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

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Abstract

The aim of this mixed-studies systematic narrative review was to ascertain the effectiveness of school-based interventions at increasing physical activity and/or reducing sedentary time (ST) in children aged 5 to 11 years, as well as explore effectiveness in relation to categories of the Theory of Expanded, Extended and Enhanced Opportunity. Adhering to the PRISMA guidelines, five databases were searched using pre-defined search terms. Following title and abstract screening of 1,044 records, the removal of duplicates (n=584) and articles that did not meet the inclusion criteria agreed *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. The interventions were summarised using the TIDierR checklist and Theory of Expanded, Extended and Enhanced Opportunity category determined. The strength of evidence was determined using a five level rating system utilising a published decision tree and overall confirmed no evidence of effect for moderate-to-vigorous physical activity (MVPA) and inconclusive evidence for ST. In relation to Theory of Expanded, Extended and Enhanced Opportunity, expansion of physical activity appeared the most promising intervention type on MVPA with moderate evidence of effect, whereas, extension and enhancement of physical activity opportunity were inconclusive and demonstrated no evidence of effect, respectively. A critical issue of possible compensatory behaviour was identified by analysis of intervention effect in relation to physical activity measurement duration; when studies measured changes in physical activity during the actual intervention there was moderate evidence of effect, whereas those that measured during the school day had inconclusive evidence, and over a whole day no evidence of effect. Meta-analysis of those studies with a whole day accelerometer measure of MVPA or ST identified a significant but moderate effect for MVPA (ES 0.51 [95% CI = 0.02, 0.99] and large but non-significant effect for ST 1.15 [95% CI = -1.03, 3.33]; both demonstrated low precision, considerable inconsistency and high heterogeneity. The findings have important implications for future intervention research in terms of intervention design, implementation and evaluation.

Key Words: Children, school, physical activity, sedentary time, intervention

1. Introduction

Physical activity has been associated with numerous physiological and psychosocial health benefits in school-aged children[1]. Consequently, global physical activity guidelines recommend children aged 5 – 18 years engage in at least 60 minutes of moderate-to-vigorous physical activity (MVPA) every day[2]. Despite this, it is widely reported that the majority of children do not meet these guidelines. Indeed, a recent review identified that less than 5% of 9- to 11-year olds across twelve countries met the guidelines on a daily basis[3] and analysis of active healthy kids report cards across 15 countries found ten 10 countries that scored grade D (20–39% meet physical activity guidelines) to grade F (<20% meet physical activity guidelines)[4]. There are also concerns about co-existing sedentary behaviour in children, which is independently associated with poorer health outcomes[5]. As such, recent 24-hour movement guidelines have promoted a need to consider whole day movement patterns that target both enhanced MVPA and restriction of sedentary time (ST)[6].

Physical activity behaviours develop in early childhood and track through to adolescence and adulthood[7]. Moreover, evidence suggests a decline in MVPA from early childhood[8-10], with a recent review which incorporated 10 countries identifying an annual decrease of 4.2% MVPA and increased ST after the age of 5 years[11]. Whilst this study was limited by its cross-sectional design[11], longitudinal research, albeit in single countries, support this notion[10]. For example, a recent longitudinal study involving over 1,000 children reported a decline in MVPA (3 minutes in girls; 7 minutes in boys) and increase in ST (83 minutes for girls; 74 minutes for boys) between UK school years 1 (5-6 years) to 4 (8-9 years)[10]. It is therefore imperative to not only promote physical activity and decrease ST, but to intervene early, prior to the steep decline in MVPA and ST[12].

School has been identified as an important setting to promote MVPA and limit ST, not least since children spend 40% of their waking time there[13]. Indeed, a recent multi-level worldwide review highlighted local school contexts as important correlates to physical activity 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 physical activity within the school-setting[16-20], 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)[26] and after-school[27], or across settings with specific analysis of the school as a setting[14,28-32]. Taken together, a review of reviews proposed strong evidence for the positive effect of school-based interventions on physical activity in youth, confirming the public health potential of high quality school-based physical activity interventions[33]. However, existing reviews considering physical activity 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 physical activity 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] advocated that more structural environmental or policy changes might be required to change child physical activity behaviour, thereby suggesting the need to examine children and adolescents distinctly.

Few systematic reviews have considered sedentary behaviour interventions within a school setting[17,18,35] despite Hynynen *et al.*[17] suggesting future research should acknowledge that MVPA and ST require different intervention strategies. Furthermore, the majority of existing systematic reviews have included only randomised controlled trials[16,17,20] and/or controlled trials[19,30,31,34]. Whilst randomised controlled trials are at the upper end of hierarchy of evidence in terms of causal inference regarding efficacy or effectiveness of interventions, they cannot explore the complex nature of physical activity interventions in the school context[12]. Insight into the key questions proposed 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 through examining a broader evidence-base including observational, qualitative and mixed method studies[36]. Furthermore, the Theory of Expanded, Extended and Enhanced Opportunities, recently proposed to provide a common taxonomy to identify appropriate targets for interventions across

different settings and contexts, could afford a more practical approach to school-based physical activity interventions[19,37]. Therefore, the aim of this mixed-studies systematic narrative review was to ascertain the effectiveness of school-based interventions at increasing physical activity and/or reducing ST in children aged 5 to 11 years. Furthermore, we sought to examine whether there are key components of interventions that enhance effectiveness, including exploration of Theory of Expanded, Extended and Enhanced Opportunity.

2. Methods

The review was registered with PROSPERO (CRD42017082184) and is reported in accordance to 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 to promote physical activity and/or reduce ST in school settings in children aged 5 – 11 years. A structured electronic bibliographic search of five 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 *a priori* and were developed by breaking down the research question (Table 1). The search terms focused on four key elements: i) outcome (e.g., physical activity, ST); ii) population (e.g., child or paediatric); iii) intervention (e.g., evaluation, intervention); and iv) context (e.g., primary or elementary and school). No date limits were applied. The outcomes of each of the searches were combined into a REFWorks library (proquest, 2017).

** Insert Table 1 here **

2.2 Inclusion Criteria and Selection Process

Figure 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: i) involved children of primary/elementary/middle school age (5-11 years old); ii) reported a physical activity or sedentary behaviour targeted intervention implemented within the school environment, lasting at least 4 weeks; and iii) reported an objectively assessed measure of physical activity and/or ST. Following title and abstract screening of 1,044 records, the removal of duplicates (n=584) and articles that did not meet the inclusion criteria (n=419) resulted in 112 studies. Two independent reviewers (ED, AL) assessed the full article text of the 112 studies against the

inclusion criteria, resulting in a further 52 studies being excluded. The systematic review therefore included 57 original studies and a further 3 studies that reported follow-up data from 3 of the 57 original studies.

** Insert Figure 1 here**

2.3 Methodological Quality

The quality of the included studies was assessed by two independent reviewers (ED, AL) using the mixed methods appraisal tool (MMAT)[39]. The MMAT checklist includes two screening questions and 19 quality criteria corresponding to five methodological designs: i) qualitative; ii) quantitative randomised controlled trial (RCT); iii) quantitative non-randomised controlled (NR); iv) quantitative observational descriptive; and v) 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 two 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 domain/s 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 consultations and workshops with experts[36,39,40]. There is evidence of both the reliability and efficiency of the MMAT as a tool to appraise the methodological quality of research[40,41].

2.4 Data Extraction and Data Synthesis

Data was extracted from all included studies and summarised into a standardised review table including the 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 Theory of Expanded, Extended and Enhanced Opportunity (**Link to supplementary data file**). The inclusion of the TIDieR checklist in data extraction followed recent guidance to improve systematic reviews[43]. Whilst the assessment of quality was undertaken independently, data extraction was accumulated by the two 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 five level rating system (strong, moderate, limited, inconclusive, no evidence) adopted from a previous high-quality systematic review[34] based on study design, methodological quality and sample size (http://www.mrc-epid.cam.ac.uk/wp-content/uploads/2014/07/Supplemental-figure-decision-making-process-levels-of-evidence.pdf). 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 as consistent.

2.6 Meta-Analysis

Heterogeneity of outcome measurement device, time frame (specific activities, school day, whole day), analysis (cut-points) and 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 were suitable for meta-analysis and so it was decided *post hoc* that this be conducted. To provide some insight into the

magnitude of effect meta-analysis was conducted on those studies with whole day physical activity measurement using accelerometer devices and including either a measure of minutes of MVPA or minutes of ST, since these are most strongly associated with health-related outcomes. Where reporting in studies was insufficient for inclusion in meta-analysis, the corresponding authors were contacted to request additional information.

All analysis was performed using the 'metafor' package in R (version 3.5.2; R Core Development Team, https://www.r-project.org/) and an alpha of 0.05 considered in all tests. Change scores from baseline to post-intervention 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 group, assuming a correlation of r=0.5 between baseline and post-intervention[44]. Standardised between group effect sizes (ES) using Hedges g were calculated for each study and outcome measure to descriptively quantify the changes in the outcomes. If a study had two intervention groups then 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 were interpreted with reference to Cohen's 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 favour of the intervention group compared with the control, whereas for ST, positive ES values indicated fewer minutes of ST in favour of the intervention compared to control.

Two separate random effects meta-analyses were performed for MVPA and ST, where point estimates for pooled ES's were estimated along with the precision of those estimates using 95% confidence intervals (CI). 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 a study 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%-100%. I^2 values of 0-40% were not important, 30-60% moderate heterogeneity, 50-90% substantial heterogeneity, and 75-100% considerable heterogeneity[46]. Publication bias was analysed by funnel plots and using Egger's regression asymmetry test. Note, neither meta-regression, nor funnels plots were conducted for ST as an outcome due to the low number of studies (n=4). Analysis code is available upon request.

3. Results

3.1 Description of Studies included

The 57 studies included 29 randomised controlled studies[47-75] (mean quality 45%), 17 non-randomised controlled studies[76-92] (mean quality 50%), 10 descriptive studies[93-102] (mean quality 83%) and one mixed-methods study[103] (quality 50%). The majority of studies (n=49, 86%) were published within the last decade[47-50,52-61,63-68,71,73-75,77-90,92-101,103]. The sample size of children with objectively assessed physical activity 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 >1,000 in eight studies[50,63,67,68,92,93,97,101]; in six studies only a sub-sample had objectively assessed physical activity and/or ST[62,70,76,78,83,95]. The studies were conducted in the United States[47-49,53,54,58,59,62,66,69,71,72,77,81,83,84,88,91,93-99,101] (n=26, 46%), seven European Union countries[50,51,55,67,70,79,80,85,87,89] (n=18, 32%) including the United Kingdom[60,61,63,76,78,82,90,100] (n=8, 14%), two Australasian countries[52,56,57,73,74,86,102] (n=7, 12%) and the remaining six studies were conducted in Canada[75,92], Hong Kong[103], Iceland[65], Norway[68] and Switzerland[64].

3.2 Strength of Evidence for Effect of Intervention on Physical Activity and Sedentary Time

A positive effect on an objective measure of physical activity 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, 62% of 37 studies 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 two of the three 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, six[47,58,59,77,78,84] of which reported a positive effect during the school 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 summarises the intervention type in relation to Theory of Expanded, Extended and Enhanced Opportunity. Expanded opportunities, where time allocated for physical activity replaced time previously

allocated for low active or sedentary activities, accounted for 17 studies (30%) and included class physical activity breaks, physically active learning, before and after school clubs, physically active homework, active travel and a whole school physical activity expansion. Overall, 82% of studies that expanded physical activity opportunities reported a positive effect on physical activity or MVPA and there was moderate evidence of positive benefit on MVPA. The evidence regarding different intervention types to expand physical activity opportunity was inconsistent. Intervention studies that extended opportunity, via increasing time for pre-existing physical activity, consisted of two studies extending PE with no evidence to support effectiveness and two studies extending recess time with inconclusive evidence. Enhancing opportunity for physical activity was identified in 18 studies and approaches to modifying current physical activity opportunities to increase the amount of physical activity included PE, recess and overall school physical activity. Of the studies enhancing physical activity opportunities, 61% reported a positive effect on either physical activity or MVPA but overall there was no evidence to support the effectiveness. A number of studies (n=18) were multi-component combining Theory of Expanded, Extended and Enhanced Opportunity categories, most commonly expanding and enhancing physical activity opportunities. Taken together, the evidence for multi-component programmes was inconclusive, with 66% reporting a positive impact on either physical activity or MVPA.

** Insert Table 2 here **

3.4 Strength of Evidence for Physical Activity Outcome Measure and Evidence of Effect

Table 3 summarises physical activity outcome measure and effect. The inclusion criteria for studies included the requirement for objectively assessed physical activity or ST. Of the 57 studies, 67% utilised accelerometer measurement and 35% pedometers. Description of the device-based measure of physical activity typically included device model details, time frame for device measures, cut-points and data inclusion criteria, although this was not consistent across all studies. The analysis of the accelerometer data collected varied with nine different cut-points utilised for time spent in MVPA. Typically, total step count was the dependent variable for pedometer measures.

As identified in Table 3, the time period for physical activity data collection varied between measurement during the actual intervention (16%, 9 studies), during the school day (28%, 16 studies) or during the whole day (58%, 33 studies). 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 nine 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 17 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 physical activity 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 evidence rating 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, during the school or whole day.

** Insert Table 3 here **

3.5 Meta-Analysis of Whole Day Accelerometer Measured MVPA and ST

Publication bias analysis with Egger's regression asymmetry test suggested evidence of publication bias for MVPA ($z = 4.3749$, $p < 0.0001$). The funnel plot for studies reporting MVPA outcomes highlighted two studies as clear outliers.

The pooled ES [95% CI] 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 indicated by the confidence intervals ranging from trivial to large. Cochrane's Q showed for a significant heterogeneity ($Q = 168.7$, $df = 10$, $p < 0.0001$) for MVPA, and a considerable inconsistency measure with I^2 of 98.43%. Figure 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, 1.08]; removal of Cohen et al.[57] = 0.50 [95% CI = -0.05, 1.06]; removal of Crouter et al. [58] = 0.52 [95% CI = -0.03, 1.07]; removal of Drummy et al.[60] = 0.52 [95% CI = -0.03, 1.07]; removal of Kriemler et al.[64] = 0.54 [95% CI = -0.01, 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, 0.64] and Mendoza et al.[66] which also reduced the estimate to 0.38 [95% CI = -0.07, 0.82].

The pooled ES [95% CI] estimates for the effects of interventions on ST was 1.15 [95% CI = -1.03, 3.33] indicating a non-significant large effect, with very low precision indicated by the confidence intervals ranging from a negative large effect to a positive large. Cochrane's Q showed for ST, a significant heterogeneity (Q = 38.7, df =3, p < 0.0001) and a considerable inconsistency measure with I^2 of 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, 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 [-0.71, 1.68], p = 0.4252) or study quality (coefficient = -0.13 [-1.30, 1.05], p = 0.8299).

3.6 Participant Characteristics and Evidence of Effect

The majority of studies have reported outcomes for the whole sample of participants or by grade, irrespective of participant characteristics. A differential response to intervention based on sex was identified in six studies[53,54,65,75,79,91], including one large high-quality RCT[75] and two 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]. Three studies identified differential responses based on baseline characteristics; including two studies which reported a larger effect for the least active[71,102].

4. Discussion

The objective of this systematic review was to ascertain the effectiveness of school-based interventions at increasing physical activity and/or reducing ST in children aged 5 to 11 years Overall, the systematic review from a synthesis approach and strength of evidence identified no evidence of effect for MVPA and inconclusive evidence for ST. Two previous reviews also identified no overall evidence for physical activity during school-based interventions when focusing on children; van Sluijs *et al.*[34] suggested less evidence in children than adolescents and Metcalf *et al.*[104] identified a small effect on MVPA and a lower mean standardised difference in children under 10 years compared to older children. In accord with van Sluijs *et al.*[34] who proposed, in part, the low effect in children may be a consequence of higher baseline physical activity levels, two studies included in this review reinforced a larger effect for the least active[71,102]. There is no previous systematic review that considers interventions to reduce ST specifically in school children and the inconclusive evidence rating and small number of studies therefore suggests further research is warranted. The finding of no evidence of effect for physical activity reinforces that systematic reviews, including meta-analyses, combining children and adolescents as one homogeneous group need careful interpretation.

Overall, in accord with previous studies[28,29], 68% of the studies in this review reported a positive impact on physical activity and 62% on MVPA. Specifically, Salmon *et al.*[28] identified 12 out of 18 studies (67%) with objective measures of physical activity reported a positive effect in children and Timperio *et al.*[29] identified 6 out of 9 studies (67%) based in primary schools had positive effect. This systematic review included a variety of study designs and, indeed, one reason for the discrepancy between the finding that 62% of studies reported a positive impact on MVPA and the overall rating of no evidence of effect, could be attributed to the impact of research design and time-related changes. Indeed, five RCTs and two NR studies reported the significant effect of the intervention was aligned to preventing, or at least reducing the decline in physical activity observed in control conditions over time, rather than to significantly increase physical activity in intervention conditions *per se*[55,58,66,70,73,81,82]. The prevention of a decline in MVPA and or increase in ST was identified in the studies included in the meta-analysis; the mean difference between

baseline and post-intervention for MVPA and ST respectively was -5.0 (12.2) and 15.1 (63.4) in the control groups versus 1.8 (16.5) and 3.4 (62.1) in the intervention group. Whilst the intervention duration of these studies was variable with four studies lasting 4-10 weeks[55,58,66], others were implemented over a longer duration, such as 10 months[73], 1 year[81] or 2 years[70], which may explain the effect in terms of preventing a decline in physical activity or ST. Moreover, interventions conducted over shorter durations (i.e., < 12 weeks) could arguably, be more subject to the impact of seasonal changes[106,107]. It is plausible such interventions could reduce negative effects of seasonal change, or indeed, in the case of non-controlled trials, changes in physical activity, 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 physical activity or MVPA and inconclusive evidence for ST is a disappointing outcome for public health practitioners and researchers who consider the school as a promising setting for interventions, it is important to understand why attempts to increase children's physical activity 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, the exploration of any types of school-based interventions that show more promising evidence of effectiveness, intervention implementation, the possible issue of compensatory behaviour, the theoretical underpinning of interventions and the reporting and methodological quality of interventions.

4.1 Intervention Approach and Theory of Expanded, Extended and Enhanced Opportunity

The Theory of Expanded, Extended and Enhanced Opportunity has been proposed to provide a common taxonomy to identify appropriate interventions across different settings and afford a more practical approach to school-based physical activity interventions[19,37]. Expanded physical activity opportunity was a more promising intervention approach (moderate evidence rating) than extending (inconclusive evidence rating) or enhancing (no evidence rating) physical activity opportunity. No previous systematic reviews have considered different types of intervention in relation to Theory of Expanded, Extended and Enhanced

Opportunity and so this is a novel finding that may help inform future research and/or policy implementation. After school clubs (moderate evidence rating), class physical activity breaks (limited evidence rating), physically active learning (limited evidence rating) and active travel (limited evidence rating) appear the most promising expanded opportunity interventions in school settings for children.

Studies expanding physical activity via after-school clubs typically involved engagement with stakeholders, including families, to develop a bespoke programme that included a physical activity programme[48,58,103]. Two studies investigated expanding physical activity 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 attendance by children is typically optional, thereby potentially reducing intervention reach. Indeed, of the three studies reporting expansion of after school physical activity, only one had > 250 participants[48], one study reported more than 80% attendance[58], whereas two studies did not report attendance rates[58,103]. Similarly, for active travel, the optional nature of the physical activity is exemplified; Heelan *et al.*[83] identified that just over a third of children actively commuted at least half of the time as a consequence of the intervention and both active travel studies included <250 participants[66,83]. Therefore, whilst after school clubs and active travel warrant further research and may provide some benefit in terms of MVPA, they should be considered as part of a broader integration of physical activity into children's lives.

Beets *et al.*[37] reinforced the importance of compulsory physical activity opportunities during the school day and in terms of expanded physical activity opportunities, both class physical activity breaks and physically active learning are worthy of further research exploration. All four studies reporting class physical activity breaks found positive outcomes for MVPA or physical activity, but the risk of bias (quality and/or sample size) led to a limited evidence rating[59,60,72,98]. Class physical activity breaks have typically involved training teachers and/or providing teacher resources to deliver 10 minute class breaks that can be implemented by the class teacher, at their discretion, to the whole class in their normal classroom setting. This type of

intervention appears to have potential for sustainability, with two of the studies reporting good teacher compliance[59,72] and all studies conducted over at least 8 weeks[59,60,72,98]. Physically active learning differs from class physical activity breaks in that physical activity has been integrated into core English and maths curriculum learning in the two high quality small RCTs which identified positive impact on MVPA[55,56].

Extending physical activity 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 two studies; one high quality large RCT increased PE time from 2 to 6 lessons (4.5 hours per 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]. Extending recess time did lead to two low quality studies reporting increases in MVPA[51,78]. The inconclusive evidence for extending physical activity opportunities during the school day, alongside the high time-pressures reported by schools, collectively suggest 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 physical activity have not been considered in this review.

Enhancing existing physical activity opportunities included enhancing physical activity in PE[62,69,79], recess[49,50,52-54,61,76,84,86,87,94] and overall school physical activity[70,71,92,100] led to an evidence rating overall of no evidence of effect. Enhancing physical activity within PE overall demonstrated no evidence of effect and studies have typically involved elements of providing training and/or resources for teachers to increase activity during existing lessons[62,69,79]. Eleven 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. The 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 physical activity[49,84] into pre-existing recess periods. Overall, the high risk of bias due to research quality led to an inconclusive evidence rating, which differs from previous systematic reviews that have suggested interventions could lead to improvements in physical activity during school recess[21-23].

Possible reasons for this difference could be a reported effect that the difference in physical activity is moderated by age[21], or it could relate to different outcome measurement time-periods (e.g., measuring effects during recess versus during the whole day). Enhancing overall school physical activity studies have included pedometer based challenges[71,100], implementation of a health facilitator role[92] and a comprehensive programme to enhance physical activity in the curriculum, PE and recess[70] but led to an inconclusive evidence rating. Collectively, within school settings for children, enhancing existing physical activity opportunities alone does not appear to be an effective evidence-based strategy to promote physical activity.

A number of studies combined aspects of Theory of Expanded, Extended and Enhanced Opportunity in a multi-component approach[64,91,99], most commonly a combination of expanding and enhancing physical activity opportunities, but overall these approaches led to an inconclusive evidence rating[63,65,74,77,81,82,85,88-90,93,96,97,101,108]. The Comprehensive School physical activity Programme that combines enhancement of physical activity through physical activity leaders, PE and recess time and extension via class physical activity breaks was reported in four studies[81,88,93,97]. Other multi-component 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]. On the basis of inconclusive evidence, even comprehensive multi-component programmes based in school settings might have little effect on children's physical activity.

4.2 Physical Activity Increases in School Intervention versus Compensatory Physical Activity Decline

Previous systematic reviews have analysed intervention effects collectively, regardless of the duration of objective physical activity measurement. Our findings, in terms of synthesis of strength of evidence ratings, indicate that there is moderate evidence for MVPA when physical activity was measured during intervention delivery, inconclusive evidence when physical activity was measured during the school day and no evidence when physical activity 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 physical activity interventions, that limited included studies to accelerometer whole day measurement, also concluded that current school-based interventions do not increase young people's daily physical activity with a pooled ES of 0.02, although this included children and adolescents[109]. Interestingly Love *et al.*[109] indicated a non-significant trend towards a decrease in standardised mean difference with increasing mean age of participants, which may explain the lower effect in comparison to our findings. This finding highlights the importance of whole day measurement of physical activity 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 specifically aimed to increase whole day physical activity, but rather focused on behaviour change over one small portion of the day.

A number of existing systematic reviews of school-based physical activity interventions[28,104] and Beets et al[37] in proposing the Theory of Expanded, Extended and Enhanced Opportunity highlighted the potential risk of the intervention increasing physical activity during actual intervention delivery but resulting in a compensatory decline elsewhere during the day. The analysis of response on the basis of outcome measurement duration provide some support for the ActivityStat hypothesis, which suggests increases in physical activity on one domain cause a compensatory reduction in another[110]. More specifically, two studies included within the review explored physical activity over different time-periods and both identified increased physical activity during the target intervention of recess[52] or PE[69], but not during the school or whole day. On the basis of these findings, it appears that practitioners and researchers are effectively identifying and implementing approaches to increasing physical activity during specific domains of the school day, but are unable to ensure these are sustained over the whole day The inconclusive evidence rating for ST over a whole day provides some promise, that whilst attempts to increase MVPA do not seem to persist through a whole day, there could be some behaviour change for instance reduced ST. This provides an important consideration for further research in terms of both implementation of interventions within school-settings, but also in terms of research.

Despite the lack of evidence of effect for physical activity interventions to increase physical activity levels across the whole day, it should be noted that the increases in physical activity exhibited during intervention periods (which were moderately evidenced) might provide benefit. For example, there is evidence that physical activity interventions with sufficiently high intensity of effort physical activity during intervention periods may increase cardiorespiratory fitness in children[111]. Indeed, expanded opportunities for physical activity 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 physical activity may be minimal due to compensatory behaviours, physical activity interventions may be successful in improving other outcomes.

4.3 Limitations and Recommendations for Future Research

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

The current systematic review was prospectively registered with Prospero and therefore the risk of bias by adjustment of protocol was minimised, however, one limitation of the current review was the relatively limited nature of the initial literature search conducted that did not include search terms related to specific intervention types and/or specifically by sex. Nonetheless, the thorough process of searching for secondary references most likely rectified this limitation. Indeed, of the final included studies 24 were identified via secondary search strategies. Specifically, a systematic review of RCTs with objective whole

day accelerometer physical activity measurements published after the search strategy was completed in the current review[109], included a final sample of 17 studies; of these 11 were focused on older children, 3 were included in the current study and the remaining 3 were screened out since the intervention focus was weight loss/obesity prevention an intervention designed to promote physical activity and/or reduce ST. Furthermore, in comparison, an additional 26 RCTs were identified in the current systematic review of which an additional 12 measured whole day physical activity via accelerometer, thereby providing confidence that the current review incorporates a comprehensive inclusion of studies.

The methodological quality of included studies was variable and intervention reporting in line with the TIDieR checklist[45] highlighted some common shortfalls. In terms of methodological quality, the most common limitations included the lack of randomisation 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 physical activity observed in control conditions over time, as opposed to significantly increasing physical activity 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 including by who and how the intervention was provided. In contrast, the majority of studies did not report any tailoring or modifications to the intervention design or delivery, or indeed adherence. 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, which suggests sex-specific interventions do not appear warranted. However, it might be important to tailor interventions on the basis of fitness and/or baseline physical activity levels[71,102 80].

A number of studies used objective physical activity assessment only in a sub-population, 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 impacts on the ability to generate firm conclusions regarding effectiveness. It is critical for future research to include whole day physical activity and ST, and week, measurement to be able to evaluate the effect of a

school-based intervention on overall physical activity and sedentary levels. Moreover, Rowlands[113] recently developed the use of raw accelerometry data to generate an activity gradient, which could be a promising more robust approach for future assessment of intervention effectiveness and remove the issue of multiple cut points. Since a number of school-based interventions may logically reduce ST and increase light physical activity, it may be they are effective at shifting the activity gradient as opposed to increasing MVPA, which could still enhance overall health profiles. Furthermore, future research should explore the potential issue of compensatory physical activity or ST that has implications in terms of research design, but also in terms of approaches to support interventions. Indeed, Ridgers *et al.*[110] advocated that strategies to negate compensatory responses were warranted and should be considered for intervention design and evaluation. Nonetheless, it is important to acknowledge the potential benefits of physical activity interventions despite resultant compensatory behaviours.

5. Conclusion

Strategies to increase MVPA and reduce ST in children are essential, not least due to the health benefits and tracking of behaviours, particularly in a school setting, given that it has been identified as an important setting for health-promoting interventions. The current review identified no evidence of effect on MVPA for interventions aimed at children implemented within school settings, and limited evidence of effect for ST. The Theory of Expanded, Extended and Enhanced Opportunity was an easily applied and useful framework to categorise intervention type and led to differential evidence rating with moderate evidence for expansion, inconclusive evidence for extension and no evidence for enhancement of physical activity opportunity. After school clubs, active travel, class physical activity breaks and physically active learning appeared the most promising interventions, but consideration to sustainability and reach should be considered. A critical issue of possible compensatory behaviour was identified by analysis of intervention effect in relation to physical activity measurement duration; when studies measured changes in physical activity during the actual intervention there was moderate evidence of effect, whereas those that measured during the school day had inconclusive evidence, and over a whole day no evidence of effect.

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

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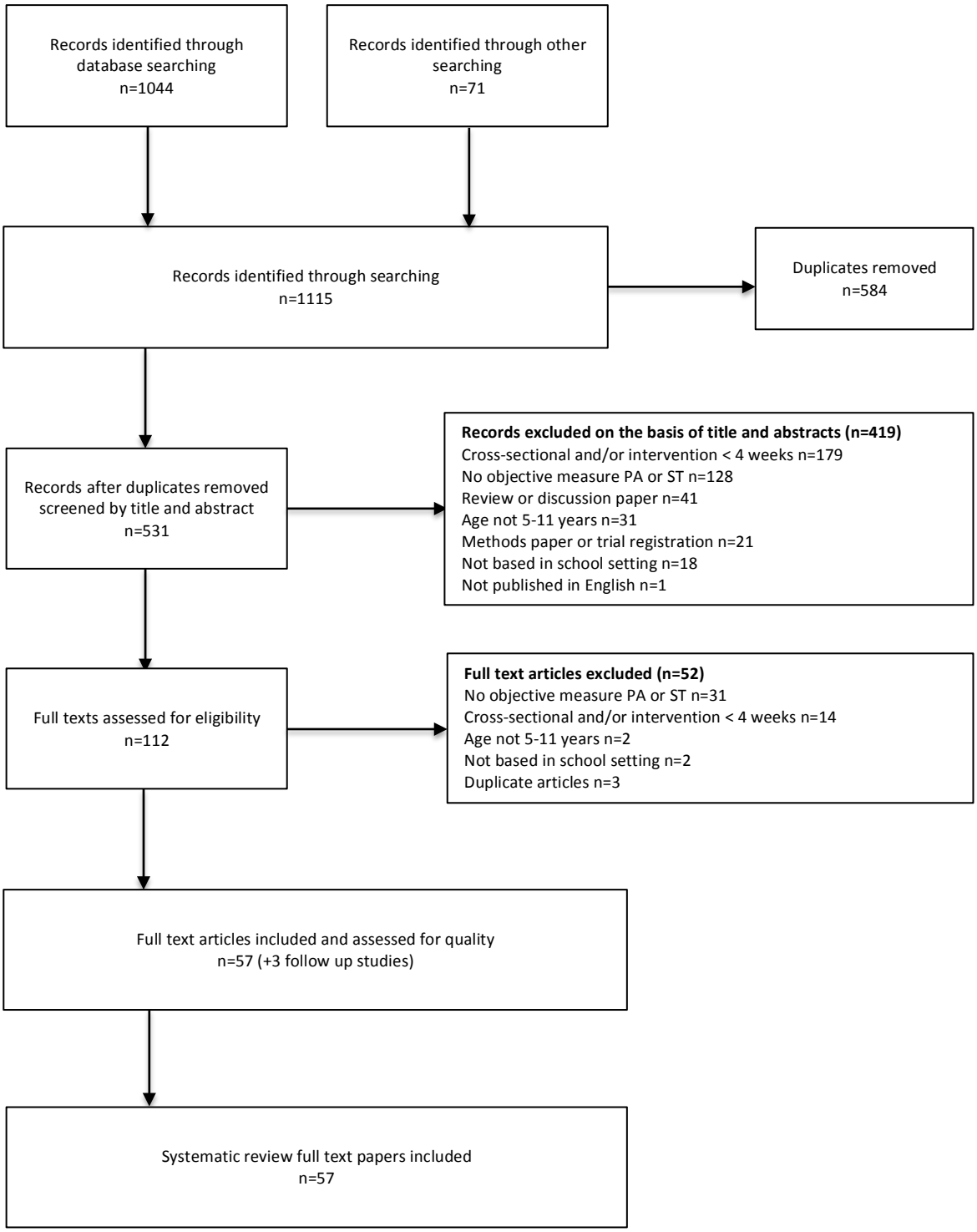

Figure 1: *Evidence Search and Exclusion Process*

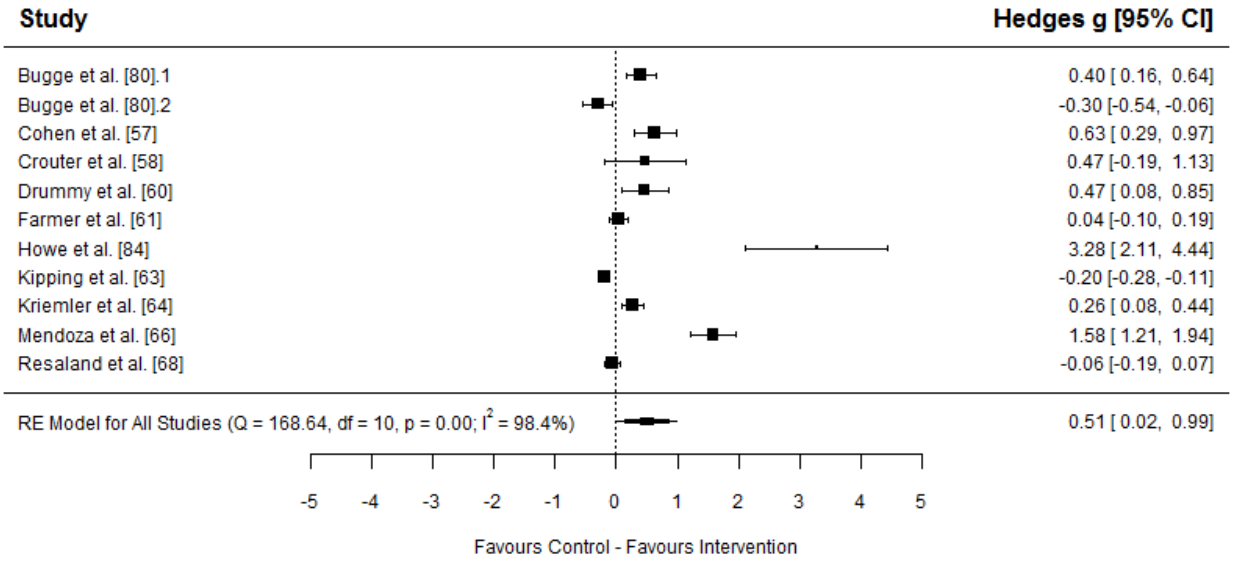

Figure 2: *Main effect for MVPA whole day accelerometer measure. Forest plot for standardised mean difference of change in physical activity between intervention and control groups of school-based physical activity interventions in children*

Table 1: *Search Terms used for Systematic Review*

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

Table 2: *Summary of* Theory of Expanded, Extended and Enhanced Opportunity *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	
	Before school clubs *Inconclusive Evidence MVPA*	RCT[47], 25%, <250	+MVPA	-ST
	After school 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	
	Active Travel *Limited Evidence PA*	RCT[68], 50%, >1000	+MVPA	0 ST
		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	
Multi-Component *Inconclusive Evidence MVPA*	**Expanded & 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
		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	

Key:
RCT Quantitative randomised controlled trial
NR Quantitative non-randomised controlled
OB Quantitative observational descriptive
MM mixed-methods
+ Significant increase in measure or intervention > control
0 No significant difference pre-post or intervention-control
- Significant decrease in measure or intervention < control

Table 3: *Summary of Physical Activity Measure and Level of Evidence Level*

Measurement Device	Time Period and Evidence Level	Design, quality score, sample size	Cut Points of MVPA threshold	PA Outcome	ST Outcome
Accelerometer	During the intervention activity *Moderate Evidence MVPA*	RCT[47], 25%, <250	Freedson	+MVPA	-ST
		RCT[48], 75%, >250	Freedson	+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 *Inconclusive Evidence MVPA and ST*	D[93], 100%, >1000	Evenson	+MVPA	
		NR[77], 75%, >250	Freedson	+MVPA	-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 *No Evidence MVPA and Inconclusive Evidence ST*	RCT[47], 25%, <250	Freedson	+MVPA	-ST
		NR[80], 50%, >250	≥ 1500 cpm	0 MVPA	
		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	During the intervention activity *Inconclusive Evidence Step Count*	MM[103], 50%, <250	step count	+PA	
		NR[86], 75%, >250	step count	+Step count	
		NR[87], 75%, <250	step count	+Step count	
	During the school day *Inconclusive Evidence Step Count*	D[93], 100%, >1000	step count	+MVPA	
		D[97], 75%, >1000	step count	+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 *No Evidence MVPA*	D[99], 50%, <250	step count	0 Step count	
		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	

Key:
Freedson *et al.*[116], Nilsson *et al.*[117], Evenson *et al.*[118], Welk[119], Trost *et al.*[120], Tudor-Locke *et al.*[121]