A systematic review of educator-led physical literacy and activity interventions

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Abstract

Introduction: Early childhood is a key time for the development of physical activity behaviours and physical literacy. A growing proportion of children spend a significant portion of their daytime in early childhood education and care (ECEC) settings where an early childhood educator cares for them. This systematic review (PROSPERO CRD42018087249) aimed to identify differences between effective and non-effective educator-led interventions with a goal to improve physical literacy and/or physical activity in children aged 3-5 in ECEC settings.

Methods: Interventions were included if they aimed to improve at least one physical literacy component or physical activity time in children aged 2-6 years through educator training. MEDLINE, EMBASE, CINAHL, ERIC, Australian Education Index, and Sport Discus were searched in March, 2018 and April, 2021. Risk of bias was assessed via a modified Cochrane assessment tool.

Results: Data from 51 studies were analyzed in 2021 and 2022 and summarized narratively. Thirty-seven interventions aimed to promote physical activity, 28 sought to promote physical literacy, 54%, and 63% of which were effective, respectively. Interventions that were underpinned by theory, included ongoing support, or measured intervention fidelity were more effective, especially when all three were done.

Discussion: This review was limited by high risk of bias and inconsistency in reporting of results across interventions. Reporting physical activity by minutes per hour, and reporting both sub- and total scores in physical literacy assessments will allow for greater cross comparison between trials. Future training of educators should be underpinned by theory, incorporate ongoing support and objective fidelity checks.

Introduction

Early childhood is a key time point for physical literacy, defined as the motivation, confidence, physical competence, knowledge, and understanding to value and take responsibility for participation in physical activity throughout the lifecourse.[1] The concept of physical literacy integrates fundamental movement skills as a component of physical competence into its theoretical framework, and physical activity as a behavioural outcome. While strong fundamental movement skills are identified as a predictor of physical activity, physical literacy enhances this model and incorporates the importance of psychological and cognitive factors in influencing physical activity behaviour.[1] Physical literacy and physical activity have a reciprocal relationship, with physical activity supporting the development of physical literacy and physical literacy promoting engagement in physical activity.[1,2] There is substantial evidence to support the importance of physical activity and fundamental movement skills for healthy development.[3-5] As well, there is growing evidence in support of the importance of physical literacy in general, but evidence suggests child levels of physical activity, fundamental movement skills, and physical literacy are low.[3-7]

Early childhood education and care (ECEC) represents a potentially viable setting to target physical activity and physical literacy in preschool children, with increasing numbers of children attending ECEC settings worldwide.[8-10] Previous survey research has identified that early childhood educator training has little-to-no focus on physical activity, fundamental movement skills, and/or physical literacy,[11,12] and there is some evidence to suggest that physical activity levels while children are in ECEC are low.[13]

Several systematic reviews have examined interventions to promote physical activity and/or fundamental movement skills in preschool-aged children.[14-16] These reviews have demonstrated that interventions can be effective, but that effectiveness varies depending on intervention design, and many studies lack rigor.[14-16] Many of the interventions included within these reviews were run by external experts particularly when the study purpose was to improve fundamental movement skill proficiency.[17-19] Interventions run by external experts lack generalizability or sustainability, as these individuals have a high level of knowledge and advanced training that typically trained educators would not possess. This is particularly pertinent as 2 reviews found that in pragmatic, or "real world" conditions, interventions were not effective at improving physical activity behaviours in ECEC.[14,16] One review examined educator-led physical activity interventions up until 2017 and found no consistent patterns,[20] but did not examine interventions focused on physical literacy. Given that long-term sustainability of improving the physical activity and physical literacy behaviours in ECEC is unlikely with short-term external expert-led interventions, researchers and policy makers need a better understanding of what has contributed to the success of educator-led interventions. Therefore, the purpose of this systematic review was to determine the characteristics of educator-led effective interventions that aimed to improve physical literacy and/or physical activity in preschool-aged children in ECEC settings.

Methods

This systematic review followed the PRISMA guidelines for reporting systematic reviews and the PRISMA checklist is included in the Appendix.[21] The study protocol was registered on

PROSPERO on March 8, 2018 (http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42018087249). A meta-analysis was not conducted, due to high statistical heterogeneity (I^2>90%) across studies, and high risk of bias in study reporting.

Inclusion Criteria

Interventions

Interventions that aimed to improve at least one component of physical literacy (i.e., motivation, confidence, physical competence, knowledge, or understanding) or time spent in physical activity in children aged 2-6 years through training of educators who implemented the intervention were included. Interventions using an experimental design with a control group were included.

Participants

Studies were included if child participants (1) attended regular, center-based childcare with a provider trained to implement the intervention, (2) were involved in a physical literacy and/or physical activity intervention, (3) were aged 2-6 years, and (4) were typically developing (inclusive of children living with overweight or obesity and children who may be living in socioeconomically disadvantaged areas). Studies were excluded if: (1) child participants were under the age of 2 or over the age of 6 years, (2) the intervention did not take place in ECEC, (3) someone other than the educators in ECEC implemented the intervention, and (4) papers were not published in English.

Search Strategy

Six relevant databases were selected and searched (MEDLINE, EMBASE, CINAHL, ERIC, Australian Education Index, and Sport Discus). The search was conducted in April 2018 and April 2021. Search terms were identified by members of the research team, through consultation with a subject librarian, examination of a similar systematic review that looked at school teachers as the implementers of interventions,[22] and using the PICOS (Population, Intervention, Comparison, Outcome, Study Design) framework.[23] Three major categories of location, study design, and intervention outcome, were used to develop the search. The full search strategy is outlined in the Appendix. One author (EJB) conducted the initial searches, and 2 authors (EJB and LD or BR) assessed titles, abstracts, and full text articles for eligibility. Disagreements were resolved via discussion with a third author (EP or GF).

Data Collection

Two authors (EJB and LD or BR) extracted data. Data extracted were categorized into 3 main categories: (1) general information about the study (authors, year published, title, country, study purpose); (2) information on the training of educators [previous experience or training of the educators, length of the training program, training modality (e.g. face to face, online), theoretical underpinnings of the training, brief description of the training, by whom the training was conducted, educator satisfaction]; and (3) information on the intervention outcomes and child participants [age and sex of child participants, study design, study duration, time points of data collection (e.g. pre, post, follow-up), data collection tools for physical activity (e.g.

accelerometers, pedometers), and/or physical literacy (e.g. the Test of Gross Motor Development (TGMD) 2 for fundamental movement skills, questionnaires for motivation or confidence), study outcomes, and intervention fidelity]. Studies were categorized as effective if a significant intervention effect (group x time) was reported on one physical activity variable, or improvement in 2 or more individual movement skills, or a larger movement skill category (e.g. locomotor or object control skills), or one psychological construct of physical literacy (e.g. motivation). Missing information was categorized as not reported.

Risk of Bias

Two authors (EJB and BR) assessed each study using a modified Cochrane Risk of Bias checklist.[23] This checklist was slightly modified from a previous publication, whereby instances of the term fundamental movement skills were replaced with physical literacy.[22] See Table 1 for the summary description of the risk of bias checklist. As per Cochrane guidelines, risk of bias results were not summed and each item was evaluated separately, with the exception of comparing risk of bias between effective and ineffective trials.[23] Studies that included all relevant category details were deemed low risk of bias. Initial agreement between reviewers was high (89%). Any disagreement was resolved via discussion with a third author (EP). Risk of bias assessment for each study is presented in Table 2.

Results

See Figure 1 for PRISMA flow diagram. A total of 51 papers, which reported on 49 interventions were included. Studies took place in the United States (k=24), Australia (k=8), Canada (k=7),

Germany (k=4), Finland (k=2), Switzerland (k=2), the United Kingdom (k=2), Ireland (k=1) and Spain (k=1). The majority of studies (k=39) took place in the past 10 years, and the earliest study took place in 2006.

Study Characteristics

Appendix Table 1 provides an overview of relevant data retrieved from each study. Thirty of the 51 included studies used a randomized controlled trial (RCT) design,[24-53] 13 studies used a quasi-experimental design,[54-66] 5 used randomization but were not RCTs,[67-71] 2 used a non-randomized controlled trial design,[72,73] and 1 used a within-subjects design.[74] Table 3 provides a comparison of characteristics of training programs. Of the 51 included interventions, 37 intended to increase physical activity,[25-29,31-35,37-44,46-52,54,58,59,62,63,65-68,70,72-74] and 28 intended to increase physical literacy.[24,30-32,36,39-41,45-48,52-57,60,61,64-67,69-71,73] Twenty-seven of the physical literacy articles focused on physical competence and one focused on the psychological components of physical activity participation.[45] Of the 51 included studies, 14 aimed to promote physical activity and physical literacy concurrently.[31,32,39-41,46-48,54,65-67,70,73] As well, for 4 included papers, the results were derived from 2 studies that split the physical activity and physical literacy results into 2 papers each.[24,25,35,52] Physical activity and physical literacy were the primary outcomes of 40 included studies, and the secondary outcomes for 8 included studies. For the remaining 3 studies, physical activity or physical literacy were the primary objectives of the published manuscript, but also secondary outcomes of a larger project that reported on the primary outcome previously.[24,30,52]

Measurement Tools

Physical activity was measured via accelerometry in 28 (of 37) studies reporting physical activity data.[25-29,31,32,34,35,37,39-44,46-51,54,62,63,68,70,74] Of the remaining 9 studies, pedometers were used in 3 studies,[33,66,67] 5 studies reported using variations of the System for Observing Fitness Instruction Time,[38,58,59,65,72] and 1 study used parent report.[73] The majority of studies (22 of 28) employed Actigraph (7164/GT1M, GT3X/GT9X) accelerometers and the remaining 6 used Actical accelerometers.[24,45,41,51,70,74] Nine different accelerometer cut points for determining physical activity intensity (i.e., sedentary, light, moderate, and vigorous physical activity) were reported. Several studies reported employing more than one set of established cut points. Pate and colleagues'[87] cut points were used most frequently, with 15 of 28 studies employing them.[26-29,31,32,34,37,39,44,46,48,49,50,61] Of the 28 studies using accelerometers, 26 reported using an epoch length of 15 seconds or less [25-29,31,32,34,35,37,39-41,44,46-51,54,62,63,68,70,74] and 2 did not report information on epoch length.[42,43]

The physical competence component of physical literacy was the most frequently assessed in the form of fundamental movement skills. Fundamental movement skills were most commonly assessed using the TGMD 2 or 3.[88,89] Six of the 27 studies measuring movement skills utilized the full test[24,41,44,52,61,70] and 7 used portions of the TGMD.[32,36,39,40,54,56,69] Two studies used the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2).[55,64,90] The remaining 12 studies described studies that used an assessment tool used by no other studies.[30,31,57,60,46,47,48,65,66,67,71,73] One study measured physical literacy components other than

physical competence (fundamental movement skills), and examined knowledge, attitudes, and habits scores on physical activity.[45]

Intervention Results

Physical Activity. Twenty of the thirty-seven studies (54%) that aimed to increase time spent in physical activity reported evidence for intervention effectiveness, 18 of which were significant group x time effects.[26-29,34,35,42,43,44,48,50,51,58,59,63,66,68,70] One study showed significant differences in change scores[72] and 1 reported significant within-group differences.[74] The remaining 17 did not demonstrate significant intervention effects[25,31-33,37-41,46,47,49,54,65,73] or change score differences for activity time.[62,67]

Physical Literacy. Seventeen of the 27 studies (63%) that aimed to promote physical literacy through fundamental movement skill improvements demonstrated significant treatment effects between the groups from baseline to end of the intervention[24,36,40,41,47,48,52,53,55,56,60,61,66,69,71] or significant change score improvement,[64,67] and the remaining 10 found no significant between group differences.[30,31,32,54,57,39,46,65,70,73] The 1 study examining psychological constructs of physical literacy demonstrated significant intervention effects.[45]

Quality Assessment (Risk of Bias)

Table 2 outlines risk of bias assessments for each paper. Almost all studies (k=47, 92%) used valid assessment tools and accounted for covariates (k=46, 90%). Assessors were rarely (k=13, 25%) blinded to allocation status of participants and few studies (k=16, 31%) provided power

calculations. There were no differences in study quality between effective interventions and interventions that were not effective as evidenced in Table 3, as determined by t-test (t=1.07, p=0.29) between the 2 groups of studies.

Characteristics of Training

Only a third of studies reported all relevant information on training.[24,31-34,37,39,41,45,46,50,52,56,61,66,69,70,72] Nearly all studies (k=49, 96%) reported training modality and 47 described face-to-face initial training sessions and one that used online training. Two studies did not provide sufficient detail to report training modality.[53,60] Duration of training was reported in 30 studies. Initial training length ranged from two 30-minute sessions[60] to a 30-hour course,[45] with the exception of 1 study that provided up to 66 hours of ongoing training.[50] As evidenced in Table 3, 21 studies reported providing booster sessions or ongoing support for educators during the intervention period,[24,25,31,33,34,35,38,41,43,45,46,48,50,52,56,58,61,66,68,69,70] 16 of which reported significant intervention effects in the treatment group compared to the control group on at least one outcome variable.[24,34,35,41,43,45,48,50,52,56,58,61,66,68-70]

In 18 studies, an intervention program or content field expert delivered the training (k=12 were effective).[24,25,31-33,35,41,43,45,46,52,54,61,63,64,68,70,72] In 10 studies, a member of the research team conducted the training (k=7 were effective),[30,34,38,44,56,59,62,66,69,74] One study, that was effective, used an experienced and trained peer coach.[50] One study that was not effective study reported using both a program expert and a member of the research team to conduct training.[39] One study, that was not effective, used insurance company staff members to deliver training.[73] Finally, one

study that was not effective, was delivered entirely online; however, the program delivered was developed by research staff.[37]

All included studies provided at least some description of the content of the training program; however, the details that were provided varied widely. Primarily, the purpose of training was to train educators in implementing the intervention. Twenty-six studies provided lesson plans for educators to implement (k=19 were effective).[30,33,34,39,40,43,45-48,53-59,63,64,66,67,69,71-74] Thirty-one studies provided knowledge and training on how to promote behaviour changes in physical activity and/or physical literacy (k=21 were effective).[24-29,31-33,35-42,44-46,48-52,60,61,65,66,70,74] Twenty-one studies provided resources to educators that were not specifically identified as lesson plans such as Healthy Opportunities for Preschoolers,[91] which outlines physically active games and activities (k=13 were effective).[24,25,31,32,35,37,38,41,43,45,49,50,52,55,60-62,65,66,70,74] Five studies, all of which were effective, provided training to support educators in modifying knowledge and attitudes in children to support engagement in physical activity,[26-29,45] although direct measurement of these variables was only conducted by Penalvo and colleagues.[45] One study, which was effective, did not provide sufficient detail to categorize it.[68]

Characteristics of Interventions

Length. Intervention length ranged from 4 days[74] to 20 months.[60] The majority of interventions were 6 months or less (k=32) and of those, 11 interventions took place over a period of less than 2 months (k=9 were effective).[27,28,32,43,56,62-64,69,71,74] Nineteen interventions took place over >6 to 12 months and 5 of these lasted a full year (k=2 were effective).[30,38,51,55,73]

Theoretical Framework. Twenty-seven studies (53%) reported theoretical underpinnings (sociological theory,[25,31,33,41-44,46,52,65,70,72] n = 12; Dynamical systems theory/Newell's model,[56,66] n =2; 7 = other). Of these, 21 demonstrated significant intervention effects[26-29,34,40-45,50,52,53,56,61,65,66,69,70] or significant between group changes scores as outlined in Table 3.[72]

Fidelity and Satisfaction

Twenty-eight studies (54.9%) provided some report of intervention fidelity. For 13 of these studies, educators who were delivering the intervention self-reported intervention fidelity.[34,38,40,41,46,54,55,60,61,66,67,71,73] For 1 study, an insufficient number of participants completed fidelity reports for analysis, but educator self-efficacy towards healthy physical activity practices improved.[32] One study measured the amount of the online program participants watched[37] and one used the logbook the peer coach completed.[50] For 15 studies, a researcher visited study sites to monitor intervention adherence.[29,37,44,45,47,49,50,56,58,59,64,65,69,72,74] In all but 2 of these 15 studies with research team driven fidelity checks, significant intervention effects or between group change scores demonstrated.[37,49] Educator satisfaction with the intervention was reported in 12 studies[31,33,40,42,49,58,59,64-67,70] and in the process evaluation of another,[77] and all reported positive satisfaction. Interestingly, when fidelity, theoretical underpinning of the intervention, and ongoing support were all present, studies appeared most likely to be effective.

Follow-Up

Six studies included in the review reported follow-up data.[40,42,43,48,51,55] For 2 interventions,[45,53] these were reported in 3 additional publications found in the search for this review.[78,85,86] Physical literacy changes in the form of fundamental movement skills were more likely to persist at follow-up than group by time differences in physical activity.[53,55,85] Intervention effects in physical activity time were no longer present at follow-up in 4 studies. Differences in moderate to vigorous physical activity were not maintained and in fact declined at 6-month follow up in Methälä and colleagues' study, but total and light physical activity intervention effects were still present at follow up.[42] Penalvo et al.'s intervention to improve knowledge, attitudes, and habits around physical activity demonstrated sustained change at one and two-year follow-up.[45,78]

Discussion

This study assessed the characteristics of effective interventions that aimed to improve physical activity/literacy in preschool-aged children through the training of educators. All interventions took place in childcare centres; therefore, minimum regional standards for indoor and outdoor space, provision of play equipment, and educator training were likely met. Training delivery method, length, description, theoretical underpinnings, and trainer were all retrieved from relevant interventions to determine the effects on intervention outcomes. Intervention fidelity and educator satisfaction with the intervention were also tracked. Overall, there was a lack of detailed reporting of educator training, reducing reproducibility and making drawing conclusions challenging. Only 3 studies received positive ratings for inclusion of all relevant risk of bias methodological and outcome data.[33,46,48]

Just over half (54%) of physical activity interventions were able to establish intervention effects in one or more physical activity behaviours at intervention completion in comparison to the control group. Increases in physical activity were more common in higher intensity (e.g.. moderate-to-vigorous vs. light) physical activities, but moderate-to-vigorous activity was the most commonly reported activity variable. Minutes/hour or percentage were more commonly used in studies within this review; however, no consistent format was used. Future publications should report both physical activity at any intensity and moderate-to-vigorous physical activity to reflect activity guidelines for the early years.[92,93] As well, the use of minutes/hour is recommended because these values can be easily compared to government physical activity guidelines and prevalence within relevant literature.[13,94]

In the context of this review, interventions were considered effective in improving physical competence if improvement was demonstrated in more than one movement skill. All but one of these studies[45] focused on improving physical competence. Across the 27 physical literacy studies focusing on movement skills there was considerable inconsistency in measurement tool usage. Fifteen unique physical literacy assessment tools were used, 14 of which examined different aspects of physical competence. Even when the same tool was used (e.g., the TGMD 2 or 3), not all studies used the tool in its entirety. Four studies reporting on intervention effects with regard to physical literacy included measures of physical fitness within their reported operationalization of physical literacy and/or fundamental movement skills (e.g. the shuttle run

within the BOT-2).[95] This is important, given criticism of researchers conflating physical literacy with physical fitness.[96]

Components of physical literacy other than physical competence were assessed in only one study.[45] This study did not explicitly use the term physical literacy, but the concepts of knowledge, attitudes, and habits were used as they relate to physical activity. These concepts fit well within Whitehead's definition of physical literacy, which were operationalized in this review.[1,97] Given the dearth of studies measuring these concepts, continued work in the area is needed.

All but one paper that reported training modality reported face-to-face training. As there was wide variation in intervention effectiveness and only one other modality (online) reported, which was not effective, firm conclusions cannot draw conclusions as to the best modality of training. However, large-scale, population level interventions may be difficult to disseminate completely in person, particularly for those in rural and remote regions. Some research has shown effectiveness in online training improving educator confidence and knowledge in promoting physical activity and physical literacy,[98] but more work is needed.

Most training sessions were under 10 hours in length, and 4-6 hours was the most prevalent length of training. Four studies used significantly longer training periods, and 3 of the 4 interventions were effective. When studies were sorted into tertiles based on training length, the longest and the shortest training periods appeared to be equally effective, and the middle tertile

had the highest number of ineffective interventions. More research is clearly needed, particularly when considering the minimum amount of training to derive effective interventions within ECEC settings. Training content and the resources that were provided varied between interventions as outlined in Table 3, but there appeared no differences in intervention effectiveness based on content or resources.

Just over half (54%) of all included studies provided some measure of intervention fidelity to capture adherence to the study protocol, Of these studies, 13 had educators self-report the number of times the educators implemented the intervention (e.g., number of lessons per week or an implementation calendar) as the measure of fidelity. While these reports provide a measure of how many times child participants received intervention programming, they do not indicate whether the intervention was implemented as intended. Fifteen interventions used research team members to assess fidelity (e.g. site visits, lesson recording) and the majority (k=13, 87%) were effective in demonstrating significant between group effects. Assessment of fidelity should be conducted by research teams or via audio/video recording of lessons, to ensure adherence to the intervention protocol is maintained, as educator self-report likely leads to bias in results.

Multiple studies used ongoing support or training for educators, such as “booster sessions” or check-ins with research teams, and these were more likely to be effective. The use of ongoing support was also found to be beneficial for elementary school teachers in a systematic review of physical activity and fundamental movement skill interventions targeting school-aged children.[22] Unfortunately, limited details about the content and format of ongoing support was reported in

the original manuscripts; therefore, it is impossible to conclude if a specific type of support is more effective than another.

Very few studies provided follow-up beyond the completion of the intervention. Only 6 studies reported follow-up data in the original published manuscripts, and 2 studies reported follow-up data in subsequent publications. Half of these studies reported no sustained behaviour changes at follow-up. Sustaining positive change is important as the interrelated behaviours of physical literacy and physical activity will likely continue to impact each other in a school setting.[99] Future studies should measure effects after a significant (≥6 months) follow-up period to determine lasting results of interventions.

Risk of bias was a concern in the majority of included studies. Only 3 studies reported sufficient detail to receive a low risk of bias on all assessed levels of information. In particular, the majority of studies (k=37) did not blind assessors to group allocation. While a large portion of these studies used accelerometers, often considered to be an "objective" tool to assess movement-based activities, there is growing evidence that results can vary significantly based on accelerometer brand and cut-points used.[100,101] Thus, accelerometers can be considered somewhat subjective as well.[100,101] Accelerometer brand may also contribute to these decisions, with higher quality studies needed to ensure accurate conclusions.

Limitations

This study is limited by the use of English language only studies, high risk of bias, and an inconsistent reporting of outcomes. A meta-analysis was not conducted due to the heterogeneity in study design, measures, and outcomes in the studies. This review has several strengths. A broad range of databases was used for the searches, as well as a robust search strategy. No date restrictions were placed on any searches. The review builds on existing syntheses through a novel examination of studies incorporating physical activity and physical literacy interventions.[14-16] Specifically, this review examines detailed characteristics of training and resource provision, and compares what characteristics were unique to effective interventions, representing a unique perspective on the literature.

Conclusions

Just over half of studies included within this review demonstrated effective interventions for physical activity or physical literacy change, highlighting that educators are capable of promoting health behaviour change in the children for which they care. The use of a physical activity or physical literacy expert is not required for effective implementation of an intervention program to change these behaviours in ECEC. This is important, as expert-led programs are not financially sustainable or practical. Future studies should ensure full reporting of intervention design, implementation, and results particularly in respect to training details, aligned with both CONSORT and TIDieR checklists.[102,103] Follow-up studies should be completed to determine if results persist once children leave the childcare setting or training support ends. Future training interventions of educators in physical activity and/or physical literacy should utilize expert observation or other non-self report measures of intervention fidelity, as well as ongoing

resources and support for trainees following program delivery. Furthermore, developing and evaluating updates to educator-trainee curricula should be prioritized to address the known gap in educator training in physical literacy and physical activity.[11,12] While more research is needed to determine the most effective training methods, training educators and educator-trainees in these areas should be prioritized, as increasing physical literacy and physical activity opportunities in ECEC settings has potential to derive positive health impacts for children in these programs.

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The authors declare no conflict of interest.

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Table 1.

Summary description of assessment of risk of bias characteristics[a]

Item	Description
A	Randomization (generation of allocation sequence, allocation concealment and implementation) clearly described and adequately completed
B	Valid measures of PA/PL (validation in same age group has been published or validation data provided by author)
C	Blinded outcome assessment (those responsible for assessing PA/PL were blinded to group allocation of individual participants)
D	Participants analyzed in group they were originally allocated to, and participants not excluded from analysis because of non-compliance for treatment or because of missing data
E	Covariates accounted for in analysis (e.g., baseline score, group or cluster for RCT, and other relevant covariates when appropriate such as age and sex)
F	Power calculations reported for main PA/PL outcome
G	Presentation of baseline characteristics for treatment groups (age, sex, and at least 1 PA/PL outcome)
H	Drop out for PA/PL outcome measure described with <20% drop out for studies with follow-up of 6 months, and <30% drop out for follow-up with >6 month follow-up
I	Summary results for each group and estimated effect size (difference between groups) and precision(e.g. 95& CI)

[a] Adapted and reproduced with permission[22]

748 Table 2

749 *Risk of bias assessment for included studies*

Studies (Protocol and follow up papers)	A Randomization (generation of allocation sequence, allocation concealment and implementation) clearly described and adequately completed	B Valid measures of PA/PL (validation in same age group has been published or validation data provided by author)	C Blinded outcome assessment (those responsible for assessing PA/PL were blinded to group allocation of individual participants)	D Participants analyzed in group they were originally allocated to, and participants not excluded from analysis because of non-compliance for treatment or because of missing data	E Covariates accounted for in analysis (e.g., baseline score, group or cluster for RCT, and other relevant covariates when appropriate such as age and sex)	F Power calculations reported for main PA/PL outcome	G Presentation of baseline characteristics for treatment groups (age, sex, and at least 1 PA/PL outcome)	H Drop out for PA/PL outcome measure described with <20% drop out for studies with follow-up of 6 months, and <30% drop out for follow-up with >6 month follow-up	I Summary results for each group and estimated effect size (difference between groups) and precision (e.g. 95% CI)
Adamo et al.[24]	Y	Y	X	Y	Y	X	Y	Y	Y

Adamo et al,[25] ([75])	Y	Y	X	Y	Y	Y (in protocol paper)	Y	X	Y (CI)
Alhassan et al.[54]	Y (but not described)	Y	X	X	Y	X	Y	Y	Y
Annesi et al.[26]	Y (but not described)	Y	X	X	Y	Y	Y	X	Y
Annesi et al.[27]	Y (but not described)	Y	X	X	Y	X	X	X	Y (effect size)
Annesi et al.[28]	Y (but not described)	Y	X	X	Y	X	X	X	Y (effect size)
Annesi et al.[29]	Y (but not described)	Y	X	X	Y	X	X	X	Y (effect size)
Bellows et al. [67]	Y (but not described)	Y	X	X	Y	X	Y	X	Y (CI)
Bellows et al. [55]	X	Y	X	X	Y	X	Y	Y	Y (effect size)
Birnbaum et al.[30] ([76])	Y (but not described)	Y (fitness)	X	X	Y	Y (in protocol paper)	Y	X	X
Bonis et al.,[68]	Y	Y	X	X	Y	Y (post only)	Y	Y	Y (effect size)
Bonvin et al.[31]	Y	X	Y	Y	Y	Y	Y	Y	Y (CI)
Brian et al.[69]	Y (but not described)	Y	Y	X	Y	X	Y	X	Y (effect size)
Brian et al.[56]	X	Y	30%	Y	Y	X	Y	Y	Y (effect size)

Chuang et al.[72]	X	Y	X	Y (at group level)	X	X	X	X	X
Duff et al.[32]	Y (but not described)	Y	X	X	Y	X	X	X	Y (effect size)
Finch et al.[33]	Y	Y	Y	Y	Y	Y	Y	Y	Y
Fitzgibbon et al.[34]	Y (but not described)	Y	X	X	Y	X	Y	X	Y (CI)
Froehlich-Chow et al.[70]	Y (but not described)	Y	X	X	X	X	X	Y	X
Goldfield et al.[35]	Y (but not described)	Y	X	Y	Y	X	Y	Y	Y (CI)
Hardy et al.[36]	Y (but not described)	Y	Y	X	Y	Y	Y	Y	Y (CI)
Hoffman et al.[37]	Y	Y	X	Y	Y	X	Y	Y	Y
Iivonen et al.[57]	X	Y	X	Y	Y	X	Y	X	X
Jones et al.[39]	Y	X	X	Y (at group level)	Y	Y	X	Y	X
Jones et al.[38]	Y	Y	Y	Y	Y	X	Y	X	Y
Jones et al.[40]	Y	Y	Y	Y	Y	X	X	Y	Y
Kirk & Kirk[58]	X	Y	X	Y (at group level)	Y	X	Y	Y	X

Kirk et al.[59]	X	Y	X	Y (at group level)	Y	X	Y	X	X
Krombholz[60]	X	Y	X	X	Y	X	Y	Y	Y (effect size)
Leis et al.[41] ([77])	Y	Y	Y	X	Y	Y	Y	X	X
Mehtälä et al.[42]	Y	Y	X	Y	Y	X	Y	Y	Y (CI)
O'Dwyer et al.[43]	Y	Y	X	X	Y	X	Y	Y	X
Palmer et al.[61]	X	Y	X	X	Y	X	Y	X	Y (CI)
Pate et al.[44]	Y (but not described)	Y	X	Y	Y	X	Y	Y	X
Penalvo et al.[45] ([78,79])	Y	X	X	Y	Y	Y	Y	Y	Y (CI)
Puder et al.[46] (80)	Y	Y	Y	Y	Y	Y	Y	Y	Y (CI)
Reilly et al.[47]	Y	Y	Y	X	Y	Y	Y	Y	X (abstract only[b])
Robinson et al.[62]	Y (but not described)	Y	X	X	X	Y	Y	X	X
Roth et al.[48]	Y	Y (fitness)	Y	Y	Y	Y	Y	Y	Y

Steenbock et al.[73] ([81])	Y (but not described)	X	X	Y	Y	Y (in protocol paper)	Y	Y	Y (CI)
Tandon et al.[49]	X	Y	X	X	Y	X	Y	X	Y (CI)
Telford et al.[50]	Y	Y	X	Y	Y	X	Y	Y	Y (CI)
Trost et al.[63]	Y (but not described)	Y	X	Y	Y	X	X	Y	X
Tucker et al.[51] ([82])	Y (but not described)	Y	Y	Y	Y	Y (in protocol paper)	Y	X	Y (CI)
Veldman et al.[71]	Y (but not described)	Y	Y	Y	Y	X	Y	Y	Y
Vidoni et al.[64]	Y (but not described)	Y	X	X	X	X	Y	X	X
Wasenius et al.[52] ([75])	Y	Y	Y	Y	Y	X	Y	X	Y
Webster et al.[74]	X	Y	X	Y	X	X	Y	X	X
Winter & Sass[65]	Y (but not described)	Y	X	Y	Y	X	X	X	Y (effect size)
Yin et al.[66]	X	Y	X	X	Y	X	Y	Y	X
Zask et al.[53] ([83-86])	Y (but not described)	Y	X	Y	Y	X	Y (in protocol paper)	X	X

Abbreviations: Y., Yes reported in full. X., not reported or reported as not completed. CI., confidence interval. RCT., randomized controlled trial. PA., physical activity. PL., physical literacy. FMS., fundamental movement skills.

[a]Adapted and reproduced with permission[22]

[b] abstract only refers to papers that reported data in the abstract but not in the manuscript text

Table 3

Summary of selected characteristics in effective vs. not effective interventions[a]

Study (additional publications data were retrieved from)	Variable	Risk of bias	Theory	Length of training	Training materials	Booster/ Ongoing support	Fidelity assessed Method	Was PA or PL primary purpose	Intervention effect?[b,e,f]	Effect size[c] (confidence interval)
Adamo et al.[24]	PL	7	X	6 hours	Behaviour promotion, resource materials	Y	X	X	PL: yes, p=0.025 LS: yes, p=0.022 OC: no, p=0.252	PL: d=0.59, (0.74 to 10.67) LS: d=0.61, (0.18 to 2.22) OC: d=0.29, -0.41 to 1.53)
Adamo et al,[25] ([75])	PA	7	Y	6 hours	Behaviour promotion, resource materials	Y	X	Y	TPA: no, p=0.810 LPA: no, p=0.741 MVPA: no, p=0.323	TPA: -, (-1.7 to 1.3) LPA: -, (-1.1 to 1.6) MVPA: -, (-1.2 to 0.4)
Alhassan et al.[54]	PA and PL	6	X	8 hours	Lesson plans	X	Y - Educator report	Y	MVPA: No, p=0.13 LPA: No, p=0.19 PL: No, p=0.19 Leap: Yes, p=0.0009	MVPA: d=0.15, (-0.7 to 7.6) LPA: d=0.67, (-1.3 to 7.2) PL: d=0.38, (-4.66 to 22.07) Leap: d=0.80, (0.41 to 2.58)

Annesi et al.[26]	PA	6	Y	4 hours	Behaviour promotion	X	X	Y	MVPA: Yes, p=0.013 VPA: Yes, p=0.037	MVPA: η_p^2=0.023 (-) VPA: η_p^2=0.016, (-)
Annesi et al.[27]	PA	4	Y	4 hours	Behaviour promotion	X	X	Y	VPA: p<0.001 MVPA: Yes, p=0.016	VPA: η^2=0.018, (-) MVPA: η^2=0.007 (-)
Annesi et al.[28]	PA	4	Y	4 hours	Behaviour promotion	X	X	Y	VPA: No, p=0.058, MVPA: Yes, p=0.026	VPA: η_p^2=0.011 (-) MVPA: η_p^2= 0.015 (-)
Annesi et al.[29]	PA	4	Y	4 hours	Behaviour promotion	X	Y - Study staff report	Y	VPA: Yes, p=<0.001 MVPA: Yes, p=0.031 LPA: No, <0.001^	VPA: η^2=0.06, (-) MVPA: η^2=0.02 (-) LPA: η^2=0.07 (-)^
Bellows et al. [67]	PA and PL	5	X	X	Lesson plans	X	Y - Educator report	Y	PL: Yes, p<0.0005 NL: Yes, p<0.0005	PL: -, (4.12 to 9.03) NL: -, (-) LS: -, (-) OC: -, (-)

									LS: Yes, p=0.001 OC: p=0.002 PA, SC: No, -	SC: -, (-)
Bellows et al. [55]	PL	5	X	X	Lesson plans, resource materials	X	Y - Educator report	Y	OC: Yes, p<0.001 NL: No, - LS: No, -	OC: -, (1.13 to 44.11) NL: -, (-) LS: -, (-)
Birnbaum et al.[30] ([76])	PL (but more fitness)	5	X	X	Lesson plans	X	X	X	Side to side jump: Yes, p=0.01 Standing long jump: No, p=0.08	Side to side jump: -, (-) Standing long jump: -, (-)
Bonis et al.,[68]	PA	7	X	X	X	Y	X	Y	VPA: Yes, p<0.05 MPA: Yes, p<0.05 MVPA: Yes, p<0.05	VPA: d=0.25, (-) MPA: d=0.30, (-) MVPA: d=0.29, (-)
Bonvin et al.[31]	PA and PL	8	Y	X	Behaviour promotion, resource materials	Y	X	Y	MVPA: No, p=0.68 VPA: No, p=0.33 PL: No, p=0.43	MVPA: -, (-4.2 to 6.4) VPA: -, (-1.25 to 3.69) PL: -, (-0.8 to 0.3)

Brian et al.[69]	PL	6	Y	7 hours	Lesson plans	Y	Y - Study staff report	Y	PL, OC: Yes, p<0.001	PL, OC: d=2.30, (-)
Brian et al.[56]	PL	6	Y	1 hour	Lesson plans	Y	Y - Study staff report	Y	PL, OC: Yes, p<0.001	PL, OC: η^2=0.61, (-)
Chuang et al.[72]	PA	2	Y	6 hours	Lesson plans	X	Y - Study staff report	Y	Indoor VPA: Yes, p=0.049 Outdoor VPA: No, p=0.257 Total VPA: No, p=0.114	Indoor VPA: -, (-) Outdoor VPA: -, (-) Total VPA: : -, (-)
Duff et al.[32]	PA and PL	4	X	4 hours	Behaviour promotion, resource materials	X	X – not completed	Y	PA: No, - PL: No, - Overhand throw: Yes, 0.049	PA: -, (-) PL: -, (-) Overhand throw: η^2=0.036, (-) No (except overhand throw)
Finch et al.[33]	PA	9	Y	6 hours	Behaviour promotion, lesson plans	Y	X	Y	PA, SC: No, p=0.12	PA/SC: 1.39 (12.57-15.17)
Fitzgibbon et al.[34]	PA	5	Y	3 hours	Lesson plans	Y	Y - Educator report	X	MVPA: Yes, p=0.02	MVPA: -, (1.41 – 13.51)

Froehlich-Chow et al.[70]	PA and PL	3	Y	X	Behaviour promotion, resource materials	Y	X	Y	PL: No, - MVPA: Yes, p<0.05 TPA: No, -	PL: -, (-) MVPA: -, (-) TPA: -, (-)
Goldfield et al.[35]	PA	7	X	6 hours	Behaviour promotion, resource materials	Y	X	Y	TPA: Yes, p=0.002 LPA: Yes, p=0.004 MVPA: No, p=0.085	TPA: -, (8.9 to 36.1) LPA: Yes, (5.2 to 26.7) MVPA: No, (-0.9 to 13.8)
Hardy et al.[36]	PL	8	X	One day	Behaviour promotion	X	X	Y	PL: Yes, p=0.001 LS: Yes, p=0.01 OC: Yes, p=0.003	PL: -, (1.95, 8.71) LS: -, (0.77 to 6.05) OC: Yes -, (0.76 to 3.41
Hoffman et al.[37]	PA	7	Y	~1.5 hours	Behaviour promotion, resource materials	X	Y – Amount of program completed	Y	MVPA: No, p=0.22	MVPA: d=0.32, (-0.94 to 4.18)
Iivonen et al.[57]	PL	4	X	6 hours	Lesson plans	X	X	Y	PL: OC, Girls: No, p=0.904 Boys: No, p=0.372	-, (-)

									PL, NL: Girls: No, p=0.596 Boys: No, p=0.944	
Jones et al.[39]	PA and PL	7	Y	4 hours	Behaviour promotion, lesson plans	X	X	Y	Run: No, p=0.22 Hop: No, p=0.66 Jump: No, p=0.45 Catch: No, p=0.49 Kick: No, p=0.62 PL: No, p=0.30 LPA: No, p=0.52 MVPA: No, p=0.43 TPA: No, p=0.96	Run: d=0.58, (0.29 to 1.72) Hop: d=0.09, (-0.61 to 0.94) Jump: d=0.19, (-0.30 to 0.80) Catch: d=0.52, (0.14 to 1.19) Kick: d=0.22, (-0.18 to 0.99) PL: d=0.23, (-0.88 to 2.79) LPA: d=0.39, (0.20 to 6.13) MVPA: d=0.18 (-1.45 to 4.14) TPA: d=0.23, (-1.42 to 6.06)
Jones et al.[38]	PA	5	X	3 hours	Behaviour promotion, resource materials	Y	Y – Educator report	Y	TPA: No, p=0.49	TPA: -, (-)
Jones et al.[40]	PA and PL	7	Y	2 hours	Behaviour promotion, lesson plans	X	Y - Educator report	Y	Run: No, p=0.94 Hop: No, p=0.09	Run: d=0.01, (-.052 to 0.57) Hop: d=0.26, (-0.11 to 1.42)

									Jump: Yes, p=0.00 Kick: No, p=0.52 Catch: No, p=0.17 PL: Yes, p=0.00 PA: Yes, p=0.01	Jump: d=0.75, (0.69 to 2.13) Kick: d=0.12, (-0.32 to 0.63) Catch: d=0.23, (-0.18 to 1.01) PL: d=0.47, (0.76 to 3.40) PA: d=0.40, (33.62 to 187.33)
Kirk & Kirk[58]	PA	5	X	One day	Lesson plans	Y	Y - Study staff report	X	TPA: Yes, $p<0.05$	TPA: -, (-)
Kirk et al.[59]	PA	4	X	One day	Lesson plans	X	Y - Study staff report	X	TPA: Yes, $p<0.01$	TPA: -, (-)
Krombholz[60]	PL	5	X	X	Behaviour promotion, resource materials	X	Y - Educator report	Y	PL: Yes, p=0.001	PL: $\eta_p^2=0.06$, (-)
Leis et al.[41] ([77])	PA and PL	6	Y	3 hours	Behaviour promotion, resource materials	Y	Y – Educator report	Y	TPA: No, p=0.3 MVPA: No, p=0.4 LPA: No, p=0.4 PL, LM: Yes, p=0.009	TPA: -, (-) MVPA: -, (-) LPA: -, (-) PL, LM: -, (-) PL, OC: -, (-)

									PL, OC: No, p=0.5	
Mehtälä et al.[42]	PA	7	Y	X	Behaviour promotion	X	Y – Educator report	Y	MVPA: Yes, p=0.016 LPA: Yes, p=0.016 TPA: Yes, p=0.030	MVPA: -, (2.0 to 27.9) LPA: -. (0.8 to 7.1) TPA: -, (1.2 to 23.1)
O'Dwyer et al.[43]	PA	5	Y	X	Lesson plans, resource materials	Y	X	Y	MVPA during active sessions: Yes, p≤0.001 TPA during active sessions: Yes, p≤0.001	MVPA during active sessions: -, (-) TPA during active sessions: -, (-)
Palmer et al.[61]	PL	4	Y	6 hours	Behaviour promotion, resource materials	Y	Y – Educator report	Y	PL: Yes, p= 0.07 LM: Yes, p= 0.01 OC: No, p= 0.57	PL: -, (−0.45 to 12.38) LM: -, (1.46 to 8.3) OC: -, (−3.12 to 5.61)
Pate et al.[44]	PA	6	Y	X	Behaviour promotion	Y	Y - Study staff report	Y	MVPA: Yes, p=0.01 LPA: No, p=0.34	MVPA: -, (-) LPA: -, (-) TPA: -, (-)

									TPA: No, p=0.79	
Penalvo et al.[45] ([78,79])	PL	7	Y	30 hours	Behaviour promotion, lesson plans, resource materials	Y	Y - Study staff report	Y	PL (knowledge): Yes, p<0.001	PL (knowledge): -, (1.17 to 2.69)
Puder et al.[46] (80)	PL and PA	9	Y	Two afternoons	Behaviour promotion, lesson plans	Y	Y - Educator report	X	PA: No, p=0.54 PL, NL: p=0.35 PL, agility: p=0.004	PA: -, (-51.5 to 26.9) NL: -, (-0.21 to 0.60) PL, agility: -, (-0.90 to -1.17)
Reilly et al.[47]	PL and PA	7	X	Three sessions	Lesson plans	X	Y - Study staff report	X	PA – No, - PL – Yes, p=0.0027	PA: -, (-) PL: -, (0.3 to 1.3)
Robinson et al.[62]	PA	4	X	X	Resource materials	X	X	Y	LPA: No, p<0.001† MPA: No, p<0.001† VPA: No, p<0.001† MVPA: No, p<0.001† TPA: No	LPA: -, (-) MPA: -, (-) VPA: -, (-) MVPA: -, (-) TPA: -, (-)

Roth et al.[48]	PA and PL	9	X	Two afternoon workshops	Behaviour promotion, lesson plans	Y	X	Y	MVPA – Yes, post-intervention: p=0.049, follow-up: p=0.859 PL – Yes, post-intervention: p=0.001 follow-up: p=0.007	MVPA (follow-up): d=0.006, (-0.006 to 0.007) PL (follow-up): d=0.590, (0.169 to 1.011)
Steenbock et al.[73] ([81])	PA and PL	7	X	Two days	Lesson plans	X	Y – Educator report	Y	TPA: No, - PL, NL: No, -	TPA: -, (−14.46 to 13.80) PL, NL: -, (-1.63 to 0.52)
Tandon et al.[49]	PA	4	X	3 hours	Behaviour promotion, lesson plans, resource materials	X	Y – Study staff report	Y	LPA: No, - MVPA: No, -	LPA: -, (-8.7 to 2.7) MVPA: -, (-10.8 to 9.8)
Telford et al.[50]	PA	7	Y	Up to 66 hours (3 hr/week x 22 weeks)	Behaviour promotion, resource materials	Y	Y – Study staff report	Y	TPA: Yes, p<0.001 MVPA: Yes, p<0.001	TPA: -, (2.66 to 5.47) MVPA: -, (1.31 to 3.34)
Trost et al.[63]	PA	5	X	3 hours	Lesson plans	X	X	Y	VPA (indoor): Yes for	-, (-)

									weeks 7-8, p<0.05 VPA (indoor + outdoor): Yes for weeks 5-6, p<0.05 MVPA (indoor): Yes for weeks 5-6 and 7-8, p<0.05 MVPA (indoor + outdoor): Yes for weeks 7-8, p<0.05	
Tucker et al.[51] ([82])	PA	8	X	4 hours	Behaviour promotion	X	X	Y	TPA: Yes, p=0.02 LPA: No, p=0.09 MVPA: Yes, p=0.0002	TPA: -, (0.58 to 3.72) LPA: -, (-0.29 to 2.11) MVPA: -, (0.57 to 1.99)

Veldman et al.[71]	PL	8	X	2 hours	Lesson plans	X	Y - Educator report	Y	PL: Yes, p=0.01 Jump: No, p=0.16 Balance: No, 0.36 Kick: Yes, p=0.01	PL: d=1.13, (1.73 to 6.96) Jump: d=0.72, (-0.76 to 2.92) Balance: d=0.47, (-2.25 to 4.60) Kick: d=0.99, (1.31 to 3.16)
Vidoni et al.[64]	PL	3	X	X	Lesson plans	X	Y - Study staff report	Y	PL: Yes, p=0.04	PL: -, (-)
Wasenius et al.[52] ([75])	PL	7	Y	6 hours	Behaviour promotion, resource materials	Y	X	X	PL: No, p=0.156 LS: Yes, p<0.001 OC: No, p=1.000	PL: -, (-0.9 to 8.6) LS: η^2=0.06, (1.0 to 4.1) OC: -, (-3.6 to 3.7)
Webster et al.[74]	PA	3	X	1.5 hours	Behaviour promotion, lesson plans, resource materials	X	Y - Study staff report	X	MVPA: Yes, p<0.001	MVPA: -, (-)
Winter & Sass[65]	PA and PL	5	Y	20 hours	Behaviour promotion, resource materials	X	Y - Study staff report	X	PL, LS: Yes, p<0.05 PL, NL: Yes, p<0.007 TPA: No, p=0.081	LS: d=0.30, (-) NL: d=0.34, (-) TPA: d=0.51, (-)

Yin et al.[66]	PA and PL	4	Y	6 hours	Behaviour promotion, lesson plans, resource materials	Y	Y - Educator report	Y	PA – Yes, $p<0.05$ PL – Yes, $p<0.01$	PA: -, (-) PL: -, (-)
Zask et al.[53] ([83-86])	PL	5	Y	X	Lesson plans	X	X	Y	PL: Yes, $p<0.0001$	PL: -. (-)

Abbreviations: PA., physical activity. PL., physical literacy. LS., locomotor skills. OC., object control skills. TPA., total physical activity. MVPA., moderate to vigorous physical activity. VPA., vigorous physical activity. MPA., moderate physical activity. SC., Step Count. NL., Non-locomotor skills.

[a]Y= completed and reported. X= not completed or not reported.

[b]Yes = significant effects were reported, No = significant effects were not reported

[c]d=Cohen's D, η^2=eta squared, η_p^2=partial eta squared

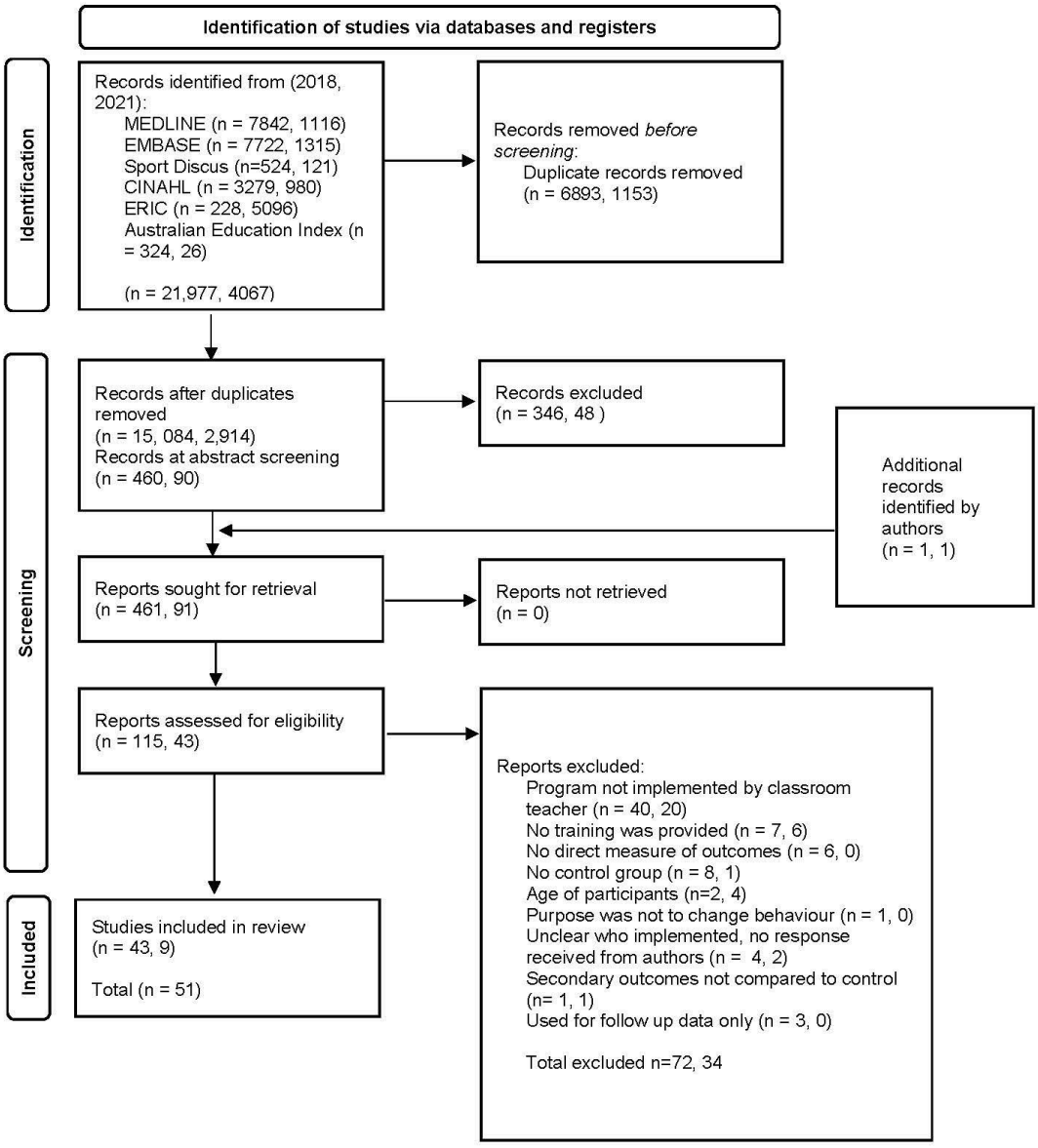
[e†] = significant within group differences in opposition to the hypothesis (e.g. PA time decreased)

[f]- = not reported

Adapted with permission from Lander, N., Eather, N., Morgan, P. J., Salmon, J., & Barnett, L. M. (2017). Characteristics of teacher training in school-based physical education interventions to improve fundamental movement skills and/or physical activity: A systematic review. *Sports Medicine*, *47*(1), 135-161.

773 **Figure Titles**

774 Figure 1. PRISMA flowchart of article retrieval and screening.[21]



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