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Highlights

- Overall evidence ratings for interventions implemented within school settings were no evidence on moderate-to-vigorous physical activity and inconclusive evidence on sedentary time.
- There was evidence of a moderate effect on physical activity measured during actual interventions, but this was not replicated across the whole day, suggesting compensatory behaviors.
- Meta–analysis of the studies with whole-day accelerometer measures suggested a pooled effect size of 0.57 and 1.57 for moderate-to-vigorous physical activity and sedentary time, respectively, but with low precision, significant heterogeneity and considerable inconsistency.
- Expansion of opportunities for physical activity, including after school clubs, active travel, class physical activity breaks and physically active learning, appeared to be the most promising intervention type.

Review

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

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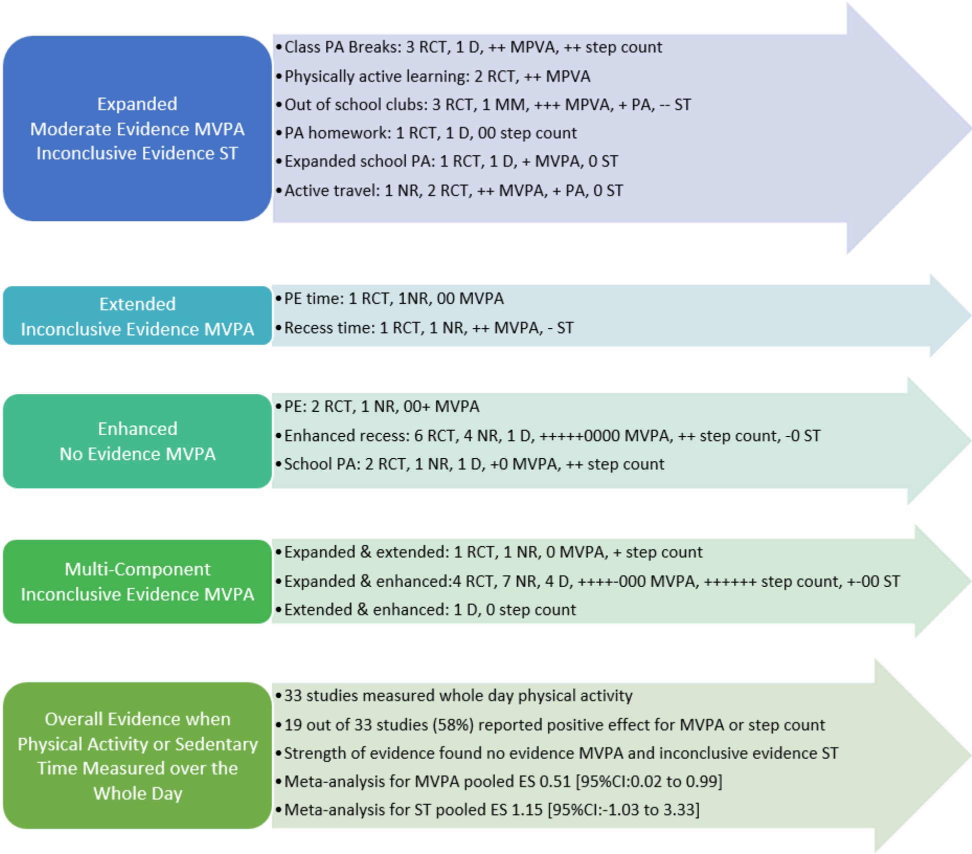
Graphical abstract



Abstract

Purpose: The aim of this mixed-studies systematic review was to ascertain the effectiveness of school-based interventions at increasing physical activity (PA) and/or reducing sedentary time (ST) in children aged 5 to 11 years, as well as to explore 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 pre-defined 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 five-level rating system utilising a published decision tree.

Results: Overall evidence ratings for interventions implemented within school settings were no evidence on moderate-to-vigorous physical activity and inconclusive evidence 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-analysis of those studies using a whole-day accelerometer measure for MVPA or ST showed a significant but moderate effect for MVPA (effect size (ES) = 0.51; 95% Confidence Interval (CI): 0.02–0.99) and a large but non-significant effect for ST 1.15 (95%CI: –1.03 to 3.33); both meta-analysis 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 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 co-existing sedentary behavior 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, support 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 Organisation,[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, or 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 sedentary behavior 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 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 at increasing PA and/or reducing ST in children aged 5–11 years. 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 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 up to 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 summarises 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 two-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 lasted at least 4 weeks, was implemented within a school environment and was targeted at PA or sedentary behavior; 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 the 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 using a percentage-based calculation alongside generic criteria. In cases where the 2 independent reviewers disagreed on either the study design or 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 its 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 standardised review table including demographic characteristics, a description of the intervention using the TIDieR checklist,[42] 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 third reviewer (MJ or KM).

2.5 Strength of the evidence

Initially, strength of evidence was assessed utilising 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 >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 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 on those studies that used accelerometer devices for whole-day PA measurement and that included either a measure of

82. Gorely T, Nevill ME, Morris JG, Stensel DJ, Nevill A. Effect of a school-based intervention to promote healthy lifestyles in 7-11 year old children. *Int J Behav Nutr Phys Act* 2009;**6**:5. doi: 10.1186/1479-5868-6-5

83. Heelan KA, Abbey BM, Donnelly JE, Mayo MS, Welk GJ. Evaluation of a walking school bus for promoting physical activity in youth. *J Phys Act Health* 2009;**6**:560-7.

84. Howe CA, Freedson PS, Alhassan S, Feldman HA, Osganian SK. A recess intervention to promote moderate-to-vigorous physical activity. *Pediatr Obes* 2012;**7**:82-8.

85. Van Kann DH, Kremers SP, de Vries NK, de Vries SI, Jansen MW. The effect of a school-centered multicomponent intervention on daily physical activity and sedentary behavior in primary school children: the active living study. *Prev Med* 2016;**89**:64-9.

86. Hyndman BP, Benson AC, Ullah S, Telford A. Evaluating the effects of the Lunchtime Enjoyment Activity and Play (LEAP) school playground intervention on children's quality of life, enjoyment and participation in physical activity. *BMC Public Health* 2014;**14**:164. doi: 10.1186/1471-2458-14-164

87. Loucaides CA, Jago R, Charalambous I. Promoting physical activity during school break times: piloting a simple, low cost intervention. *Prev Med* 2009;**48**:332-4.

88. Burns RD, Brusseau TA, Hannon JC. Effect of a comprehensive school physical activity program on school day step counts in children. *J Phys Act Health* 2015;**12**:1536-42.

89. Sigmund E, El Ansari W, Sigmundova D. Does school-based physical activity decrease overweight and obesity in children aged 6-9 years? A two-year non-randomized longitudinal intervention study in the Czech Republic. *BMC Public Health* 2012;**12**:570. doi: 10.1186/1471-2458-12-570.

90. Eyre EL, Cox VM, Birch SL, Duncan MJ. An integrated curriculum approach to increasing habitual physical activity in deprived South Asian children. *Eur J Sport Sci* 2016;**16**:381-90.

91. Pangrazi RP, Beighle A, Vehige T, Vack C. Impact of promoting lifestyle activity for youth (PLAY) on children's physical activity. *J Sch Health* 2003;**73**:317-21.

92. Vander Ploeg KA, McGavock J, Maximova K, Veugelers PJ. School-based health promotion and physical activity during and after school hours. *Pediatrics* 2014;**133**:e371-8. doi: 10.1542/peds.2013-2383

93. Brusseau TA, Hannon J, Burns R. The effect of a comprehensive school physical activity program on physical activity and health-related fitness in children from low-income families. *J Phys Act Health* 2016;**13**:888-94.

94. Huberty JL, Siahpush M, Beighle A, Fuhrmeister E, Silva P, Welk G. Ready for recess: a pilot study to increase physical activity in elementary school children. *J Sch Health* 2011;**81**:251-7.

95. Holt E, Bartee T, Heelan K. Evaluation of a policy to integrate physical activity into the school day. *J Phys Act Health* 2013;**10**:480-7.

96. King KM, Ling J. Results of a 3-year, nutrition and physical activity intervention for children in rural, low-socioeconomic status elementary schools. *Health Educ Res* 2015;**30**:647-59.

97. Burns RD, Brusseau TA, Hannon JC. Effect of comprehensive school physical activity programming on cardio-metabolic health markers in children from low-income schools. *J Phys Act Health* 2017;**14**:1-20.

98. Goh TL. Children's physical activity and on-task behavior following active academic lessons. *Quest* 2017;**69**:177.doi: 10.1080/00336297.2017.1290533.

99. Dauenhauer B, Keating X, Lambdin D. Effects of a three-tiered intervention model on physical activity and fitness levels of elementary school children. *J Prim Prev* 2016;**37**:313-27.

100. Duncan M, Birch S, Woodfield L. Efficacy of an integrated school curriculum pedometer intervention to enhance physical activity and to reduce weight status in children. *Euro Phys Edu Rev* 2012;**18**:396-407.

101. Ling J, King KM, Speck BJ, Kim S, Wu D. Preliminary assessment of a school-based healthy lifestyle intervention among rural elementary school children. *J Sch Health* 2014;**84**:247-55.

102. Oliver M, Schofield G, McEvoy E. An integrated curriculum approach to increasing habitual physical activity in children: a feasibility study. *J Sch Health* 2006;**76**:74-9.

103. Cheung PP. Parental attitude on children's after-school physical activity participation: lesson from a pilot study. *Asian J Phys Edu Recr* 2015;**21**:13-20.

104. Metcalf B, Henley W, Wilkin T. Effectiveness of intervention on physical activity of children: systematic review and meta-analysis of controlled trials with objectively measured outcomes (EarlyBird 54). *BMJ* 2012;**345**:e5888. doi: 10.1136/bmj.e5888.

105. Rowlands AV, Pilgrim EL, Eston R. Seasonal changes in children's physical activity: An examination of group changes, intra-individual variability and consistency in activity pattern across season. *Ann Hum Biol 2009;***36**:363-78.

106. Harrison F, van Sluijs, Esther M F, Corder K, Ekelund U, Jones A. The changing relationship between rainfall and childrens physical activity in spring and summer: a longitudinal study. *Int J Behav Nutr Phys Act* 2015;**12**.doi: 10.1186/s12966-015-0202-8

107. Ridgers ND, Fairclough SJ, Stratton G. Twelve-month effects of a playground intervention on children’s morning and lunchtime recess physical activity levels. *J Phys Act Health* 2010;**7**:167-75.

108. Cohen KE, Morgan PJ, Plotnikoff RC, Barnett LM, Lubans DR. Improvements in fundamental movement skill competency mediate the effect of the SCORES intervention on physical activity and cardiorespiratory fitness in children. *J Sports Sci* 2015;**33**:1908-18.

109. Love R, Adams J, van Sluijs EMF. Are school-based physical activity interventions effective and equitable? A meta-analysis of cluster randomized controlled trials with accelerometer-assessed activity. *Obes Rev.* 2019;20:859-870.

110. Ridgers ND, Timperio A, Cerin E, Salmon J. Compensation of physical activity and sedentary time in primary school children. *Med Sci Sports Exerc* 2014;**46**:1564-9.

111. Tuvey S, Steele J, Horton E, Mayo X, Liguori G, Mann S, et al. *Do changes in cardiorespiratory fitness resulting from physical activity interventions impact academic performance and executive function in children and adolescents? A systematic review, meta-*

analysis, and meta-regression. preprint. Available at: https://osf.io/preprints/sportrxiv/4j2sa/ ;2019. [accessed 04.03.2019].

112. Budzynski-Seymour E, Wade M, Lawson R, Lucas A, Steele J. Heart rate, energy expenditure, and affective responses from children participating in trampoline park sessions compared with traditional extra-curricular sports clubs. *J Sports Med Phys Fitness* 2019,in press. doi: 10.23736/S0022-4707.18.09351-9.

113. Rowlands AV. Moving Forward With Accelerometer-Assessed Physical Activity: Two Strategies to Ensure Meaningful, Interpretable, and Comparable Measures. *Pediatr Exerc Sci* 2018;**30**:450-6.

114. Gorely T, Morris JG, Musson H, Brown S, Nevill A, Nevill ME. Physical activity and body composition outcomes of the GreatFun2Run intervention at 20 month follow-up. *Int J Behav Nutr Phys Act* 2011;**8**:74. doi: 10.1186/1479-5868-8-74.

115. Meyer U, Schindler C, Zahner L, Ernst D, Hebestreit H, van Mechelen W, et al. Long-term effect of a school-based physical activity program (KISS) on fitness and adiposity in children: a cluster-randomized controlled trial. *PLoS One* 2014;**9**:e87929. doi: 10.1371/journal.pone.0087929.

116. Freedson P, Pober D, Janz KF. Calibration of accelerometer output for children. *Med Sci Sports Exerc* 2005;**37**(Suppl. 11):S523-30.

117. Nilsson A, Ekelund U, Yngve A, Söström M. Assessing physical activity among children with accelerometers using different time sampling intervals and placements. *Pediatr Exerc Sci* 2002;**14**:87-96.

118. Evenson KR, Catellier DJ, Gill K, Ondrak KS, McMurray RG. Calibration of two objective measures of physical activity for children. *J Sports Sci* 2008;**26**:1557-65.

119. Welk GJ. Principles of design and analyses for the calibration of accelerometry-based activity monitors. *Med Sci Sports Exerc* 2005;**37**(Suppl. 11):S501-11.

120. Trost SG, Loprinzi PD, Moore R, Pfeiffer KA. Comparison of accelerometer cut points for predicting activity intensity in youth. *Med Sci Sports Exerc* 2011;**43**:1360-8.

121. Tudor-Locke C, Bassett DR Jr, Rutherford WJ, Ainsworth BE, Chan CB, Croteau K, et al. BMI-referenced cut points for pedometer-determined steps per day in adults. *J Phys Act Health* 2008;**5**(Suppl. 1):S126-39.

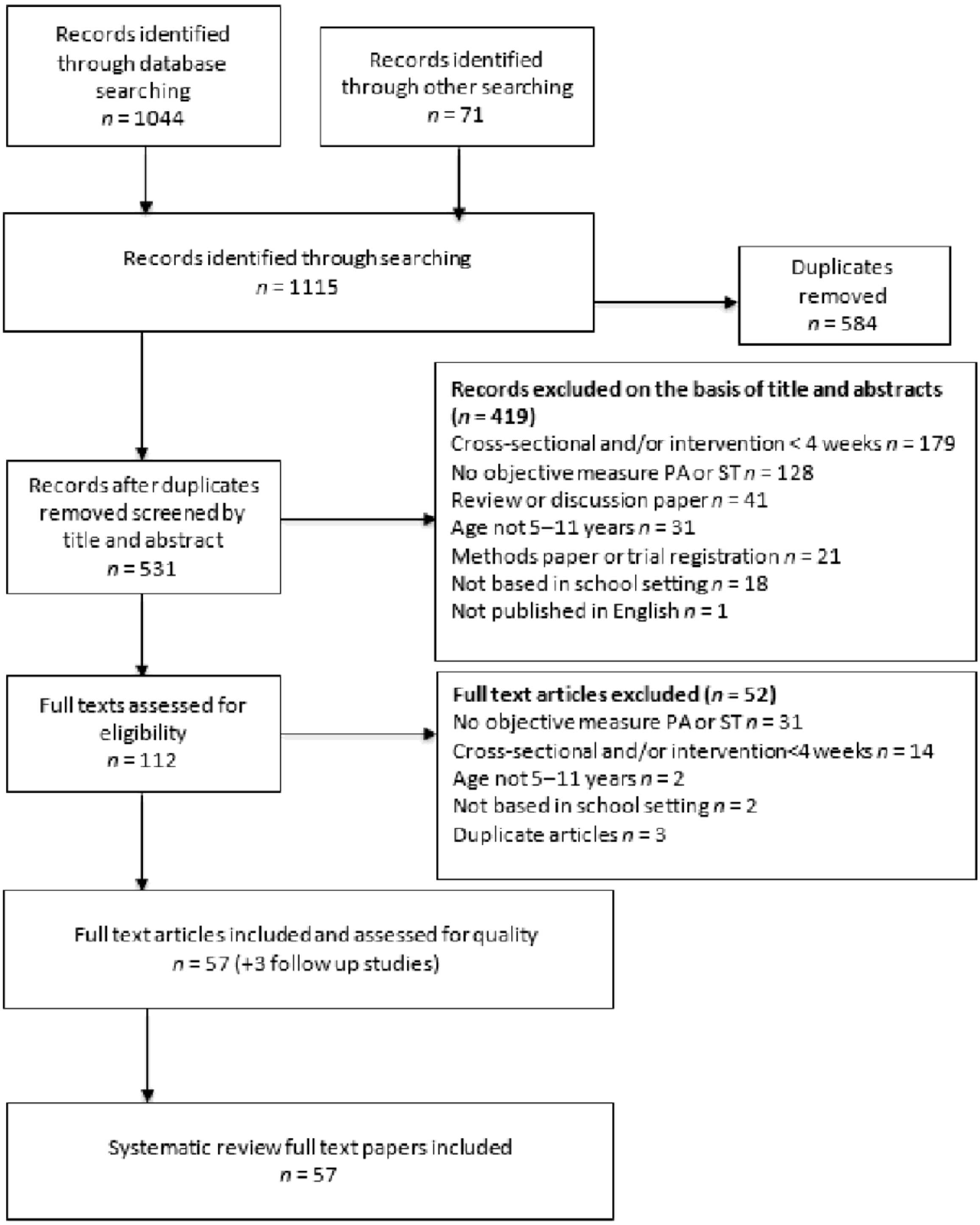


Fig. 1. Evidence search and exclusion process. PA = physical activity; ST = sedentary time.

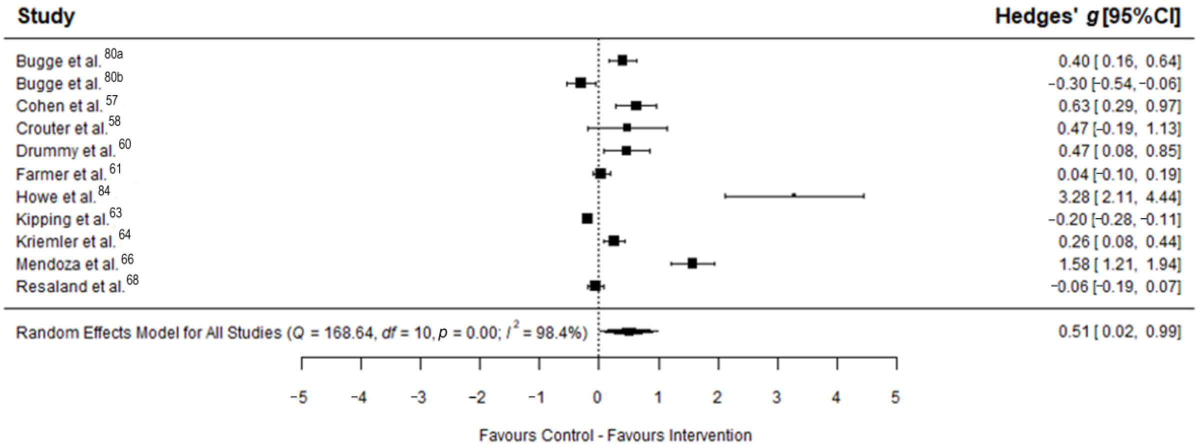


Fig. 2. Main effect for MVPA whole day accelerometer measure. Forest plot for standardised mean difference of change in physical activity between intervention and control groups of school-based physical activity interventions in children.

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 .

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 *Moderate evidence MVPA and inconclusive evidence ST*	**Class PA breaks** *Limited evidence MVPA*	RCT[59], 100%, <250	+MVPA	
		RCT[60], 50%, <250	+MVPA	
		D[98], 100%, <250	+Step count	
		RCT[72], 50%, <250	+Step count	
	PA learning *Limited evidence MVPA*	RCT[55], 75%, <250	+MVPA	
		RCT[56], 75%, <250	+MVPA	
	Beforeïschool clubs *Inconclusive evidence MVPA*	RCT[47], 25%, <250	+MVPA	–ST
	Afterïschool clubs *Moderate evidence MVPA*	MM[103], 50%, <250	+PA	
		RCT[58], 75%, <250	+MVPA	–ST
		RCT[48], 75%, >250	+MVPA	
	PA homework *No evidence PA*	RCT[73], 0%, <250	0 step count	
		D[102], 100%, <250	0 step count	
	Expanded school PA *Inconclusive evidence PA*	D[95], 75%, <250	+MVPA	
		RCT[75], 75%, >250	0 step count	
		RCT[68], 50%, >1000	+MVPA	0 ST
	Active travel *Limited evidence PA*	NR[83], 75%, <250	+PA	
		RCT[66], 75%, <250	+MVPA	
Extended *Inconclusive evidence MVPA*	**Increased PE time** *No evidence MVPA*	NR[80], 50%, >250	0 MVPA	
		RCT[67], 75%, >1000	0 MVPA	
	Increased recess time *Inconclusive evidence MVPA*	NR[78], 25%, <250	+ MVPA	–ST
		RCT[51], 25%, <250	+ MVPA	
Enhanced *No evidence MVPA*	**Enhanced PE** *No evidence MVPA*	RCT[62], 0%, >250	0 MVPA	
		RCT[69], 0%, >250	0 MVPA	
		NR[79], 25%, <250	+ MVPA	
	Enhanced recess *Inconclusive evidence MVPA*	RCT[49], 25%, <250	+ 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 *Inconclusive evidence MVPA*	D[100], 100%, <250	+Step count	
		RCT[71], 50%, <250	0 MVPA	
		NR[92], 25%, >1000	+Step count	
		RCT[70], 50%, <250	+MVPA	
Multiï component *Inconclusive evidence*	**Expanded and enhanced** *Inconclusive evidence MVPA*	D[93], 100%, >1000	+MVPA	
		D[97], 75%, >1000	+Step count	
		NR[88], 50%, >250	+Step count	
		NR[81], 50%, >250	–MVPA,	+ST

MVPA		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	

+ Significant increase in measure or intervention > control
0 No significant difference pre–post or intervention–control
– 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.

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

Measurement device	Time period and evidence level	Design, quality score, sample size	Cutpoints of MVPA threshold	PA outcome	ST outcome
Accelerometer (*n* = 38 studies)	During the intervention activity	RCT[47], 25%, <250	Freedson	+MVPA	–ST
		RCT[48], 75%, >250	Freedson	+MVPA	
	Moderate evidence MVPA	RC[49]T, 25%, <250		+MVPA	
		RCT[50], 0%, >1000		+MVPA	
		NR[76,107], 75%, >250	Nilsson	+MVPA	
		RCT[51], 25%, <250	Nilsson	+ MVPA	
	During the school day	D[93], 100%, >1000	Evenson	+MVPA	
		NR[77], 75%, >250	Freedson	+MVPA	–ST
	Inconclusive evidence MVPA and ST	RCT[52], 50%, <250	Evenson	0 MVPA	0 ST
		D[94], 100%, <250	Nilsson	+MVPA	
		RCT[53], 50%, >250	Freedson	0 MVPA	
		RCT[54], 0%, >250	Freedson	0 MVPA	
		NR[78], 25%, <250	Evenson	+ MVPA	–ST
		RCT[55], 75%, <250	Evenson	+MVPA	
		RCT[56], 75%, <250	Evenson	+MVPA	
		NR[79], 25%, <250	Evenson	+ MVPA	
	During the whole day	RCT[47], 25%, <250	Freedson	+MVPA	–ST
		NR[80], 50%, >250	≥ 1500 cpm	0 MVPA	
	No evidence MVPA and inconclusive evidence ST	NR[81], 50%, >250	Evenson	–MVPA,	+ST
		RCT[57], 25%, >250	Evenson	0 MVPA	
		RCT[58], 75%, <250	Freedson	+MVPA	–ST
		RCT[59], 100%, <250		+MVPA	–ST
		RCT[60], 50%, <250	> 2000 cpm	+MVPA	
		RCT[61], 25%, >250	Evenson	0 MVPA	
		RCT[62], 0%, >250		0 MVPA	
		NR[82,114], 50%, >250	Freedson	+MVPA	
		NR[83], 75%, <250	Welk	+PA	
		D[95], 75%, <250	Trost	+MVPA	
		NR[84], 25%, <250	Freedson	+ 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	+MVPA	
		RCT[67], 75%, >1000	Evenson	0 MVPA	
		RCT[68], 50%, >1000	Evenson	+MVPA	0 ST
		RCT[69], 0%, >250		0 MVPA	
		NR[85], 50%, >250	Evenson	0 MVPA	0 ST
		RCT[70], 50%, <250	Trost 02	+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	
	No evidence MVPA	RCT[73], 0%, <250	step count	0 step count	
		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	+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

Note: Reference 93 used both accelerometer and pedometer.

Abbreviations: 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.