaviour change theories) in the health domain have also been associated with small but significant improvements in health-related behaviours.[23] However, a recent meta-analysis examining the effects of theory and non-theory school-based interventions on PA and/or ST found no differences in these movement behaviours among children.[12] Nevertheless, several authors have recommended theory-based approaches as they guide behaviour change techniques in target variables during intervention development.[24] Regarding duration, most previous meta-analyses showed that the duration of school-based interventions does not appear to yield additional benefits for movement behaviours.[12 14 25 26] Finally, while a recent meta-analysis has found that studies with higher methodological quality seem to report greater effects on PA and ST,[12] other meta-analyses have found no differences.[13 14 18]

To our knowledge, there are no previous systematic reviews and meta-analyses analysing the effects of school-based interventions on all three 24-hour movement behaviours. Only a recent scoping review identified a lack of school-based interventions targeting 24-hour movement behaviours among children in 2023.[27] Given this lack of studies among children, we have decided to expand the scope of this review to include preschoolers and adolescents, as well as to update the search for studies involving children. Determining the efficacy of these school-based interventions is important because it may provide new evidence for teachers, policy-makers or health practitioners about the role of schools in promoting these 24-hour movement behaviours. Therefore, this systematic review and meta-analysis examined the effects of school-based interventions promoting all 24-hour movement behaviours (ie, PA-related outcomes, SB-related outcomes and sleep duration) on these behaviours among preschoolers, children and adolescents.

METHOD

This systematic review and meta-analysis adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis guidelines (see Research Checklist).[28] Additionally, it was registered (ID: CRD42023465427) in the International Prospective Register of Systematic Reviews (PROSPERO). This PROSPERO registration has not been modified from its original version.

Eligibility criteria

Eligible studies were included if they met the following criteria: (1) healthy young people aged 3–17 years; (2) randomised controlled trials (RCTs) with a minimum intervention duration of 8 weeks; (3) at least two exposure measurement points (ie, baseline and post-test) in both intervention and control groups; (4) school-based interventions targeting and assessing all 24-hour movement behaviours (ie, PA, SB and sleep duration) using self-reported questionnaires or device-based measures and (5) preschool settings with the sole purpose of enjoyment.

Information sources

A structured bibliographic search was conducted across four databases (Scopus, Web of Science, PubMed and the Cochrane Library) to retrieve peer-reviewed studies published in the Spanish, English and French languages from inception to February 2024.

Search strategy

The search followed the Population, Interventions, Comparisons and Outcomes framework.[29] Based on previous review studies on movement behaviours,[27] the following terms were selected: (a) "child*" OR "student*" OR "pupil*" OR "kid" OR "infant*" OR "adolescen*" OR "teen*" OR "youth*" OR "young*" OR "minor" OR "boy" OR "girl"); (b) "strateg*" OR "technique*" OR "intervention*" OR "program*"; (c) "physical activity" OR "sport*" OR "exercis*"; (d) "sedentar*" OR "sit" OR "sitting" OR "computer*" OR "media" OR "internet surfing" OR "video games" OR "video-games" OR "tablet" OR "smartphone" OR "mobile phone" OR "television" OR "TV" OR "gaming" OR "screen*"; (e) "sleep*" OR "bedtime" OR "wake-up". The search terms have been adapted for each database in combination with database-specific filters. These different combinations did not include restrictive terms and contained a high number of references to screen, minimising the risk of missing relevant studies. An example of each database search is provided in online supplemental table 1. In addition, the reference list of the studies included in this review, as well as one previous systematic review,[27] was thoroughly reviewed to ensure that no eligible studies were omitted (see online supplemental table 2). The exclusion of studies analysed after full-text reading is detailed in online supplemental table 3.

Selection process

Two review authors (JR-S and MAT-S) identified the searched studies in three steps according to the literature.[30] A kappa coefficient was calculated to test the reliability of the screening process. The obtained coefficient showed strong concordance (k=0.91, p<0.001), exceeding 70%.[31] Discrepancies between review authors were resolved through consensus-based decision-making with a third author (JS-S).

Data collection process

The same two review authors independently and systematically extracted the information from the selected articles. To avoid data duplication, we carefully checked the authors, sample size, dates and country of each study. When potential duplicates were identified, we selected the most complete or relevant report for analysis. All the extracted data was synthesised and pooled together using tables created with Microsoft Excel.

Data items

The following information was extracted from the table of studies that met the selection criteria: publication details (ie, author/s, year); study characteristics (ie, design, country, sample size, population, 24-hour movement behaviours assessment); intervention characteristics (ie, theoretical framework, intervention providers, intervention components and intervention duration) and main findings (related to pre–post differences of PA, SB and sleep duration for both intervention and control groups). The studies were classified by age group: preschoolers (3–5 years), children (6–12 years) and adolescents (13–17 years). More details about the extracted data are available in online supplemental tables 4–7.

Study risk of bias assessment

Risk of bias and quality assessment were independently conducted by two review authors (JR-S and MAT-S). The kappa coefficient calculated to test the reliability of the risk of bias (k=0.79, p<0.001) and quality assessment (k=0.86, p<0.001) showed strong concordance.[31] For assessing the risk of bias in RCTs, we selected the Cochrane 'Risk of Bias Tool 2', as recommended by the Cochrane Handbook.[32] This tool includes five domains of potential bias and focuses on the study's internal validity: (1) bias arising from the randomisation process; (2) bias to deviation from intended interventions; (3) bias due to missing outcome data; (4) bias in the measurement of the outcome and (5) bias in the selection of the reported result. Studies were categorised as having low risk, some concerns or a high risk of bias. As recommended by experts in conducting systematic reviews,[30] we selected the 'Quality Assessment of Controlled Intervention Studies' tool, developed by the National Institutes of Health, for the quality assessment. This tool comprises 14 items and classifies studies into low (1–4), medium (5–9) and high quality (10–14). For further information, see https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools.

Effect measures

Different meta-analyses were independently performed to examine the effect of school-based interventions on 24-hour movement behaviours (ie, PA, SB and sleep). A restricted maximum likelihood random-effects model was used to estimate between-study variance.[33] Additionally, sensitivity analyses were conducted using Hartung-Knapp-Sidik-Jonkman (HKSJ) adjusted confidence intervals (CIs) to assess the robustness of the results.[34] Study ESs were calculated by subtracting change differences between the intervention and control groups using the pooled standard deviation (SD) of change in both groups, as well as pre-and post-SD values, assuming a correlation of r=0.5 between baseline and postintervention.[35] ESs were classified as small ($0 \leq g \leq 0.50$), medium ($0.50 < g \leq 0.80$) and large ($g > 0.80$) using Hedges' g parameter. For PA and sleep behaviours, positive ES values indicated more minutes of PA and more hours of sleep in the experimental group compared with the control group, whereas for SB, negative ES values indicated fewer minutes of screen time or ST in the experimental group compared with the control group.

To assess the robustness of the estimates obtained, sensitivity analyses were conducted by eliminating (one at a time) each study from the total estimates (ie, PA, SB or sleep). The proportion of variation across studies was estimated using the inconsistency index (I^2), which

ranges from 0% to 100%. The interpretation of I^2 values is as follows: 'small (0%–30%)', 'moderate (30%–60%)', 'substantial (60%–75%)' or 'considerable (75%–100%)' inconsistency. All statistical analyses were conducted using the R statistical software (V.4.3.2), R Core Team (Vienna, Austria) and RStudio (Posit, Boston, Massachusetts, USA). A significance level of p<0.05 was chosen to establish statistical significance.

Synthesis methods

Three separate random effects meta-analyses were then performed for PA, SB and sleep duration outcomes. Pooled ESs were estimated along with 95% CIs. In cases where interventions involved a comparison between multiple experimental groups and a control group, we opted to merge these experimental groups to establish a singular pairwise comparison. This strategy was selected to avoid a unit-of-analysis error in studies where multiple correlated comparisons could be generated.[36] According to the literature,[36] no subgroup analyses were planned due to the reduced number of studies meta-analysed (ie, less than 10).

Publication and reporting biases

Finally, publication bias was examined using the Luis Furuya-Kanamori (LFK) index.[37] No skewness, minor skewness or major skewness were considered with values of 1, between 1 and 2, and 2, respectively.[37] To evaluate reporting bias arising from unpublished studies, a thorough search was conducted in clinical trial registries.

Certainty assessment

The results of the meta-analysis and risk of bias assessment were used to complete the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) certainty assessment.[38] This tool qualitatively assesses five domains, including risk of bias, inconsistency, indirectness, imprecision and publication bias, providing a summary rating of high, moderate or low certainty of evidence. The GRADE was independently assessed by two review authors (JR-S and MAT-S), and the kappa coefficient (k=0.81, p<0.001) indicated strong concordance.[31]

Patient and public involvement

This study did not involve direct participation from patients in its design, conduct or dissemination. The research questions and outcome measures were developed through a comprehensive review of existing literature. Consequently, patient recruitment and the analysis of intervention burden were not applicable. Results were primarily disseminated through publication in peer-reviewed journals and presentations at academic conferences.

RESULTS

Study selection

A total of 5141 records were initially identified (see figure 1). After removing duplicate records, ineligible records, and those removed for other reasons, 2596 records remained. Among these, 2554 were excluded after reading their titles and abstracts, resulting in a total of 41 studies for full-text review. After full reading, 34 studies were excluded for various reasons described in figure 1. Finally, seven studies met the inclusion criteria and were included in this systematic review and meta-analysis.

Study characteristics

The description of the seven studies included is presented in table 1. Regarding study design, four studies were cluster RCT,[39–42] and three were RCTs.[43–45] In terms of the country, three studies were conducted in Spain,[43–45] one in the United States of America (USA),[40] one in Australia,[41] one in Scotland[42] and one in Switzerland.[39] About the population, two studies were developed among preschoolers,[39 40] three studies among children,[42–44] and two studies among adolescents,[41 45] from a minimum of 121[43] to a maximum of 6640[41] participants, comprising a total sample size of 8234 young people (49% girls), of whom 977 were preschoolers (12%), 407 children (5%) and 6850 (83%) adolescents.

Regarding the intervention components, the average number of components on intervention studies was three and all interventions were multicomponent.[39–45] In terms of intervention providers, four interventions were implemented by both the research team and teachers,[40 42 44 45] while one was exclusively conducted by teachers,[41] another one was carried out by teachers and other specialists,[39] and the last one was exclusively conducted by the research team.[43] The intervention duration of school-based interventions ranged from 2 to 3 months in two studies,[42 43] and more than 6 months in five studies.[39–41 44 45] Regarding the theoretical framework, six studies[39–43 45] were supported by one or more theoretical frameworks, while only one study did not rely on any theoretical framework.[44] Finally, in terms of assessment, PA was measured with accelerometers in three studies,[39 42 44] with accelerator and questionnaire in one study,[45] and only with questionnaires in three studies.[40 41 43] SB was measured with accelerometers and questionnaires in two studies,[42 45] and only with questionnaires in five studies.[39–41 43 44] One study measured sleep duration with an accelerometer device,[42] while the rest measured sleep duration with a questionnaire.[39–41 43–45]

Risk of bias and quality assessment

The complete risk of bias assessment for each study is presented in the Supplemental Microsoft Excel file (online supplemental file 2). Figure 2 provides an overview of the risk of bias assessment of included studies. The overall risk of bias is provided in online supplemental figure 1. Four studies[39–42] reported a low risk of bias (57%), and three[43–45] reported some concerns (43%).

The results of the quality assessment are shown in table 1. The quality assessment of each study can also be found in online supplemental table 8. Overall, 29%

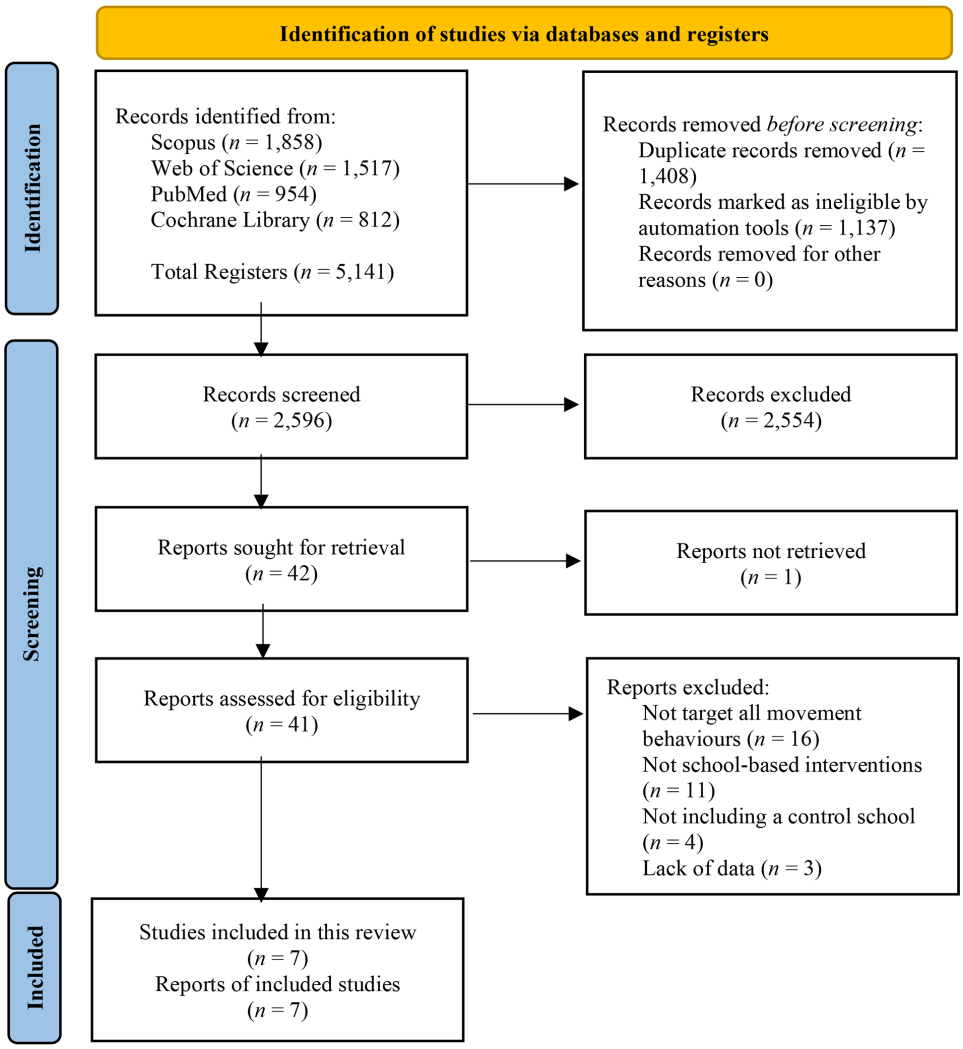

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.

(n=2) of studies were considered high quality,[39 41] and 71% (n=5) were considered medium quality.[40 42–45]

Results of individual studies and syntheses of effects

Summary of results

In the total sample, the individual studies and the summary effects of the interventions on PA-related outcomes, SB-related outcomes and sleep duration were depicted in figures 3–5, respectively. The pooled ES for PA-related outcomes was g=0.12 (95% CI −0.05 to 0.28), suggesting a slight increase in PA, with a considerable inconsistency measure (I^2=73.3%). The pooled ES for SB-related outcomes was g=−0.33 (95% CI −0.51 to −0.16), indicating a small reduction, with a substantial inconsistency measure (I^2=64.1%). The pooled ES for sleep duration was g=0.30 (95% CI 0.16 to 0.43), indicating a small increase, with a moderate inconsistency measure (I^2=55.8%). Also, pooled ESs were calculated individually for moderate-to-vigorous PA (MVPA): n=4, g=0.37 (95% CI −0.19 to 0.92), I^2=95.7%; PA: n=4; g=0.14 (95% CI −0.07 to 0.36), I^2=66.2%; screen time: n=7; g=−0.38 (95% CI −0.58 to −0.17), I^2=73.1%; and ST: n=2; g=−0.42 (95% CI −0.65 to −0.18, I^2=0%). These estimates suggest a slight increase in MVPA and PA, and a small reduction in screen time and ST. For further details, refer to online supplemental figures 2–5, respectively.

Sensitivity analyses

The sensitivity analyses, which involved eliminating one study at a time from the total estimates for PA, SB and sleep duration, revealed no potential outliers or influential studies (see online supplemental figures 6–8, respectively). In addition, sensitivity analyses using the HKSJ can be found in online supplemental table 10.

Publication and reporting bias

For PA-related outcomes and sleep duration, significant asymmetries, indicative of small study effects, were identified (PA: LFK index=4.92; sleep duration: LFK index=6.75). Conversely, no asymmetry suggestive of small study effects was observed for SB-related outcomes (LFK=−2.07). All LFK index figures are available in online supplemental figures 9–11, respectively. Moreover, in terms of reporting bias, we did not find any relevant registered protocols or unpublished studies that might influence our study results.

Table 1 Characteristics of included studies and interventions characteristics in preschoolers, children and adolescents

Study	Design and theoretical framework	Country	Sample size (n, SD, range, % of girls)	Targeted behaviours	Intervention providers	Assessment of 24-hour movement behaviours	Intervention components	Duration (months)	Quality assessment
Preschoolers (3–5 years)									
Puder *et al*[39]	Cluster RCT SEM	Switzerland	652, *M*=5.20±0.60, 4–5 years, 50%	PA, SB, SD, diet and well-being	School teachers and other specialists (ie, psychologists and nutritionists)	PA: Accelerometer SB (ST): Questionnaire (Parents reported) SD: Questionnaire (Parents reported)	School curriculum (health education lessons and recess), teachers and family involvement	10 months	HQ
Ullevig *et al*[40]	Cluster RCT SCT and SEM	USA	325, *M*=3.59± 0.29, 3–5 years, 57%	PA, SB, SD and diet	Research team and teachers	PA: Questionnaire (Parents reported) SB (SC): Questionnaire (Parents reported) SD: Questionnaire (Parents reported)	School curriculum (health education lessons), teachers and family involvement	8 months	MQ
Children (6–11 years)									
Pablos *et al*[44]	RCT No theoretical framework	Spain	158, *M*=10.66± 0.71, 10–12 years, 52%	PA, SB, SD and diet	Research team and teachers	PA (MVPA): Accelerometer SB (SC): Questionnaire (Self-reported) SD: Questionnaire (Self-reported)	School programme (at lunchtime), teachers and family involvement	8 months	MQ
Tapia *et al*	RCT SDT and CAS	Spain	121, *M*=9.01± 0.09, 8–9 years, 47%	PA, SB, SD and diet	Research team	PA: Questionnaire (Self-reported) SB (SC): Questionnaire (Self-reported) SD: Questionnaire (Self-reported)	School curriculum (health education lessons, physical education lessons, and recess), teachers and family involvement.	2 months and a half	MQ
Donnelly *et al*[42]	Cluster RCT SDT	Scotland	128, *M*=10.30± 0.50, 9–12 years, 69%	PA, SB, SD and diet	Research team and teachers	PA (MVPA): Accelerometer SB (ST): Accelerometer SB (SC): Questionnaire (Self-reported) SD: Accelerometer	School curriculum (activity-related behaviours homework, workbooks and health promotion reminders), teachers and family involvement.	2 months	MQ
Adolescents (12–17 years)									
Sevil *et al*[45]	RCT SEM, SDT and TPB	Spain	210, *M*=13.06± 0.61, 12–14 years, 53%	PA, SB, SD, diet, and alcohol and tobacco consumption	Physical education teachers, other teachers and research team	PA (MVPA): Accelerometer PA: Questionnaire (Self-reported) SB (ST): Accelerometer SB (SC): Questionnaire (Self-reported) SD: Questionnaire (Self-reported)	School curriculum (tutorial action plan, physical education lessons, interdisciplinary project, recess, active commuting), family involvement and extracurricular actions (noncurricular activities, dissemination of health information and health events)	10 months	MQ
Champion *et al*[41]	Cluster RCT SCT and SDT	Australia	6640, *M*=12.70± 0.50, 12–14 years, 48%	PA, SB, SD, diet and alcohol and tobacco consumption	School teachers	PA (MVPA): Questionnaire (Self-reported) SB (SC): Questionnaire (Self-reported) SD: Questionnaire (Self-reported)	School curriculum (health education lessons and smartphone app) and teachers' involvement.	24 months	HQ

The quality assessment was measured with the National Institute of Health tool (for further information see: https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools).
CAS, creating active school; HQ, high quality; LQ, low quality; *M*, mean; MQ, medium quality; MVPA, moderate-to-vigorous physical activity; PA, physical activity; RCT, randomised controlled trial; SB, sedentary behaviour; SC, screen time; SCT, social cognitive theory; SD, sleep duration; SDT, self-determination theory; SEM, social ecological model; ST, sedentary time; TPB, theory planned behaviour; USA, United States of America.

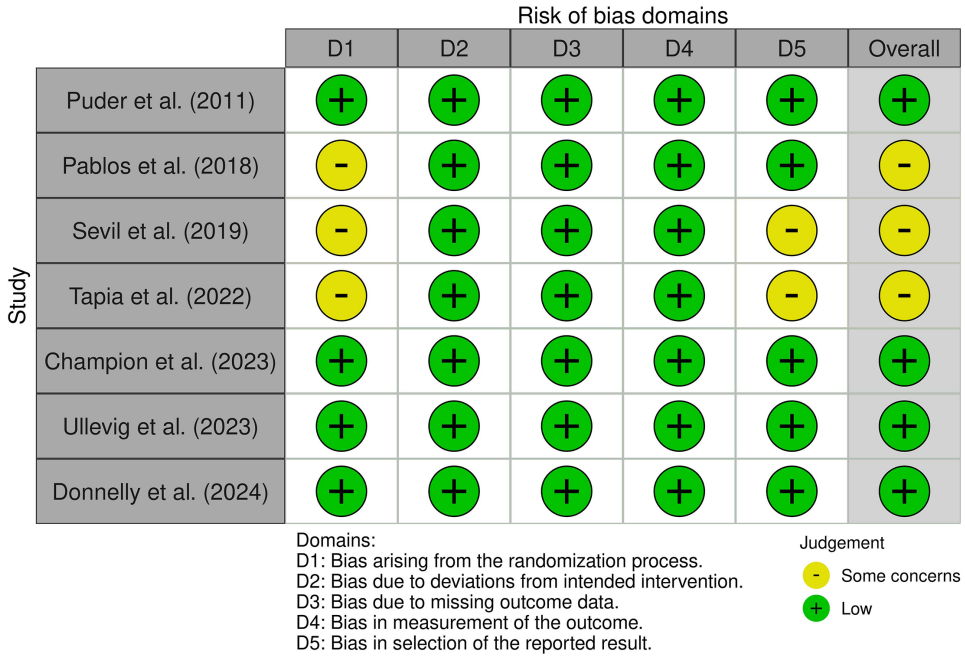

Figure 2 Risk of bias of the studies included in this systematic review and meta-analysis.

Certainty of evidence

The GRADE evidence summary revealed that PA-related outcomes and sleep duration were rated as moderate certainty, while SB-related outcomes were rated as high certainty (see online supplemental table 9).

DISCUSSION

This is the first systematic review and meta-analysis that examined the effects of school-based interventions on all three 24-hour movement behaviours among preschoolers, children and adolescents. The main finding is that multicomponent school-based interventions targeting 24-hour movement behaviours did not increase PA levels (ie, general PA and MVPA), but they reduced SB-related outcomes (ie, particularly screen time) and increased sleep duration. It must be noted that the risk of bias, quality assessment and GRADE assessing tools indicated studies included are low biased, of good quality and have moderate to high certainty.

In terms of PA-related outcomes, this variable did not increase after the implementation of school-based interventions targeting 24-hour movement behaviours. This result is consistent with most previous meta-analyses that examined the effects of school-based PA and/or SB interventions on PA levels in young people.[12–14 26] These findings suggest that PA may be a behaviour that is more challenging to modify solely through interventions implemented within the school environment. Given that PA is influenced by multiple factors, the development of multilevel interventions incorporating extracurricular actions that complement school-based interventions (such as the establishment of out-of-school PA programmes, PA policies and other PA-supportive initiatives) could potentially lead to larger ESs.[46] Another possible explanation is that the wide range of behaviours addressed in the school-based interventions of this study may be too demanding for young people, diluting the effects found for some movement behaviours that are more complex to change.[47] Finally, the complex, multicomponent and

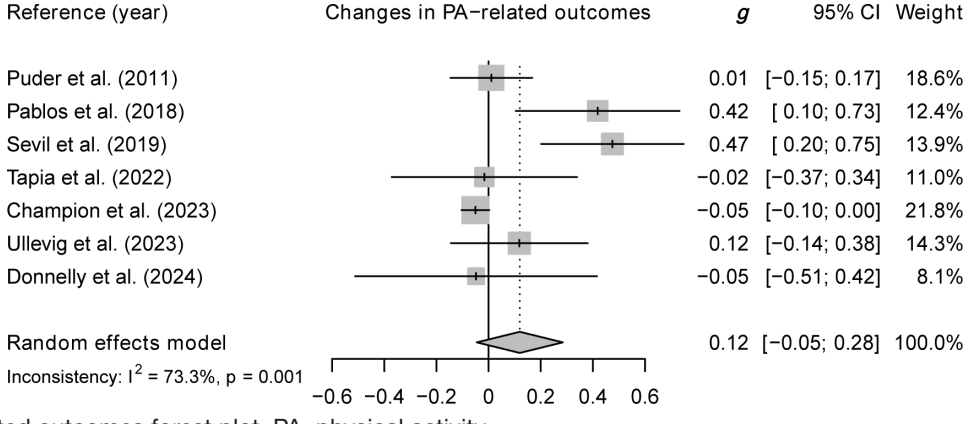

Figure 3 PA-related outcomes forest plot. PA, physical activity.

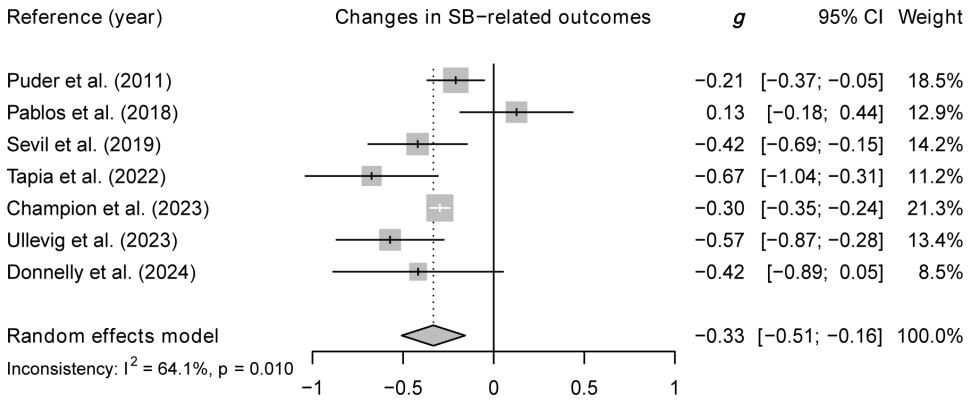

Figure 4 SB-related outcomes forest plot. SB, sedentary behaviour.

multibehavioural nature of most school-based interventions included in this study may result in low implementation fidelity.[15]

In terms of SB-related outcomes, we found a small effect on overall SB, screen time and ST. In recent meta-analyses that examined the effects of school-based PA and/or SB interventions, a small reduction in device-measured ST and screen time was also found.[12 18] However, mixed results in SB-related outcomes have been found in previous school-based interventions.[15] One possible explanation for the results found is that the strategies employed to increase PA levels and sleep duration may have also contributed to the reduction in screen time and ST, given that these three movement behaviours are codependent and interact across the entire 24-hour period.[21] Specifically, the increase in sleep duration observed in our meta-analysis may also have had a ripple effect on the overall reduction of screen time and ST. Another possible justification is that the higher levels of screen time and ST identified in the studies of this meta-analysis may have provided more room for improvement in these risk behaviours compared with PA-related outcomes.

Regarding sleep duration, school-based interventions revealed a small increase. These results seem more promising than a recent systematic review in which most interventions revealed no improvement in sleep duration.[48] These results suggest that increased sleep duration can be attributed not only to the effectiveness of sleep behaviour strategies, but also more importantly to the reduction of SB-related outcomes. Previous meta-analyses have suggested that reducing screen time can also improve sleep duration.[49] The fact that all school-based interventions in this meta-analysis were multicomponent and involved families could also explain the positive results observed for sleep duration. This reinforces the message that, in addition to school-based actions, the involvement of other agents such as families appears to be a key aspect in promoting this behaviour.[50]

Overall, our results suggest that the small improvement found in SB-related outcomes and sleep duration did not have a downstream effect on PA-related outcomes. Surprisingly, school-based interventions targeting all three 24-hour movement behaviours failed to report improvements in PA or MVPA levels. As shown in the results, this is likely related to inconsistencies in measurement methods, both among studies and within individual studies (ie, mixing device-measured and self-reported data), which could lead to potential variability due to measurement error. Also, considering the interplay of all movement behaviours throughout the day, these results could be attributed to the possibility that school-based interventions may initially impact light PA (LPA) rather than MVPA. Future studies should investigate the impact of school-based interventions on LPA to determine if they have any effect on this intensity level.

Finally, it is worth noting that although the 24-hour approach has been in place for almost a decade,[6] this meta-analysis reveals that there are only seven school-based interventions targeting PA, SB and sleep that

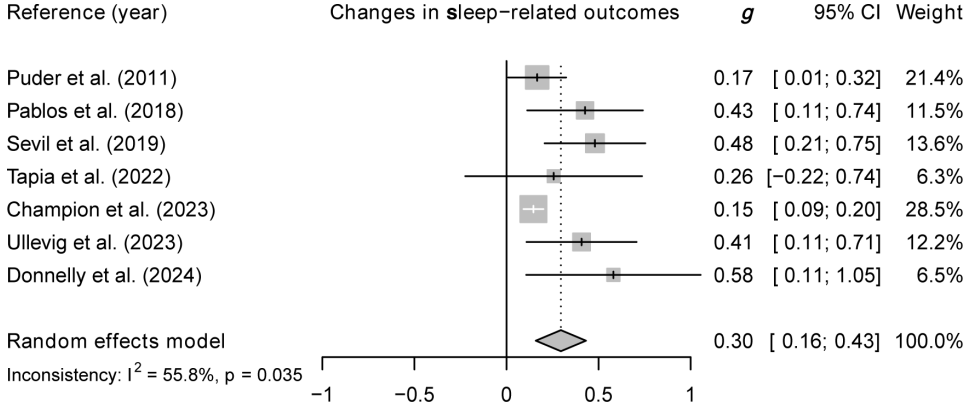

Figure 5 Sleep-related outcomes forest plot.

have examined their effects on all these three 24-hour movement behaviours. These findings serve as a call to policymakers, health practitioners, teachers and other stakeholders to pursue further research to determine the extent to which schools can contribute to improving these movement behaviours.

The main strength of the study lies in the inclusion criteria used (eg, RCT design, a minimum of 2-month intervention duration, school-based interventions targeting all 24-hour movement behaviours and the wide age range covered). It should be noted that the quality of the evidence was moderate despite the few studies identified. Nevertheless, this study is not without limitations. They are as follows: (1) some asymmetries were found in PA and sleep duration LFK plots suggesting a publication bias; (2) due to the low number of studies included and the homogeneity of them (ie, all multicomponent, supported by a theoretical framework, etc), it was not possible to perform moderation analyses (ie, meta-regression or subgroup analyses); (3) most studies did not examine LPA and, therefore, it was not possible to. examine the effects of school-based interventions on this PA intensity and (4) it was not feasible to examine the effects of school-based interventions according to gender, body mass index (BMI), socioeconomic status or ethnicity because a limited number of studies examined or reported such differences.

These limitations also point towards future research perspectives. First, there is a need for more school-based interventions targeting 24-hour movement behaviours in all school stages (ie, preschool, elementary and high school). Second, the device-based assessment of 24-hour movement behaviours throughout the entire day will facilitate the use of compositional data analyses, thereby enhancing our understanding of intervention effects. Third, the effects of school-based interventions should be examined according to gender, BMI or ethnicity for a better understanding of the equity effects of interventions on the target groups. Fourth, knowing potential intervention characteristics related to these effects may provide valuable information for designing future school-based interventions. Finally, examining follow-up postintervention effects seems necessary to ascertain the maintenance of these behaviours.

CONCLUSIONS

Overall, intervention effects were small on sleep duration and SB-related outcomes, and there was no effect on PA-related outcomes, suggesting that modifying 24-hour movement behaviours through school-based interventions among young people is challenging to date. Since only seven studies were identified, more school-based interventions targeting all three movement behaviours are needed among preschoolers, children and adolescents to draw sound conclusions.

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