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Review

A mixed-studies systematic review and meta-analysis of school-based interventions to promote physical activity and/or reduce sedentary time in children

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Abstract

Purpose: The aim of this mixed-studies systematic review was to ascertain the effectiveness of school-based interventions in increasing physical activity (PA) and/or reducing sedentary time (ST) in children aged 5−11 years, as well as to explore their effectiveness in relation to categories of the theory of expanded, extended, and enhanced opportunity (TEO).

Methods: Adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, 5 databases were searched using predefined search terms. Following title and abstract screening of 1115 records, the removal of duplicates ($n = 584$) and articles that did not meet the inclusion criteria agreed to *a priori* ($n = 419$) resulted in 112 records that were full-text screened. Two independent reviewers subsequently used the mixed-methods appraisal tool to assess the methodological quality of 57 full-text studies that met the inclusion criteria after full-text screening. The interventions were summarised using the TIDierR checklist and TEO. The strength of evidence was determined using a 5-level rating system utilising a published decision tree.

Results: Overall evidence ratings for interventions implemented within school settings were: no evidence of effects on moderate-to-vigorous physical activity (MVPA) and inconclusive evidence of effects on sedentary time. In relation to the TEO, expansion of PA appeared to be the most promising intervention type for MVPA, with moderate evidence of effect, whereas extension and enhancement of PA opportunity demonstrated no evidence of effect. A critical issue of possible compensatory behavior was identified by analysis of intervention effect in relation to PA measurement duration; when studies measured changes in PA during the actual intervention, there was moderate evidence of effect, whereas those that measured changes in PA during the school day presented inconclusive evidence of effect, and those that measured changes in PA over a whole day yielded no evidence of effect. Two meta-analyses of those studies using a whole-day accelerometer measure for MVPA or ST showed a significant but moderate effect for MVPA (effect size = 0.51; 95% confidence interval (CI): 0.02−0.99) and a large but nonsignificant effect for ST (effect size = 1.15; 95%CI: −1.03 to 3.33); both meta-analyses demonstrated low precision, considerable inconsistency, and high heterogeneity.

Conclusion: The findings have important implications for future intervention research in terms of intervention design, implementation, and evaluation.

Keywords: Children; Intervention; Physical activity; School; Sedentary time

1. Introduction

Physical activity (PA) has been associated with numerous physiological and psychosocial health benefits in school-aged children.[1] Consequently, global PA guidelines recommend that children aged 5−18 years engage in at least 60 min of moderate-to-vigorous physical activity (MVPA) every day.[2] Nevertheless, it is widely reported that the majority of children do not meet these guidelines. Indeed, a recent review found that less than 5% of 9- to 11-year-olds across 12 countries met the guidelines,[3] and an analysis of report cards of active healthy kids across 15 countries found that 20%−39% of kids

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in 10 of those countries earned a grade of D in meeting PA guidelines and <20% earned an F.[4] There are also concerns about coexisting sedentary behavior (SB) in children, which is independently associated with poorer health outcomes.[5] Recent 24-h movement guidelines have promoted whole-day movement patterns that target both enhanced MVPA and restriction of sedentary time (ST).[6]

PA behaviors develop in early childhood and track through to adolescence and adulthood.[7] Moreover, evidence suggests a decline in MVPA after early childhood,[8−10] with a recent review finding that 10 countries had an annual decrease of 4.2% in PA and an increase in ST after the age of 5 years.[11] Whilst the study was limited by its cross-sectional design,[11] longitudinal research, albeit in single countries, supports a decline in MVPA after early childhood.[10] For example, a recent longitudinal study involving more than 1000 children reported a decline in MVPA (3 min for girls; 7 min for boys) and an increase in ST (83 min for girls; 74 min for boys) between UK School Year 1 (5−6 years) and 4 (8−9 years).[10] It is, therefore, imperative not only to promote PA and decrease ST but also to intervene early in childhood, prior to the steep decline in MVPA and increase in ST.[12]

School has been identified as an important setting in which to promote MVPA and limit ST, particularly since children spend 40% of their waking time at school.[13] Indeed, a recent multi-level, worldwide review highlighted local school contexts as important correlates to PA in children.[3] In accord with the World Health Organization,[14] Booth and Okely[15] highlighted the compulsory nature of attendance, teachers as credible change agents, and access to facilities as the primary strengths of a school as an intervention setting. A number of existing systematic reviews, meta-analyses, and narrative reviews have examined the effectiveness of interventions promoting PA within the school-setting[16−20] and during specific parts of a school day, including during play/recess,[21−23] outside of curricular time,[24] physically active curriculum,[25] within-school physical education (PE) classes,[26] and after-school[27] or across settings, with specific analysis of the school as a setting.[14,28−32] A review of these reviews found strong evidence for the positive effect of school-based interventions on PA in youth and confirmed the public health potential of high-quality, school-based PA interventions.[33] However, existing reviews of PA interventions in school settings have examined evidence across childhood and adolescence[16,28,29,32,34] or focused exclusively on adolescents.[17−20,30,31] Despite the decline in PA levels from the early years and the need to strengthen the evidence regarding school-based interventions in children, there are no systematic reviews that focus exclusively on children. Moreover, van Sluijs et al.[34] have suggested that additional structural environmental and policy changes might be required to change children's PA behavior, thereby advocating for the need to examine children and adolescents as separate groups.

Few systematic reviews have considered SB interventions within a school setting.[17,18,35] One exception is a review by Hynynen et al.,[17] who suggested that future research should acknowledge that MVPA and ST require different intervention strategies. Also, the majority of existing systematic reviews have included only randomised controlled trials (RCTs)[16,17,20] and/or controlled trials.[19,30,31,34] Whilst RCTs are at the upper end of the hierarchy of evidence in terms of causal inference regarding the efficacy or effectiveness of interventions, they cannot explore the complex nature of PA interventions in the school context.[12] Insight into the key questions posed by existing systematic reviews, including the sustainability of interventions,[16,17,30,32] factors influencing the mediation or moderation of intervention effect,[28] implementation strategies,[20,31,34] generalisability of results,[34] and transferability to the real world[17] might be answered by examining a broader evidence base, that is, by evaluating observational, qualitative, and mixed-method studies.[36] Furthermore, the theory of expanded, extended, and enhanced opportunities (TEO), which proposes a common taxonomy to identify appropriate targets for interventions across different settings and contexts, could afford a more practical approach to school-based PA interventions.[19,37] Therefore, the aim of this mixed-studies, systematic review was to ascertain the effectiveness of school-based interventions in increasing PA and/or reducing ST in children aged 5−11 years of age. Furthermore, we sought to examine whether there are key components of interventions that enhance effectiveness, including exploration of the TEO.

2. Methods

The present review was registered with the prospective register of systematic reviews (PROSPERO) (CRD42017082184) and is reported in accordance with the preferred items for systematic reviews and meta-analysis (PRISMA) criteria.[38]

2.1. Information sources and search strategy

A literature search was conducted to identify peer-reviewed intervention studies of any methodological design that promoted PA and/or reduced ST in school settings in children aged 5−11 years. A structured electronic bibliographic search of 5 databases (ERIC, MEDLINE, PsychINFO, SPORTDiscus, and Web of Science) was used to retrieve articles published in the English language through 30 June 2017. The search strategies combined multiple keyword search terms agreed to *a priori* and were developed by breaking down the research question (Table 1). The search terms focused on 4 key elements: (1) outcome measure; (2) study population; (3) study type; and (4) setting. No date limits were applied. The outcomes of each of the searches were combined into a REFWorks library (ProQuest, 2017).

2.2. Inclusion criteria and selection process

Fig. 1 summarizes the outcomes of the search process, including the initial search, as well as the secondary search of reference lists of the studies following first screening and relevant reviews, alongside the exclusion/inclusion process. A 2-step screening process was used to determine whether each study met the inclusion criteria. Studies were included if they: (1) involved children of primary/elementary/middle school age, e.g., 5−11 years old; (2) reported on an intervention that

Table 1
Search terms used for systematic review.

Database	Search terms
ERIC	Physical activity or exercise or sedentary (TI) AND Child or adolescent or children or youth or pediatric (TI) AND School (AB) AND Evaluation or intervention or outcome or program (AB) AND Primary or elementary (AB) Peer-reviewed journal
MEDLINE	Physical activity or exercise or sedentary (TI) AND Child or adolescent or children or youth or pediatric (TI) AND School (AB/TI) AND Evaluation or intervention or outcome or program (AB/TI) AND Primary or elementary (AB/TI)
PsychINFO	Physical activity or exercise or sedentary (TI) AND Child or adolescent or children or youth or pediatric (TI) AND School (AB) AND Evaluation or intervention or outcome or program (AB) AND Primary or elementary (AB) Peer-reviewed journal
SPORTDiscus	Physical activity or exercise or sedentary (TI) AND Child or adolescent or children or youth or pediatric (TI) AND School (AB) AND Evaluation or intervention or outcome or program (AB) AND Primary or elementary (AB) Language = English Journal articles
Web of Science	Physical activity or exercise or sedentary (TI) AND Child or adolescent or children or youth or pediatric (TI) AND School (TS) AND Evaluation or intervention or outcome or program (TS) AND Primary or elementary (TS) Journal article

Abbreviations: AB = abstract; TI = title; TS = topic.

lasted at least 4 weeks, was implemented within a school environment, and was targeted at PA or SB; and (3) reported an objectively assessed measure of PA, ST, or both. Following title and abstract screening of 1115 records, the removal of duplicates ($n = 584$) and articles that did not meet the inclusion criteria ($n = 419$) resulted in 112 studies remaining. Two independent reviewers (ED, AL) assessed the full-text of the remaining 112 studies against the inclusion criteria, resulting in a further 52 studies' being excluded. The systematic review, therefore, included 57 original studies and 3 additional studies that reported follow-up data from 3 of the 57 original studies.

2.3. *Methodological quality*

The quality of the included studies was assessed by 2 independent reviewers (ED, AL) using the mixed-methods appraisal tool (MMAT).[39] The MMAT checklist includes 2 screening questions and 19 quality criteria corresponding to 5 methodological designs: (1) qualitative, (2) quantitative RCT, (3) quantitative non-randomised controlled (NR), (4) quantitative observational descriptive, and (5) mixed methods.[39] The MMAT assesses qualitative studies according to the appropriateness of the approach, description of context, justification of sampling, and description of data collection and analysis. Quantitative experimental studies are assessed according to randomisation appropriateness, blinding, and complete outcome data, whereas quantitative observational studies use items that reflect the appropriateness of sampling, justification of measures, and control of confounding variables. The overall quality score for each study was based on the methodological domain-specific criteria by using a percentage-based calculation alongside generic criteria. In cases where the 2 independent reviewers disagreed on either the study design or the scoring of criteria within a study design criteria, a third reviewer (MJ or KM) considered the study and mediated agreement. Mixed-methods studies were quality assessed within their own domain plus the domains used by its quantitative and qualitative components. The MMAT was used to provide an informative description of overall quality and to assess the potential for bias in the findings. The MMAT has been content-validated for each domain, and items were developed from the literature as well as from consultations and workshops with experts.[36,39,40] There is evidence of both the reliability and efficiency of the MMAT as a tool for appraising the methodological quality of research.[40,41]

2.4. *Data extraction and data synthesis*

Data were extracted from all included studies and summarised into a standardized review table, including demographic characteristics, a description of the intervention using the template for intervention description and replication (TIDieR) checklist,[42] and key outcomes and comments, including reference to the category of intervention in relation to the TEO. The inclusion of the TIDieR checklist in data extraction followed recent guidance for improving systematic reviews.[43] Whilst the assessment of quality was undertaken independently, data extraction was accumulated by the 2 independent reviewers (ED, AL) into a shared file and then was checked and expanded by a 3rd reviewer (MJ or KM).

2.5. *Strength of the evidence*

Initially, strength of evidence was assessed utilizing a 5-level rating system (strong, moderate, limited, inconclusive, and no evidence) adopted from a previous high-quality systematic review[34] based on study design, methodological quality, and sample size. In relation to the decision tree, large studies included a sample of >250 children;[34] high-quality studies had a quality score of 75% or above on the MMAT, and RCT and NR studies were included. Conclusions were drawn on the basis of consistency of results of studies with the highest available level of quality. If at least two-thirds of the relevant studies with the highest available level of quality were reported to

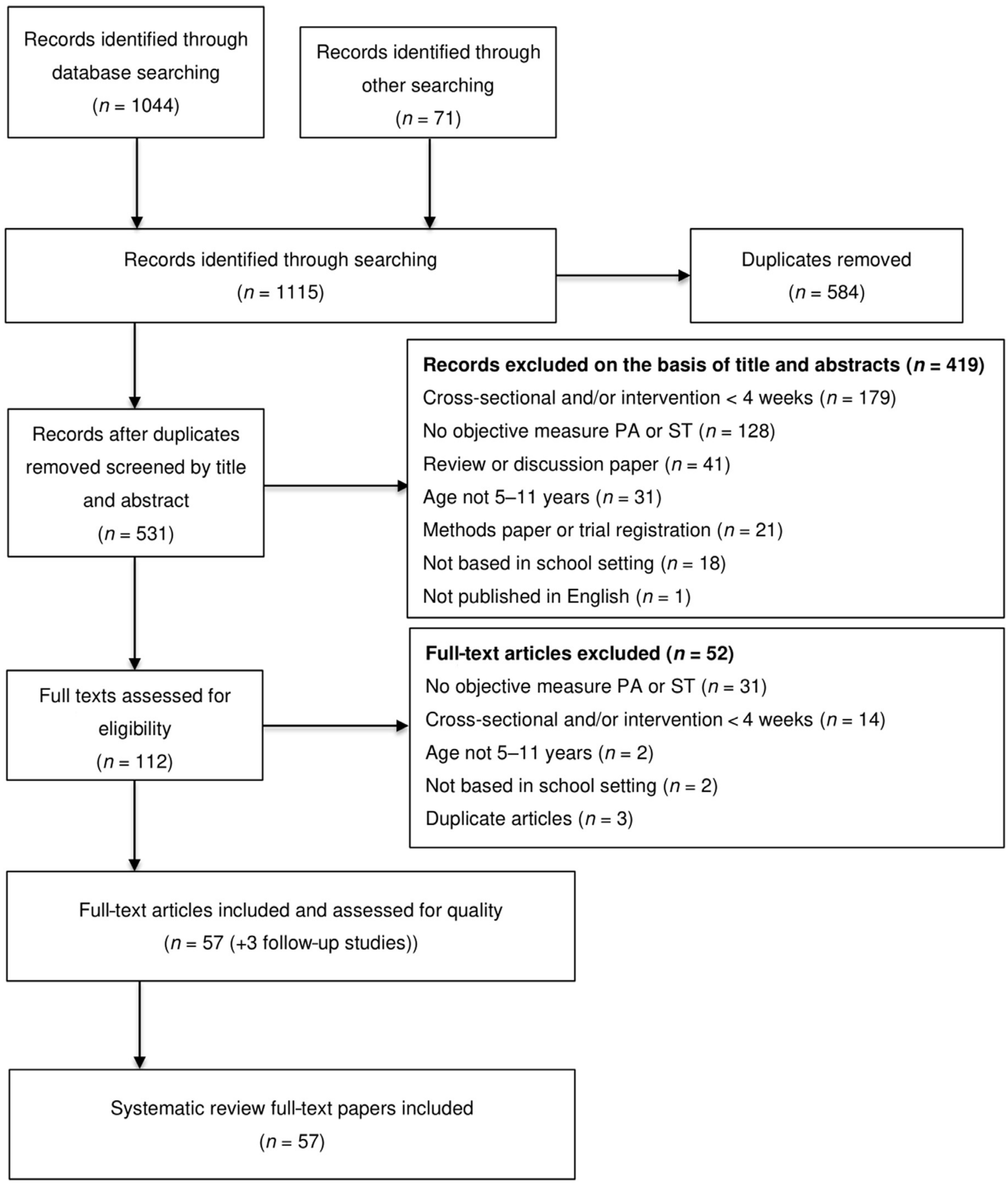

Fig. 1. Evidence search and exclusion process. PA = physical activity; ST = sedentary time.

have significant results in the same direction, then overall results were considered to be consistent.

2.6. Meta-analysis

Heterogeneity of outcome measurement device, time frame (specific activities, school day, and whole day), analysis (cut-points), varied methodological quality, and research design made an overall meta-analysis inappropriate. Upon completion of the review, it was deemed that a subset of studies was suitable for meta-analysis, so it was decided *post hoc* that this be conducted. To provide some insight into the magnitude of effect, a meta-analysis was conducted of those studies that used accelerometer devices for whole-day PA measurement and that included either a measure of minutes of MVPA or minutes of ST, since these are most strongly associated with health-related outcomes. When the reporting in the studies was insufficient for inclusion in the meta-analysis, the corresponding authors were contacted to request additional information.

All analyses were performed using the "metafor" package in R (Version 3.5.2; the R Foundation, St. Louis, MO, USA), and an α of 0.05 was considered to be significant in all tests.

Change scores from baseline to postintervention were calculated for intervention and control groups. Intervention effects were calculated by dividing the between-group difference of mean change in MVPA or ST minutes from baseline by the pooled SD of change in MVPA or ST for the intervention and control groups, assuming a correlation of $r = 0.5$ between baseline and postintervention.[44] Standardized between-group effect sizes (ES) using the Hedges' g were calculated for each study and outcome measure to descriptively quantify the changes in the outcomes. If a study had 2 intervention groups, their data were analysed independently, with the control group thus yielding multiple ES for that study and outcome. The magnitude of each ES using Hedges g was interpreted with reference to Cohen thresholds:[45] trivial (<0.2), small (≥0.2 to <0.5), moderate (≥0.5 to <0.8), and large (≥0.8). For MVPA, positive ES values indicated more minutes of MVPA in favor of the intervention group compared with the control group, whereas for ST, positive ES values indicated fewer minutes of ST in favor of the intervention group compared to the control group.

Two separate random effects meta-analyses were performed for MVPA and ST, where point estimates for pooled ESs were estimated along with the precision of those estimates using 95% confidence intervals (CIs). Random effects meta-analyses were chosen because heterogeneity was expected, given differences in interventions. Estimates were weighted by inverse sampling variance, and restricted maximal likelihood estimation was used in all models. Sensitivity analyses were performed for random effects meta-analyses by removing studies one by one to assess the robustness of the summary estimates. This would also indicate whether an individual study accounted for a large proportion of the heterogeneity. Additionally, mixed-effect meta regression analyses were carried out using study type (RCT or NR) and quality (high > 75% or low ≤ 75%) as fixed dichotomous moderators. Heterogeneity was examined through the Q statistic and the I^2 statistic. The Q statistic assesses the statistical significance of the variability of effects within and between study groups; a significant Q statistic suggests that studies are likely not drawn from a common population. The I^2 statistic provides an estimate of the degree of heterogeneity in effects among a set of studies between 0 and 100%. The Cochrane review's rough guide to interpretation of of I^2 values was utilised; I^2 values of 0%−40% might not be important, values of 30%−60% may represent moderate heterogeneity, values of 50%−90% may represent substantial heterogeneity, and values of 75%−100% had considerable heterogeneity.[46] Publication bias was analysed using funnel plots and the Egger regression asymmetry test. Notably, neither meta regression nor funnels plots were conducted for ST as an outcome due to the low number of studies ($n = 4$). The analysis code is available upon request.

3. Results

3.1. Description of studies included in the analysis

The 57 studies included 29 RCT studies[47−75] (mean quality 45%), 17 NR studies[76−92] (mean quality 50%), 10 descriptive studies[93−102] (mean quality 83%), and 1 mixed-methods study[103] (quality 50%). The majority of studies ($n = 49$, 86%) were published within the past decade.[47−50,52−61,63−68,71,73−75,77−90,92−101,103] The sample size of children with objectively assessed PA and/or ST was < 250 in 30 studies,[47,49,51,52,55,56,58−60,65,66,70−74,78,79,83,84,87,89,90,94,95,98−100,102,103] between 250 and 999 in 19 studies,[48,53,54,57,61,62,64,69,75−77,80−82,85,86,88,91,96] and > 1000 in 8 studies.[50,63,67,68,92,93,97,101] In 6 studies, only a subsample had objectively assessed PA and/or ST.[62,70,76,78,83,95] The studies were conducted in the USA,[47−49,53,54,58,59,62,66,69,71,72,77,81,83,84,88,91,93−99,101] ($n = 26$, 46%), 7 European Union countries[50,51,55,67,70,79,80,85,87,89] ($n = 18$, 32%), within the UK ($n = 8$, 14%),[60,61,63,76,78,82,90,100] and in 2 Australasian countries[52,56,57,73,74,86,102] ($n = 7$, 12%); the remaining 6 studies were conducted in Canada;[75,92] Hong Kong, China;[103] Iceland;[65] Norway;[68] and Switzerland.[64]

3.2. Strength of evidence for effect of intervention on PA and ST

A positive effect on PA was reported in 68% of the 57 studies.[47−51,55,56,58−60,65,66,68,70,72,74,76−79,82−84,86−98,100,101,103] Focusing specifically on those studies that measured MVPA (37 studies), 62% indicated a positive effect.[47−51,55,56,58−60,65,66,68,70,76−79,82,84,93−95] There was no overall evidence of effect for MVPA due to the quality of evidence, with 2 of the 3 large, high-quality RCTs[48,63,67] reporting no effect on MVPA. Only 11 studies[47,52,58,59,63,68,77,78,81,84,85] included a measure of ST, 6 of which[47,58,59,77,78,84] reported a positive effect during the school day or whole day. Overall, the evidence rating for ST was inconclusive.

3.3. Strength of evidence for type of intervention and evidence of effect

Table 2 summarizes the intervention type in relation to the TEO. Expanded opportunities, where time allocated for PA replaced time previously allocated for low-active or sedentary activities, were present in 17 studies (30%) and included class PA breaks, physically active learning, before- and after-school clubs, physically active homework, active travel, and a whole-school PA expansion. Overall, 82% of studies that expanded PA opportunities reported a positive effect on PA or MVPA, and there was moderate evidence of effect on MVPA. The evidence regarding the use of differing intervention types to expand PA opportunity was inconsistent. Intervention studies that extended opportunity by increasing time for pre-existing PA comprised 2 studies that extended PE, with no evidence to support their effectiveness, and 2 studies that extended recess time, with inconclusive evidence of their effectiveness. Enhancing opportunity for PA was identified in 18 studies, and approaches to modifying current PA opportunities in order to increase the amount of PA included PE, recess, and overall school PA. Of the studies enhancing PA opportunities, 61% reported a positive effect on either PA or MVPA, but the evidence ratings showed no evidence on MVPA. A number of studies ($n = 18$) were multicomponent, combining TEO categories, most commonly expanding and enhancing PA opportunities. Taken together, the evidence rating for multicomponent

Table 2
Summary of TEO intervention type and level of evidence.

TEO and level of evidence	Intervention type and level of evidence	Design, quality score, sample size	PA outcome	ST outcome
Expanded	Class PA breaks	RCT,[59] 100%, <250	+MVPA	
Moderate evidence MVPA and inconclusive evidence ST	Limited evidence MVPA	RCT,[60] 50%, <250	+MVPA	
		D,[98] 100%, <250	+Step count	
		RCT,[72] 50%, <250	+Step count	
	PA learning	RCT,[55] 75%, <250	+MVPA	
	Limited evidence MVPA	RCT,[56] 75%, <250	+MVPA	
	Before-school clubs	RCT,[47] 25%, <250	+MVPA	−ST
	Inconclusive evidence MVPA			
	After-school clubs	MM,[103] 50%, <250	+PA	
	Moderate evidence MVPA	RCT,[58] 75%, <250	+MVPA	−ST
		RCT,[48] 75%, >250	+MVPA	
	PA homework	RCT,[73] 0%, <250	0 Step count	
	No evidence PA	D,[102] 100%, <250	0 Step count	
	Expanded school PA	D,[95] 75%, <250	+MVPA	
	Inconclusive evidence PA	RCT,[75] 75%, >250	0 Step count	
		RCT,[68] 50%, >1000	+MVPA	0 ST
	Active travel	NR,[83] 75%, <250	+PA	
	Limited evidence PA	RCT,[66] 75%, <250	+MVPA	
Extended	Increased PE time	NR,[80] 50%, >250	0 MVPA	
Inconclusive evidence MVPA	No evidence MVPA	RCT,[67] 75%, >1000	0 MVPA	
	Increased recess time	NR,[78] 25%, <250	+ MVPA	−ST
	Inconclusive evidence MVPA	RCT,[51] 25%, <250	+ MVPA	
Enhanced	Enhanced PE	RCT,[62] 0%, >250	0 MVPA	
No evidence MVPA	No evidence MVPA	RCT,[69] 0%, >250	0 MVPA	
		NR,[79] 25%, <250	+ MVPA	
	Enhanced recess	RCT,[49] 25%, <250	+ MVPA	
	Inconclusive evidence MVPA	RCT,[52] 50%, <250	0 MVPA	0 ST
		RCT,[61] 25%, >250	0 MVPA	
		NR,[84] 25%, <250	+ MVPA	−ST
		D,[94] 100%, <250	+MVPA	
		RCT,[53] 50%, >250	0 MVPA	
		RCT,[54] 0%, >250	0 MVPA	
		NR,[86] 75%, >250	+Step count	
		RCT,[50] 0%, >1000	+MVPA	
		NR,[87] 75%, <250	+Step count	
		NR,[76] 75%, >250	+MVPA	
	Enhanced school PA	D,[100] 100%, <250	+Step count	
	Inconclusive evidence MVPA	RCT,[71] 50%, <250	0 MVPA	
		NR,[92] 25%, >1000	+Step count	
		RCT,[70] 50%, <250	+MVPA	
Multi-component	Expanded and enhanced	D,[93] 100%, >1000	+MVPA	
Inconclusive evidence MVPA	Inconclusive evidence MVPA	D,[97] 75%, >1000	+Step count	
		NR,[88] 50%, >250	+Step count	
		NR,[81] 50%, >250	−MVPA	+ST
		RCT,[57] 25%, >250	0 MVPA	
		NR,[77] 75%, >250	+MVPA	−ST
		RCT,[74] 100%, <250	+Step count	
		NR,[90] 25%, <250	+Step count	
		NR,[82,114] 50%, >250	+MVPA	
		D,[96] 50%, >250	+PA	
		RCT,[63] 75%, >1000	0 MVPA	0 ST
		D,[101] 75%, >1000	+Steps	
		RCT,[65] 0%, <250	+MVPA	
		NR,[89] 50%, <250	+Step count	
		NR,[85] 50%, >250	0 MVPA	0 ST
	Extended and enhanced	D,[99] 50%, <250	0 Step count	
	Expanded and extended	RCT,[64,115] 50%, >250	0 MVPA	
		NR,[91] 25%, >250	+Step count	

Notes: As for the outcome, + indicates significant increase in measure or intervention > control; 0 indicates no significant difference between pre- and post- or intervention and control; − indicates significant decrease in measure or intervention < control.

Abbreviations: D = quantitative observational descriptive; MM = mixed-methods; MVPA = moderate-to-vigorous physical activity; NR = quantitative non-randomised controlled; OB = quantitative observational descriptive; PA = physical activity; PE = physical education; RCT = quantitative randomised controlled trial; ST = sedentary time; TEO = theory of expanded, extended and enhanced opportunity.

programmes was inconclusive evidence on MVPA, with 66% reporting a positive impact on either PA or MVPA.

3.4. Strength of evidence for PA outcome measure and evidence of effect

Table 3 summarizes PA outcome measure and effect. The inclusion criteria for studies included the requirement for objectively assessed PA or ST. Of the 57 studies, 67% utilised accelerometer measurement, and 35% used pedometers. One study[93] used both accelerometer and pedometer measures. The descriptions of the device-based measurements of PA typically included device-model details, time frame for device measures, cut-points, and data-inclusion criteria, although the descriptions were not consistent across all studies. The analysis of the accelerometer data collected varied; 9 different cut-points were utilized for time spent in MVPA. Typically, total step count was the dependent variable for pedometer measures.

As shown in Table 3, the time period for PA data collection varied, with measurements being taken during the actual intervention (16%, 9 studies), during the school day (28%, 16 studies), or during the whole day (58%, 33 studies). Notably, 1 study[47] analyzed multiple time frames (during the intervention and during the whole day). The time frame for measurement appeared to influence the reported outcomes, irrespective of the type of intervention applied. When intervention effectiveness was measured during actual intervention delivery, 100% of the 9 studies reported a positive effect, with moderate evidence of effect for MVPA and inconclusive evidence for step count. When intervention effectiveness was measured during the school day, 76% of the 16 studies reported a positive effect for MVPA or step count. The quality and nature of evidence led to an overall rating of inconclusive evidence for MVPA and step count when intervention effectiveness was measured during the school day. When PA was measured over a whole day (excluding sleep), the reported effectiveness of the intervention was lower, with 58% (19 of 33 studies) reporting a positive effect for MVPA or step count. There was, therefore, no evidence of effect for either step count or MVPA when intervention effectiveness was measured across a whole day. There was inconclusive evidence for ST, primarily due to the low number of studies of higher quality, whether measurements were taken during the school day or during the whole day.

3.5. Meta-analysis of whole-day accelerometer-measured MVPA and ST

Publication bias analysis using the Egger regression asymmetry test suggested evidence of publication bias for MVPA ($z = 4.3749$, $p < 0.0001$). The funnel plot for studies reporting MVPA outcomes identified 2 studies as clear outliers.

The pooled ES estimates for the effects of interventions on MVPA was 0.51 (95%CI: 0.02−0.99), indicating a statistically significant moderate effect, albeit with relatively low precision, as indicated by the CIs ranging from trivial to large. The Cochrane Q showed a significant heterogeneity ($Q = 168.7$, $df = 10$, $p < 0.0001$) for MVPA and a considerable inconsistency measure, with $I^2 = 98.43\%$. Fig. 2 shows a forest plot of studies reporting MVPA outcomes. Sensitivity analysis revealed that effect estimates for MVPA were no longer significant after removal of several individual studies, though the magnitude of the estimates and their precision were similar (removal of Bugge et al.[80] = 0.53, 95%CI: −0.03 to 1.08; removal of Cohen et al.[57] = 0.50, 95%CI: −0.05 to 1.06; removal of Crouter et al.[58] = 0.52, 95%CI: −0.03 to 1.07; removal of Drummy et al.[60] = 0.52, 95%CI: −0.03 to 1.07; removal of Kriemler et al.[64] = 0.54, 95%CI: −0.01 to 1.10), with the exception of Howe et al.,[84] which reduced the estimate but increased the precision to 0.31 (95%CI: −0.02 to 0.64), and Mendoza et al.,[66] which reduced the estimate to 0.38 (95%CI: −0.07 to 0.82).

The pooled ES estimates for the effects of interventions on ST were 1.15 (95%CI: −1.03 to 3.33), indicating a nonsignificant large effect, with very low precision, as indicated by the CIs from a negative large effect to a positive large effect. For ST, the Cochrane Q showed a significant heterogeneity ($Q = 38.7$, $df = 3$, $p < 0.0001$) and a considerable inconsistency measure, with $I^2 = 98.6\%$. Sensitivity analysis revealed a substantial reduction in magnitude and increase in the precision of the estimate upon removal of Howe et al.[84] (−0.05; 95%CI: −0.12 to 0.02).

The mixed-effect meta regression model showed that the interventions with an MVPA measure were not associated with study type (coefficient = 0.49 ± 1.19, $p = 0.4252$) or study quality (coefficient = −0.13 ± 1.18, $p = 0.8299$).

3.6. Participant characteristics and evidence of effect

The majority of studies reported outcomes for the whole sample of participants or by grade, irrespective of participants' characteristics. A differential response to intervention based on sex was identified in 6 studies,[53,54,65,75,79,91] including 1 large high-quality RCT[75] and 2 large low-quality RCTs.[53,54] There was no overall pattern, with some studies reporting a greater effect for girls than boys[79,91] and *vice versa*.[75] A total of 3 studies identified differential responses based on baseline characteristics, including 2 studies that reported a larger effect for the least active participants.[71,102]

4. Discussion

The objective of this systematic review was to ascertain the effectiveness of school-based interventions in increasing PA and/or reducing ST in children aged 5−11 years. Overall, the systematic review identified no evidence of effect for MVPA and inconclusive evidence for ST. Two previous reviews also identified no overall evidence for PA during school-based interventions when focusing on children: van Sluijs et al.[34] found less evidence for children than for adolescents, and Metcalf et al.[104] identified a small effect on MVPA and a lower mean standardised difference among children younger than 10 years of age compared to older children. In accord with van Sluijs et al.,[34] who proposed, in part, that the low effect in children might be a consequence of higher baseline PA levels, 2 studies included in this review reinforced a larger effect for

Table 3
Summary of physical activity measure and level of evidence.

Measurement device	Time period and evidence level	Design, quality score, sample size	Cut-points of MVPA threshold	PA outcome	ST outcome
Accelerometer (*n* = 38 studies)	During the intervention activity	RCT,[47] 25%, <250	Freedson et al.[116]	+MVPA	−ST
		RCT,[48] 75%, >250	Freedson et al.[116]	+MVPA	
	Moderate evidence MVPA	RCT,[49] 25%, <250		+MVPA	
		RCT,[50] 0%, >1000		+MVPA	
		NR,[76,107] 75%, >250	Nilsson et al.[117]	+MVPA	
		RCT,[51] 25%, <250	Nilsson et al.[117]	+MVPA	
	During the school day	D,[93] 100%, >1000	Evenson et al.[118]	+MVPA	
		NR,[77] 75%, >250	Freedson et al.[116]	+MVPA	−ST
	Inconclusive evidence MVPA and ST	RCT,[52] 50%, <250	Evenson et al.[118]	0 MVPA	0 ST
		D,[94] 100%, <250	Nilsson et al.[117]	+MVPA	
		RCT,[53] 50%, >250	Freedson et al.[116]	0 MVPA	
		RCT,[54] 0%, >250	Freedson et al.[116]	0 MVPA	
		NR,[78] 25%, <250	Evenson et al.[118]	+MVPA	−ST
		RCT,[55] 75%, <250	Evenson et al.[118]	+MVPA	
		RCT,[56] 75%, <250	Evenson et al.[118]	+MVPA	
		NR,[79] 25%, <250	Evenson et al.[118]	+MVPA	
	During the whole day	RCT,[47] 25%, <250	Freedson et al.[116]	+MVPA	−ST
		NR,[80] 50%, >250	≥ 1500 cpm	0 MVPA	
	No evidence MVPA and inconclusive evidence ST	NR,[81] 50%, >250	Evenson et al.[118]	−MVPA	+ST
		RCT,[57] 25%, >250	Evenson et al.[118]	0 MVPA	
		RCT,[58] 75%, <250	Freedson et al.[116]	+MVPA	−ST
		RCT,[59] 100%, <250		+MVPA	−ST
		RCT,[60] 50%, <250	> 2000 cpm	+MVPA	
		RCT,[61] 25%, >250	Evenson et al.[118]	0 MVPA	
		RCT,[62] 0%, >250		0 MVPA	
		NR,[82,114] 50%, >250	Freedson et al.[116]	+MVPA	
		NR,[83] 75%, <250	Welk[119]	+PA	
		D,[95] 75%, <250	Trost et al.[120]	+MVPA	
		NR,[84] 25%, <250	Freedson et al.[116]	+MVPA	−ST
		D,[96] 50%, >250		+PA	
		RCT,[63] 75%, >1000	MVPA ≥2296 cpm ST 0−100 cpm	0 MVPA	0 ST
		RCT,[64,115] 50%, >250	MVPA >2000 cpm	0 MVPA	
		RCT,[65] 0%, <250	>2000 cpm	+MVPA	
		RCT,[66] 75%, <250	Freedson et al.[116]	+MVPA	
		RCT,[67] 75%, >1000	Evenson et al.[118]	0 MVPA	
		RCT,[68] 50%, >1000	Evenson et al.[118]	+MVPA	0 ST
		RCT,[69] 0%, >250		0 MVPA	
		NR,[85] 50%, >250	Evenson et al.[118]	0 MVPA	0 ST
		RCT,[70] 50%, <250	Trost et al.[120]	+MVPA	
Pedometer (*n* = 20 studies)	During the intervention activity	MM,[103] 50%, <250	Step count	+PA	
		NR,[86] 75%, >250	Step count	+Step count	
	Inconclusive evidence step count	NR,[87] 75%, <250	Step count	+Step count	
	During the school day	D,[93] 100%, >1000	Step count	+MVPA	
		D,[97] 75%, >1000	Step count	+Step count	
	Inconclusive evidence step count	NR,[88] 50%, >250	Step count	+Step count	
		D,[98] 100%, <250	Step count	+Step count	
		RCT,[71] 50%, <250	Step count	0 MVPA	
		RCT,[72] 50%, <250	Step count	+Step count	
		NR,[89] 50%, <250	Step count	+Step count	
	During the whole day	D,[99] 50%, <250	Step count	0 Step count	
		RCT,[73] 0%, <250	Step count	0 Step count	
	No evidence MVPA	D,[100] 100%, <250	Step count	+Step count	
		RCT,[74] 100%, <250	Step count	+Step count	
		NR,[90] 25%, <250	Step count	+Step count	
		D,[101] 75%, >1000	Tudor-Locke et al.[121]	+Steps	
		RCT,[75] 75%, >250	Step count	0 Step count	
		D,[102] 100%, <250	Step count	0 Step count	
		NR,[91] 25%, >250	Step count	+Step count	
		NR,[92] 25%, >1000	Step count	+Step count	

Notes: Reference 93 used both an accelerometer and a pedometer. As for the outcome, + indicates significant increase in measure or intervention > control; 0 indicates no significant difference between pre- and post- or intervention and control; − indicates significant decrease in measure or intervention < control.
Abbreviations: cmp = count per minute; D = quantitative observational descriptive; MM = mixed-methods; MVPA = moderate-to-vigorous physical activity; NR = quantitative non-randomised controlled; RCT = quantitative randomised controlled trial; ST = sedentary time.

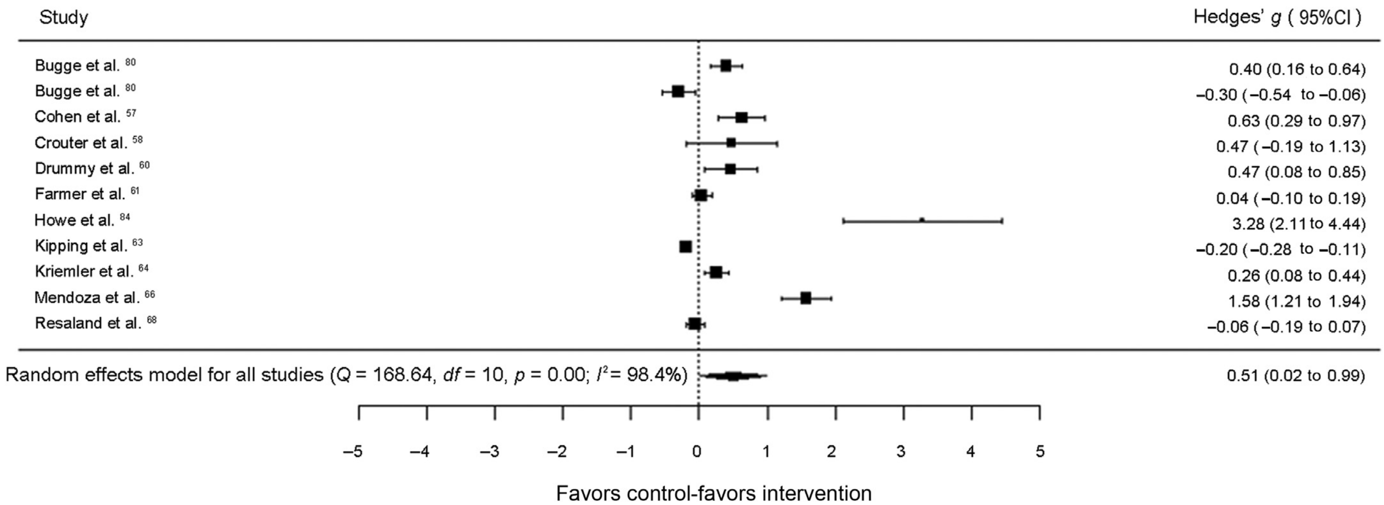

Fig. 2. Main effect for moderate-to-vigorous physical activity whole-day accelerometer measure. Forest plot for standardised mean difference of change in physical activity between intervention and control groups of school-based physical activity interventions in children.

the least active participants.[71,102] To the best of our knowledge, there has been no previous systematic review that considered interventions to reduce ST specifically in school children, and the inconclusive evidence rating and small number of studies, therefore, suggests that further research is warranted. The finding of no evidence of effect for PA reinforces the point that systematic reviews, including meta-analyses, that combine children and adolescents as 1 homogeneous group need careful interpretation.

In accord with previous studies,[28,29] 68% of the studies in our review reported a positive impact on PA, and 62% reported a positive impact on MVPA. Specifically, Salmon et al.[28] found that 12 of 18 studies (67%) with objective measures of PA reported a positive effect in children, and Timperio et al.[29] found that 6 of 9 studies (67%) based in primary schools had a positive effect. Our systematic review included a variety of study designs. Indeed, 1 reason for the discrepancy in our findings that between the 62% of studies reporting a positive impact on MVPA and no evidence of effect being found for the overall rating could be attributed to the impact of research design and time-related changes. In fact, 5 RCTs and 2 NR studies reported that the significant effect of the intervention was aligned with preventing, or at least reducing, the decline in PA observed in control conditions over time, rather than significantly increasing PA in intervention conditions *per se*.[55,58,66,70,73,81,82] The prevention of a decline in MVPA and or an increase in ST was analysed in the studies included in our meta-analysis; the mean difference between baseline and postintervention for MVPA and ST, respectively, was -5.0 ± 12.2 min and 15.1 ± 63.4 min in the control groups *vs.* 1.8 ± 16.5 min and 3.4 ± 62.1 min in the intervention groups. Whilst the intervention duration of these studies was variable, with 4 studies lasting 4−10 weeks,[55,58,66] others were implemented over a longer duration, for example, 10 months,[73] 1 year,[81] or 2 years.[70] The differing implementation times may explain the effects in terms of preventing a decline in PA or ST. Moreover, interventions conducted over shorter durations (i.e., <12 weeks) could arguably be more subject to the impact of seasonal changes.[105,106] It is plausible that such interventions could reduce the negative effects of seasonal change or, indeed, in the case of noncontrolled trials, changes in PA, irrespective of whether they are positive or negative, may be a consequence of time rather than the intervention itself.

Whilst the finding of no evidence of effect for PA or MVPA and inconclusive evidence for ST is a disappointing outcome for public health practitioners and researchers who consider the school a promising setting for interventions, it is important to understand why attempts to increase children's PA levels and reduce ST have been largely unsuccessful.[104] Such information is imperative to enhance future intervention design, delivery, and outcomes. A number of factors warrant discussion in relation to this overall finding, including, but not limited to: (1) the exploration of any types of school-based interventions that show more promising evidence of effectiveness; (2) methods of intervention implementation; (3) the possibility of compensatory behaviors; (4) the theoretical underpinnings of interventions; and (5) the reporting and methodologicalal quality of interventions.

4.1. Intervention approach and the TEO

The TEO has been proposed to provide a common taxonomy to identify appropriate interventions across different settings and afford a more practical approach to school-based PA interventions.[19,37] Expanded PA opportunity was a more promising intervention approach (moderate evidence rating) than extending (inconclusive evidence rating) or enhancing (no evidence rating) PA opportunity. No previous systematic reviews have considered different types of interventions in relation to the TEO, so this is a novel finding that may help inform future research and/or policy implementation. After-school clubs (moderate evidence rating), class PA breaks (limited evidence rating), physically active learning (limited evidence rating), and active travel (limited evidence rating) appear to be the most promising expanded opportunity interventions in school settings for children.

Studies expanding PA via after-school clubs typically involved engagement with stakeholders, including families, to develop a bespoke programme that included a PA programme.[48,58,103] Two studies investigated expanding PA via active travel through the implementation of a "walking" school bus, which employed a researcher or paid staff member to supervise specific walking routes to the school.[66,83] Whilst after-school clubs and active travel appear to lead to promising outcomes for MVPA, scaling-up implementation is likely to be challenging due to the resources required and given that participation by children is typically optional, thereby potentially reducing intervention reach. Indeed, of the 3 studies reporting expansion of after-school PA, only one had >250 participants,[48] and although 1 study reported more than 80% attendance,[58] the other 2 studies did not report attendance rates.[58,103] Similarly, for active travel, the optional nature of the PA is exemplified; Heelan et al.[83] found that just over a third of children actively commuted at least half of the time as a consequence of the intervention. Therefore, whilst after-school clubs and active travel warrant further research and may provide some benefit in terms of MVPA, they should be considered to be part of a broader integration of PA into children's lives.

Beets et al.[37] emphasized the importance of compulsory PA opportunities during the school day and in terms of expanded PA opportunities. Both class PA breaks and physically active learning are worthy of further research exploration. In our review, all 4 studies reporting class PA breaks found positive outcomes for MVPA or PA, but the risk of bias (quality and/or sample size) led to a limited-evidence rating.[59,60,72,98] Class PA breaks have typically involved training teachers and/or providing teacher resources to deliver 10-min class breaks that can be implemented by the class teachers, at their discretion, to the whole class in their normal classroom setting. This type of intervention appears to have potential for sustainability, with 2 of the 4 studies we reviewed reporting good teacher compliance[59,72] and with all 4 studies having been conducted over at least 8 weeks.[59,60,72,98] Physically active learning differs from class PA breaks in that PA was integrated into core English and math curriculum learning in the 2 high-quality, small RCTs that identified positive impact on MVPA.[55,56]

Extending PA opportunities via increasing PE time[62,69,79] or increasing recess time[51,78] led to an inconclusive evidence rating. Extending PE time did not lead to any reported increase in MVPA in 2 studies; in fact, 1 high-quality, large RCT increased PE time from 2 to 6 lessons (4.5 h/week) and found that, when measured over a whole day, there was no significant difference in MVPA between children in intervention and control schools.[67] However, in 2 low-quality studies, extending recess time did lead to increases in MVPA.[51,78] The inconclusive evidence for extending PA opportunities during the school day, alongside the significant time pressure reported by schools, suggest that there is little evidence to support extending PE or recess time as an evidence-based approach to increasing MVPA. It is noteworthy, however, that the impact on other health-related measures and the importance of developing fundamental movement skills for later PA have not been considered in this review.

Enhancing existing PA opportunities included enhancing PA in PE,[62,69,79] recess,[49,50,52–54,61,76,84,86,87,94] and overall school PA,[70,71,92,100] but these enhancements resulted in an overall rating of no evidence of effect on MVPA. Studies that reported on the enhancement of PA within PE have typically involved the provision of training and/or resources for teachers to increase activity during existing lessons.[62,69,79] A total of 11 studies[49,50,52–54,61,76,84,86,87,94] with intervention durations ranging from 4 weeks to 10 months, and one 12-month follow-up study,[107] explored enhancing recess. This approach has included the addition of resources such as play equipment[50,52–54,76,86,87,94] or playground-environment improvement,[50,61,76,87,94] teacher or supervisor education,[49,50,53,54,94] and/or the addition of structured PA[49,84] into pre-existing recess periods. Overall, the high risk of bias due to research quality led to an inconclusive evidence rating on MVPA, which differs from previous systematic reviews, which have suggested that interventions could lead to improvements in PA during school recess.[21–23] Possible reasons for this difference could be a reported effect that the difference in PA is moderated by age,[21] or it could relate to the use of different time periods for the measurement of outcomes (e.g., measuring effects during recess *vs.* during the whole day). Studies that report on the enhancement of overall school PA have included pedometer-based challenges,[71,100] creation of a health-facilitator role,[92] and a comprehensive programme to enhance PA in the curriculum, PE, and recess.[70] However, these enhancements led to an inconclusive evidence rating of MVPA. Within school settings, enhancing existing PA opportunities alone does not appear to be an effective evidence-based strategy to promote PA among children.

A number of studies combined aspects of the TEO in a multicomponent approach.[64,91,99] This most commonly took the form of a combination of expanding and enhancing PA opportunities, but overall these approaches led to an inconclusive evidence rating of MVPA.[63,65,74,77,81,82,85,88–90,93,96,97,101,108] Results from the implementation of the Comprehensive School Physical Activity Programme, which combines enhancement of PA through PA leaders, PE, and recess time and extension via class PA breaks, were reported in 4 studies.[81,88,93,97] Other multicomponent studies included implementation of a healthy/active schools policy,[77,96,101,108] health curriculum,[65,74,89,101] active homework,[63,74,90] involvement of family/community[101,108] and out-of-school events or activities.[82,85,89] Our review of these studies resulted in an inconclusive evidence rating on MVPA; thus, even comprehensive multicomponent programmes based in school settings may have little effect on children's PA.

4.2. PA increases in school intervention vs. compensatory PA decline

Previous systematic reviews have analysed intervention effects collectively, regardless of the duration of objective PA measurement. Our findings, in terms of synthesis of strength-of-evidence ratings, indicate that there is moderate evidence for MVPA when PA was measured during intervention delivery, inconclusive evidence when PA was measured during the school day, and no evidence when PA was measured over a whole day. Indeed, analysing studies based on measurement duration is a key strength of the present review. Whilst the meta-analysis of the studies with whole-day accelerometer measures suggested a pooled ES of 0.57 and 1.57 for MVPA and ST, respectively, both of these had low precision, significant heterogeneity, and considerable inconsistency. A very recent meta-analysis of school-based PA interventions, which included only studies using whole-day accelerometer measurements, found a pooled ES of 0.02 and concluded that current school-based interventions do not increase young people's (children's and adolescents') daily PA.[109] Interestingly, Love et al.[109] indicated a nonsignificant trend towards a decrease in standardised mean difference with increasing mean age of participants, which may explain the study's lower effect in comparison to our findings. This finding highlights the importance of whole-day measurement of PA in order to fully elucidate the effect of an intervention in a particular setting and the likely health impacts. It should be noted that a number of intervention studies might not have aimed specifically to increase whole-day PA, but rather focused on behavior change over 1 small portion of the day.

A number of existing systematic reviews of school-based PA interventions,[28,104] as well as Beets et al.,[37] highlighted the potential risk that the intervention might increase PA during actual intervention delivery but result in a compensatory decline elsewhere during the day. The analysis of response on the basis of outcome measurement duration provides some support for the ActivityStat hypothesis, which suggests that increases in PA in 1 domain cause a compensatory reduction in another.[110] More specifically, 2 studies included in our review explored PA over differing time periods, and both identified increased PA during the target intervention of recess[52] or PE[69] but not during the school day or the whole day. On the basis of these findings, it appears that practitioners and researchers are effectively identifying and implementing approaches to increasing PA during specific domains of the school day but are unable to ensure that the increases are sustained over the whole day. The inconclusive evidence rating for ST over a whole day provides some promise in that even though attempts to increase MVPA do not seem to persist through a whole day, they may bring about some other behavior changes, for instance, reduced ST. Future research needs to consider both the implementation of interventions within school settings and the research design so as to account for compensatory behavior.

Despite the lack of evidence for the effect of PA interventions in increasing PA levels across the whole day, it should be noted that the increases in PA exhibited during intervention periods (which were moderately evidenced) might provide some benefit. For example, there is evidence that PA interventions with sufficiently high-intensity effort PA during intervention periods may increase cardiorespiratory fitness in children.[111] Indeed, expanded opportunities for PA, such as after-school clubs, have been reported to result in high levels of energy expenditure thought to be sufficient to stimulate improved cardiorespiratory fitness, both with traditional activities (i.e., soccer and netball) and novel activities (i.e., trampoline-park sessions).[112] Thus, although whole-day increases in PA may be minimal due to compensatory behaviors, PA interventions may be successful in improving other outcomes.

4.3. Limitations and recommendations for future research

The TEO was not used specifically to underpin any studies included in the current review but was retrospectively applied as a taxonomy to describe interventions. The TEO was, generally, easily applied in this context, and analysis by intervention category identified differential effectiveness, suggesting that the theory provided a useful taxonomy and framework for considering intervention effectiveness. Therefore, future research should consider using the TEO as part of intervention design.

The current systematic review was prospectively registered with the Prospective Register of Systematic Reviews (PROSPERO) and, therefore, the risk of bias by adjustment of protocol was minimized. However, 1 limitation of the current review was the relatively limited nature of the initial literature search, in that it did not include search terms related to specific intervention types or to sex. Nonetheless, the thorough process of searching for secondary references most likely rectified this limitation. Indeed, 24 of the 57 studies reviewed were identified via secondary search strategies. Specifically, a systematic review of RCTs with objective, whole-day accelerometer PA measurements published after the search strategy was completed[109] included a final sample of 17 studies. Of these 17 studies, 11 were focused on older children, 3 were included in the current study, and the remaining 3 were screened out because the intervention focus of those 3 studies was weight loss/obesity prevention. Furthermore, an additional 26 RCTs were identified in the current systematic review, including 12 that measured whole-day PA via accelerometer, thereby providing confidence that the current review included a comprehensive set of studies.

The methodological quality of studies included in our review was variable, and the intervention reporting was in line with the TIDieR checklist,[45] which highlighted some common shortcomings. In terms of methodological quality, the most common limitations included the lack of randomization and lack of clarity regarding drop-out rates. From a methodological perspective, it is important that future intervention studies incorporate a control group to account for age- or time-related changes, not least because some interventions specifically sought to prevent or reduce the decline in PA observed in control conditions over time, as opposed to significantly increasing PA in intervention conditions.[55,58,66,70,73,81,82] From an intervention reporting perspective, it was typically possible to identify the rationale, materials, and procedures used in the studies, including who administered the intervention and how it was implemented. However, the majority of studies did not report any tailoring or modifications of the intervention design or delivery, nor, indeed, were adherence levels reported. Whilst a small number of studies considered sex differences in terms of intervention effectiveness,[53,54,65,75,79,91] there was no overall pattern in the results, which suggests sex-specific interventions do not appear to be warranted. However, it might be important to tailor interventions on the basis of fitness and/or baseline PA levels.[71,102,80]

A number of studies used objective PA assessment only in a subpopulation, which may have introduced selection bias.[62,70,76,78,83,95] The measurement device, time period of measurement, and analysis methods, including cut-points for thresholds, varied substantially across studies, which collectively weakens confidence in generating firm conclusions regarding effectiveness. It is critical that future research include whole-day PA and ST measurements if the effect of school-based interventions on overall PA and sedentary levels is be accurately evaluated. Rowlands[113] recently used raw accelerometer data to generate an activity gradient, which removed the issue of multiple cut-points and, thus, could be a more promising and robust approach for future assessment of intervention effectiveness. Since a number of school-based interventions may logically focus on reducing ST and increasing light PA, it may be they are effective in shifting the activity gradient as opposed to increasing MVPA, which could still enhance overall health profiles. Furthermore, future research should consider the potential issue of compensatory PA or ST in terms of research design, e.g., measuring PA during the intervention period and whole day, but also in terms of approaches to support interventions (e.g., including strategies to negate compensatory responses). Ridgers et al.[110] has advocated for strategies that negate compensatory responses and for the use of these strategies in intervention design and evaluation. Indeed, it is important to acknowledge the potential benefits of PA interventions despite possible compensatory behaviors.

5. Conclusion

Strategies to increase MVPA and reduce ST among children are essential, given the health benefits that can result and the importance of the school setting as a location for health-promoting interventions. The current review identified no evidence of effect on MVPA for interventions aimed at children and implemented within school settings, and there was inconclusive evidence of effect on ST. The TEO was an easily applied and useful framework for categorizing intervention type, and it led to differential evidence ratings, with moderate evidence for expansion, inconclusive evidence for extension, and no evidence for enhancement of PA opportunity. After-school clubs, active travel, class PA breaks, and physically active learning appeared to be the most promising interventions, but sustainability and reach should also be considered. In the analysis of intervention effect in relation to PA measurement duration, the critical issue of compensatory behavior was identified as an important consideration. When studies measured changes in PA during the actual intervention, there was moderate evidence of effect, whereas there was inconclusive evidence of changes in PA when changes were measured during the school day. There was no evidence of effect when measured over the course of a whole day. The findings have important implications for future intervention research in terms of intervention design, implementation, and evaluation.

Authors' contributions

MJ led the study and was responsible for the conception and design, drafted the manuscript, was 3rd reviewer of methodological quality, and checked for consistency of data extraction; ED and AL supported retrieval of incorporated studies, reviewed the methodological quality of studies, were responsible for the data extraction, and revised and edited the manuscript; JS completed the data analysis and edited the manuscript; KAM contributed to article conception and design, drafted the manuscript, was third reviewer of methodological quality, and checked for consistency of data extraction. All authors have read and approved the final version of the manuscript, and agree with the order of the presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

Supplementary materials

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