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Review

A systematic review and meta-analysis of interventions designed to increase moderate-to-vigorous physical activity in school physical education lessons

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A R T I C L E I N F O

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A B S T R A C T

Objectives. Physical education (PE) that allows students to engage in moderate-to-vigorous physical activity (MVPA) can play an important role in health promotion. Unfortunately, MVPA levels in PE lessons are often very low. In this review, we aimed to determine the effectiveness of interventions designed to increase the proportion of PE lesson time that students spend in MVPA.

Methods. In March 2012, we searched electronic databases for intervention studies that were conducted in primary or secondary schools and measured the proportion of lesson time students spent in MVPA. We assessed risk of bias, extracted data, and conducted meta-analyses to determine intervention effectiveness.

Results. From an initial pool of 12,124 non-duplicate records, 14 studies met the inclusion criteria. Students in intervention conditions spent 24% more lesson time in MVPA compared with students in usual practice conditions (standardized mean difference = 0.62).

Conclusions. Given the small number of studies, moderate-to-high risk of bias, and the heterogeneity of results, caution is warranted regarding the strength of available evidence. However, this review indicates that interventions can increase the proportion of time students spend in MVPA during PE lessons. As most children and adolescents participate in PE, these interventions could lead to substantial public health benefits.

Contents

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There is ample evidence that participating in moderate-to-vigorous physical activity (MVPA) can lead to a variety of benefits for children and adolescents. Compared with their inactive counterparts, youth who are sufficiently active enjoy better physical health (U.S. Department of Health and Human Services, 2000), report more positive physical self-concept and global self-esteem (Dishman et al., 2006), perceive a better quality of life (Shoup et al., 2008), and achieve higher academic results (Singh et al., 2012). Unfortunately, the physical activity (PA) levels of many children and adolescents are currently insufficient to promote these benefits (Crawford, 2009; Hardy et al., 2010; Sallis, 2000; U.S. Department of Health and Human Services, 2000).

In response to this evidence, the importance of schools in PA promotion has been highlighted (Cox et al., 2010; Pate et al., 2006; Salmon et al., 2007; Timperio et al., 2004; van Sluijs et al., 2007), and the central role of physical education (PE) programs in this effort has been emphasized. PE classes encompass virtually all members of an age cohort; therefore, quality PE could have far-reaching health implications for nearly all youth (Crawford, 2009). Unfortunately, students' MVPA levels in PE lessons are often very low (Fairclough and Stratton, 2005b, 2006). Indeed, the proportion of lesson time during which students are engaged in MVPA is typically less, and often far less, than the 50% target that was proposed by the U.S. Department of Health and Human Services (2000) and the UK's Association for Physical Education (2008). As a result, these lessons may provide insufficient MVPA for students to benefit.

School-based interventions can promote MVPA in youth (Dudley et al., 2011; Kriemler et al., 2011) and increasing active learning time in PE (i.e., the proportion of PE lesson time students spend in MVPA) has been a component of many of these interventions. However, to our knowledge, no systematic review has been completed to determine the effect of interventions aimed at increasing active learning during PE lessons. Fairclough and Stratton (2005b) completed a narrative review on the topic. Other systematic reviews were not focused specifically on interventions designed to increase MVPA during PE. Instead, these reviews have examined: (a) the effect of school-based interventions on total daily MVPA (Dobbins et al., 2009); or (b) a mixture of interventions designed to increase total daily MVPA and those specifically designed to increase MVPA during PE lessons (Dudley et al., 2011). Also, to our knowledge, no meta-analysis of PE-focused interventions has been conducted. As a result, the effectiveness of interventions on MVPA in PE has not been determined.

Table 1
Study design and sample characteristics.

Citation	Study design (country)	Schools (n)	Intervention sample size (n)	Control sample size (n)	Data unit represents	Total students in intervention	Total students in control	Year level	Gender
Fairclough and Stratton (2005a)	Cluster RCT (UK)	1	12 (Heart rate monitor data)	14 (Heart rate monitor data)	Students	15	18	7	Girls
Fairclough and Stratton (2005a)	Cluster RCT (UK)	1	5 (SOFIT data)	5 (SOFIT data)	Lessons	15	18	7	Girls
Ignico et al. (2006)	Cluster RCT (USA)	1	68	18	Students	68	18	5[a]	Both (54% boys)
McKenzie et al. (1996)	Cluster RCT (USA)	96	648[a]	400[a]	Lessons	5352	3743	3	Both (52% boys)
McKenzie et al. (2004)	Cluster RCT (USA)	24	351	360	Lessons	12,500[a]	12,500[a]	6 to 8	Both (% not indicated)
Quinn and Strand (1995)	Cluster RCT (USA)	1	29	31	Students	29	31	7	Boys
Rowlands et al. (2008)	Cross-over design (UK)	1	45	[b]	Students	45	45	5	Both (56% girls)
Sallis et al. (1997)	Cluster RCT (USA)	7	70	33	Classes	1045[a]	493[a]	4	Both (53% boys)
Scantling and Dugdale (1998)	Cluster RCT (USA)	1	21	22	Students	21	22	9	Girls
Simons-Morton et al. (1991)	Cluster RCT (USA)	4	96	73	[c]	96[c]	73[c]	3 to 4	Not reported
Strand and Anderson (1996)	Cluster RCT (USA)	1	30	30	Students	30	30	7	Boys
van Beurden et al. (2003)	Quasi-experiment (Australia)	18	117[a]	117[a]	Lessons	523[a]	523[a]	3 to 4	Both (53% boys)
Verstraete et al. (2007)	Cluster RCT (Belgium)	16	190 (Accelerometer data)	190 (Accelerometer data)	Students	399	365	4 to 5	Both (50% boys)
Verstraete et al. (2007)	Cluster RCT (Belgium)	16	19 (SOFIT data)	19 (SOFIT data)	Lessons	399	365	4 to 5	Both (50% boys)
Webber et al. (2008)	Cluster RCT (USA)	36	215[a]	215[a]	Lessons	1080[a]	1080[a]	6 to 8	Girls
Young et al. (2006)	RCT (USA)	1	40	41	Lessons	116	105	9	Girls

Note: RCT = Randomized Controlled Trial and SOFIT = System for Observing Fitness Instruction Time.
[a] Estimated value.
[b] Participants served as their own controls.
[c] Unclear value.

Table 2
Intervention and control condition descriptions.

Citation	Intervention type (activities involved)	Intervention description (duration of intervention)	Theoretical basis for intervention	Control description
Fairclough and Stratton (2005a)	Teaching strategies (gymnastics)	The teacher was made aware of study aim (to improve students' MVPA). Suggested strategies were: (1) organization of groups and use of space, equipment and resources; (2) teaching approaches; (3) lesson pace; (4) teacher positioning; (5) active learning; and (6) having fun. (5 weeks)	None stated	Same lesson content, but no emphasis on increasing MVPA.
Ignico et al. (2006)	Fitness infusion (various)	Fitness infusion: Skill development with short bouts of MVPA between practice attempts. (24 weeks)	None stated	Traditional skill development.
McKenzie et al. (1996)	Teaching strategies (various)	CATCH: Goal to provide MVPA during enjoyable PE lessons. Intervention included: (a) CATCH PE curriculum and materials; (b) teacher training; and (c) on-site consultation with teachers. (130 weeks)	Social Learning Theory	Usual practice. Schools agreed to provide a minimum of 90 min of PE, spread over 3 sessions per week.
McKenzie et al. (2004)	Teaching strategies (various)	M-SPAN: Professional development sessions for teachers. Sessions designed to create awareness, assist teachers to promote MVPA through modified curricula, improved curricula, and enhanced management and instructional skills. (104 weeks)	Social Learning Theory, Ecological Theory[a]	Usual practice.
Quinn and Strand (1995)	Fitness infusion (American football)	Fitness Skill Play Integration Model: Time for skill development and game play was reduced to allow for an aerobic fitness component in the last 10 min of lesson. (4 weeks)	None stated	Skill development and game play continued for entire lesson.
Rowlands et al. (2008)	Other (dance and soccer)	Motiv8: Instructors from an external agency taught PE lessons with goals of 20 min moderate and 10 min vigorous activity during lesson. (1 week)	None stated	Lessons taught by specialist PE teacher employed by school.
Sallis et al. (1997)	Teaching strategies (various)	SPARK: PE classes designed to promote high levels of physical activity, teach movement skills and be enjoyable. Schools were recommended to schedule three 30 minute PE lessons each week. (104 weeks)	Social Learning Theory	Schools provided with equipment only
Scantling and Dugdale (1998)	Fitness infusion (badminton)	Fitness Skill Play Integration Model: Fitness activities during attendance taking place at start off class, followed by skill development and game play, 10-minute aerobic fitness component in the last 10 min of lesson. (4 weeks)	None stated	Attendance followed by skill development game play for remainder of class.
Simons-Morton et al. (1991)	Teaching strategies (various)	CAPE: 5 × 6-to-8-week units designed to encourage MVPA. Each unit included cardiovascular fitness activities such as dancing, running, aerobic games, jump rope and obstacle courses. (35 weeks)	Social Cognitive Theory	Usual practice.
Strand and Anderson (1996)	Fitness infusion (American football)	Fitness Skill Play Integration Model: Time for skill development and game play was reduced to allow for an aerobic fitness component in the last 10 min of lesson. (4 weeks)	None stated	Skill development and game play continued for entire lesson.
van Beurden et al. (2003)	Teaching strategies (various)	Move It Groove It: Intervention focused on supporting teachers and creating supportive environments and healthy school policies. Buddy system used to improve PE teaching and increase PA levels and fundamental movement skills mastery by matching pre-service teachers with generalist classroom teachers. (22 weeks)	None stated	Usual practice.
Verstraete et al. (2007)	Teaching strategies (various)	Portions of SPARK intervention: Guidelines to provide health-related physical education and increase MVPA during lessons, including organization, management and instruction tips. (78 weeks)	Based on SPARK intervention	Usual practice.
Webber et al. (2008)	Teaching strategies (various)	TAAG: PE-specific portions of the intervention included class management strategies, skill-building activities, emphasis on the importance of engaging girls in MVPA during class, and the provision of appropriate equipment and choices of physical activity. (104 weeks)	Operant Learning Theory, Social Cognitive Theory, Organizational Change Theory, and the Diffusion of Innovation Model in a Social–Ecologic Framework	Usual practice.

Table 2 (*continued*)

Citation	Intervention type (activities involved)	Intervention description (duration of intervention)	Theoretical basis for intervention	Control description
Young et al. (2006)	Teaching strategies (various)	MVPA during PE was promoted by teaching topics that were active in nature (e.g., soccer vs. softball), breaking skills training into small-group activities, and playing games in small groups. Skills training was limited to that needed for competency, rather than proficiency. (35 weeks)	None stated for this aspect of intervention.	Usual practice.

Note: MVPA = Moderate-to-Vigorous Physical Activity and SOFIT = System for Observing Fitness Instruction Time.
[a] Personal communication from T. McKenzie on June 30th, 2012.

Objectives

Our aim was to systematically review the evidence related to interventions designed to increase active learning time during school PE lessons. Our objectives were to: (a) describe the nature of the interventions that have been undertaken (i.e., the theories, strategies, or approaches researchers have used to design their interventions); and (b) conduct meta-analyses to determine the effectiveness of these interventions.

Methods

Eligibility criteria

Included studies sampled students from PE classes in primary schools (i.e., elementary) or secondary schools (i.e., high school). Pre-school or post-secondary institution samples were excluded.

Studies must have tested an intervention, namely a deliberate attempt to implement a change to usual teaching practice in order to increase the proportion of PE lesson time spent in MVPA. Studies focusing on a comparison of conditions, but not an intervention, were excluded. For example, a study comparing active learning time during ball games (e.g., soccer) versus net sports (e.g., badminton) would not have been included, because both types of activities are considered part of usual practice in PE.

We included studies employing experimental (e.g., randomized controlled trials and cross-over designs) and quasi-experimental methods. Cross-sectional and cohort designs were excluded. No limitations were set regarding the duration of the intervention or the follow-up period.

Studies needed to include a measure of the proportion of PE lesson time spent in MVPA. This measure could be objective (e.g., accelerometer) or involve systematic direct observation by an independent rater (e.g., SOFIT; System for Observing Fitness Instruction Time) (McKenzie, 2009). We included English-language, peer-reviewed articles (not abstracts) that reported primary data and had been published online or in print by March 24, 2012. We set no limits on the earliest publication date.

Information sources

We searched four databases, including: Scopus, SPORTDiscus, PubMed, and PsycINFO. From these searches, we identified review articles and examined their reference lists for primary sources that met our inclusion criteria. We also inspected the reference lists of all included primary source articles.

Search

Our Scopus search terms and strategy are detailed below. We employed the same key words in our searches of the other three databases.

((TITLE-ABS-KEY("Physical activit*" OR "active learning" OR movement OR exercise OR fitness OR "motor activity" OR "activity level*")) AND (TITLE-ABS-KEY("Physical education" OR PE OR P.E.)) AND (TITLE-ABS-KEY(Intervention OR experiment OR Training OR compar* OR Contrast* OR Condition)) AND (TITLE-ABS-KEY(Student* OR pupil OR learner OR child* OR adolesc* OR school*))) AND (LIMIT-TO(LANGUAGE,"English")) AND (LIMIT-TO(SRCTYPE,"j")).

Study selection

After exporting records into Endnote reference manager software and deleting duplicate records, we removed studies whose title clearly indicated the study did not meet the inclusion criteria. Next, we read abstracts from the remaining studies and excluded those that did not meet our inclusion criteria. Finally, two researchers (CL and DL) independently read the full version of the remaining articles and recommended each for inclusion or exclusion, recording the specific criterion not fulfilled for studies recommended for exclusion. When a criterion was not fulfilled, the article was not considered any further. The order in which criteria were considered was as follows:

1. Duplicate data from another article
2. No objective or observational measure of MVPA
3. No proportion of time in MVPA reported (or data from which proportions could be calculated)
4. Incorrect age (non-primary/secondary school sample)
5. No intervention designed to increase MVPA compared with a control (e.g., usual practice condition)
6. Not a full-text peer-reviewed article containing primary data
7. Other

Disagreements regarding criteria fulfillment were resolved by discussion between the two researchers.

Data collection process

Two members of the research team independently extracted data from each article. Data items included characteristics of study design and sampling (Table 1), intervention delivery (Table 2), outcome measure used to estimate the proportion of lesson time spent in MVPA, duration of follow-up, and the mean (and SD) proportion of lesson time spent in MVPA in the intervention and control conditions. Following extraction, any non-identical data were discussed and points of difference resolved.

When data required for meta-analysis were not presented (e.g., standard deviations not reported), these were estimated, where possible, based on calculations and/or assumptions possible from the information provided in the report. A biostatistician (PF) made all estimations, consistent with procedures outlined by the Cochrane Collaboration (Higgins and Green, 2011).

Risk of bias of individual studies

We assessed risk of bias for each study using criteria adapted from van Sluijs et al. (2007). These criteria aligned with standards outlined in the Consolidated Standards of Reporting Trials (CONSORT) statement (Schulz et al., 2010). A 'risk of bias' score for each study was calculated on an eight-point scale after two researchers (CL and DL) independently assigned a value of 0 (absent or inadequately described) or 1 (present and explicitly described) to each of the following questions:

1. Were groups comparable at baseline on key characteristics (positive if baseline characteristics were presented for the proportion of MVPA during PE class, plus one other demographic detail, such as age or gender)?
2. Were baseline values accounted for in the analyses?
3. Were randomization procedures clearly described and adequately carried out (e.g., random number generating algorithm)?
4. Did the authors report a power calculation, and was the study adequately powered to detect MVPA changes during PE lessons?

5. Did the study include measures of MVPA known to produce reliable and valid scores (positive if reliability and validity evidence was reported or referred to in the article)?
6. Were participant dropout rates described, and not more than 20% for studies with follow-up of six months or shorter, and 30% for studies with follow-up of more than six months?
7. Was timing of measurements comparable between intervention and control conditions?
8. Were outcome assessments blinded (positive if those responsible for assessing MVPA blinded to allocation)?

Studies with a score of zero to two were considered to have a high risk of bias. Studies with scores of three to five and six to eight were considered to have moderate and low risk of bias, respectively.

Summary measures and synthesis of results

Difference of means (proportion of lesson time spent in MVPA) between the intervention and control conditions at follow-up was the summary measure. We conducted the meta-analyses in Stata Version 12 (StataCorp LP, 2011). This included an overall analysis to determine the effectiveness of interventions generally, as well as sub-group analyses to determine the effectiveness of different types of interventions. We also conducted sub-group analyses to investigate the effects of age, gender, and intervention duration. For each analysis, a forest plot of between-group differences in the proportion of lesson time spent in MVPA was generated, and an I^2 consistency statistic was calculated. This statistic provides an indication of the extent to which results are consistent across trials. I^2 values of .25, .50, and .75 were considered low, moderate, and high, respectively (Higgins et al., 2003).

Risk of bias across studies

We examined a funnel plot to assess risk of publication bias (Egger et al., 1997). If smaller studies were found to have larger effects, there would be evidence that publication bias was present in the meta-analysis.

Results

Study selection

Study selection results are detailed in Fig. 1. From an initial pool of 12,124 non-duplicate records, screening of titles and abstracts lead to 109 full-text articles read. From these, 14 articles met the inclusion criteria.

Study characteristics

Study characteristics can be viewed in Table 1. Publication dates ranged from 1991 to 2008. Ten studies were conducted in the USA, two in the UK, one in Belgium and one in Australia. The number of schools involved in each study ranged from n = 1 (in seven studies) to n = 96 (McKenzie et al., 1996).

Eleven studies employed a cluster randomized controlled design, with randomization occurring at the school or class level. Other studies included a cross-over design (Rowlands et al., 2008), a quasi-experimental design (Van Beurden et al., 2003) and a randomized controlled trial with treatment group allocation at the student level (Young et al., 2006).

The number of participants in the intervention conditions ranged from n = 15 (Fairclough and Stratton, 2005a) to n = 12,500 (McKenzie et al., 2004), with a median of n = 106. Control condition samples ranged from n = 18 (Fairclough and Stratton, 2005a; Ignico et al., 2006) to n = 12,500 (McKenzie et al., 2004), with a median of n = 89. In some studies, not all participants provided MVPA data. Full details regarding sample size can be viewed in Table 1.

Seven interventions were conducted during primary school years (i.e., elementary school grades 3–5), while five were implemented in grades 6–8. Two interventions were tested in grade 9 students (i.e., secondary/high school) (Scantling and Dugdale, 1998; Young et al., 2006).

Half of the studies were conducted with a mixture of boys and girls, and the gender distribution in these studies was generally equal (range = 46%–56% girls). Two studies were conducted exclusively with boys (Quinn and Strand, 1995; Strand and Anderson, 1996), while four studies focused on girls only (Fairclough and Stratton, 2005a; Scantling and Dugdale, 1998; Webber et al., 2008; Young et al., 2006).

Complete details regarding intervention and control conditions can be viewed in Table 2. We identified two main types of interventions: (a) 'teaching strategies' with an MVPA focus (n = 9 studies), in which teachers learned strategies to encourage MVPA through effective activity selection, class organization and management, and instruction; and (b) 'fitness infusion' (n = 4 studies), in which teachers supplemented students' participation in sport activities (e.g., basketball) with vigorous fitness activities (e.g., running, jumping). One study (Rowlands et al., 2008) did not provide enough information to determine the nature of the intervention. In all studies, the control condition involved usual practice teaching.

Risk of bias within individual studies

Complete results of risk of bias assessments can be viewed in Table 3. There was 98.2% agreement on risk of bias ratings (110 of 112 items) and raters reached agreement on these two discrepant items after discussion. Five studies were rated as having high risk of bias. Eight studies had moderate risk, while one study had low risk of bias (Webber et al., 2008).

Outcome measures

As shown in Table 4, two studies used accelerometers to measure the proportion of lesson time spent in MVPA (Rowlands et al., 2008; Verstraete et al., 2007). Heart rate monitors were employed in five studies. Nine studies included direct observation methods. Verstraete et al. (2007) simultaneously employed SOFIT and accelerometry, while Fairclough and Stratton (2005a) measured MVPA using SOFIT and heart rate monitors.

Ten of the 14 studies included baseline MVPA data collection. In these investigations, follow-up assessments were conducted one to 156 weeks later, with eight studies involving assessments completed at least 35 weeks after baseline.

Qualitative synthesis

All data related to the proportion of lesson time spent in MVPA can be viewed in Table 4. Five studies included analyses that accounted for baseline MVPA levels (see Table 3 for details), while others only involved comparisons at follow-up. As a result, significance levels and effect sizes are not directly comparable. In some studies, a significant finding indicated a between-group difference in the change in the proportion of lesson spent in MVPA (e.g., Verstraete et al., 2007). In other studies, a significant finding indicated a between-group difference at follow-up only (e.g., Scantling and Dugdale, 1998).

All studies found a higher proportion of active learning time in the intervention group compared with the control group. In 10 of the 12 studies that employed a single measurement instrument, the difference was statistically significant ($p < .05$). Among studies that employed two measures of MVPA, Verstraete et al. (2007) reported a significant effect only on the SOFIT measure of MVPA ($p < .001$), while in Fairclough and Stratton's (2005a) study, both heart rate monitor ($p = .008$) and SOFIT ($p < .05$) scores favored the intervention condition.

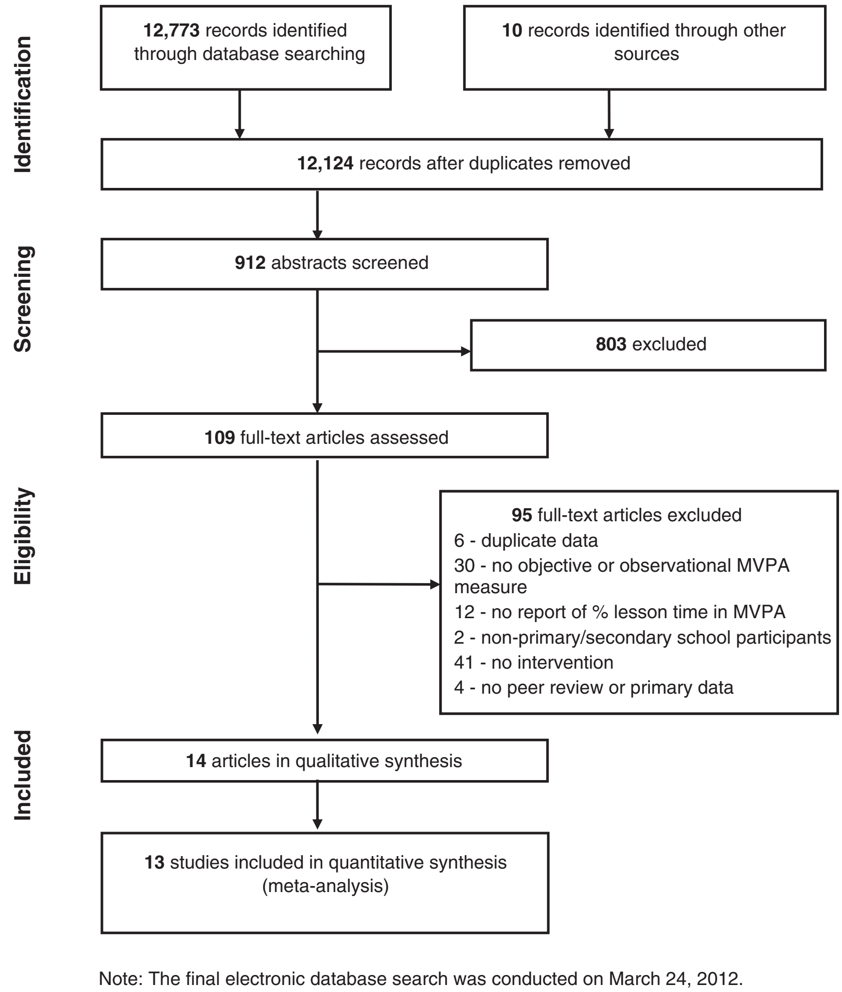

Fig. 1. Flow diagram.

Quantitative synthesis

We conducted meta-analyses on data extracted from 13 of the 14 studies (see Fig. 2). Data from one study (Simons-Morton et al., 1991) could not be included because most results were presented graphically and accurate estimates of results could not be made. For studies in which two measures of MVPA were obtained (SOFIT plus an objective measurement device) (Fairclough and Stratton,

Table 3
Risk of bias results for included studies.

Citation	1. Baseline comparable	2. Baseline in analysis	3. Random assignment	4. Power	5. Valid assessment	6. Dropout	7. Timing	8. Blind	9. Total
Fairclough and Stratton (2005a)	1	1	0	0	1	0	0	0	3
Ignico et al. (2006)	0	0	0	0	1	0	1	0	2
McKenzie et al. (1996)	1	1	0	0	1	1	1	0	5
McKenzie et al. (2004)	1	0	0	0	1	1	1	0	4
Quinn and Strand (1995)	0	0	0	0	1	0	1	0	2
Rowlands et al. (2008)	0	0	0	0	1	0	1	0	2
Sallis et al. (1997)	1	0	0	0	1	1	1	0	4
Scantling and Dugdale (1998)	1	0	0	0	1	0	1	0	3
Simons-Morton et al. (1991)	0	0	0	0	1	1	1	0	3
Strand and Anderson (1996)	0	0	0	0	1	0	1	0	2
van Beurden et al. (2003)	0	1	0	0	1	0	0	0	2
Verstraete et al. (2007)	1	1	0	0	1	1	1	0	5
Webber et al. (2008)	1	0	0	1	1	1	1	1	6
Young et al. (2006)	1	1	0	0	1	1	1	0	5

Note: 1. Were groups comparable at baseline on key characteristics (positive if baseline characteristics were presented for the proportion of MVPA during PE class, plus one other demographic detail, such as age or gender)? 2. Were baseline values accounted for in the analyses? 3. Were randomization procedures clearly described and adequately carried out (e.g., random number generating algorithm)? 4. Did the authors report a power calculation, and was the study adequately powered to detect MVPA changes during PE lessons? 5. Did the study include measures of physical activity known to produce reliable and valid scores (positive if reliability and validity evidence was reported or referred to in the study)? 6. Were participant dropout rates described, and not more than 20% for studies with follow-up of six months or shorter, and 30% for studies with follow-up of more than six months? 7. Was timing of measurements comparable between intervention and control conditions? 8. Were outcome assessments blinded (positive if those responsible for assessing MVPA were blinded to allocation)? 9. Total Risk of Bias Score (0–2 = high risk of bias, 3–5 = moderate risk of bias, 6–8 = low risk of bias).

Table 4
Intervention results relating to the proportion of lesson time spent in MVPA.

Citation	Type of intervention	Outcome measure (data level)	Criterion for MVPA	Follow-up period after baseline	Type of analysis reported (p-value)	Proportion of Lesson time in MVPA at follow-up	
						Intervention mean % (SD) (n)	Control mean % (SD) (n)
Fairclough and Stratton (2005a)	Teaching strategies	Heart rate monitor (student)	≥50% of estimated heart rate reserve	5 weeks	ANCOVA (0.008)	40.8 (17.2) (n = 12)	28.9 (21.8) (n = 14)
Fairclough and Stratton (2005a)		SOFIT (lesson)	≥Walking	5 weeks	*t*-Test (0.047)	18.5 (4.2) (n = 5)	13.5 (2.2) (n = 5)
Ignico et al. (2006)	Fitness infusion	Heart rate monitor (student)	≥150 bpm	No baseline measure	ANOVA (<0.001)	54.4 (10.7) (n = 68)	24.3 (10.7) (n = 18)
McKenzie et al. (1996)	Teaching strategies	SOFIT (lesson)	≥Walking	52 weeks	Mixed-model ANOVA (0.0016)	51.9 (32.7) (n = 648)	42.3 (30.0) (n = 400)
McKenzie et al. (2004)	Teaching strategies	SOFIT (lesson)	≥Walking	52 weeks	Randomized regression models (0.02)	53.2 (9.2) (n = 351)	48.6 (6) (n = 360)
Quinn and Strand (1995)	Fitness infusion	Heart rate monitor (student)	≥156 bpm	No baseline measure	*t*-Test (<0.05)	49.6 (17.4) (n = 29)	34.2 (18.6) (n = 31)
Rowlands et al. (2008)	Other	Accelerometer (student)	≥192 cpm	1 week	ANOVA (<0.05)	47.4 (12.7) (n = 19)	35.0 (14.1) (n = 19)
Sallis et al. (1997)	Teaching strategies	SOFIT (lesson)	≥Walking	104 weeks	ANOVA (<0.001)	50.5 (15.3) (n = 70)	46.8 (35.1) (n = 33)
Scantling and Dugdale (1998)	Fitness infusion	Heart rate monitor (student)	≥155 bpm	No baseline measure	*t*-Test (<0.001)	14.8 (12.2) (n = 21)	0.6 (0.9) (n = 22)
Simons-Morton et al. (1991)	Teaching strategies	Children's physical activity observation form (student)	Unclear	104 weeks	Confidence intervals as graphs	36.2[a] (.04)[a] (n = 96)	7.6[a] (9.0)[a] (n = 73)
Strand and Anderson (1996)	Fitness infusion	Heart rate monitor (student)	≥156 bpm	No baseline measure	*t*-Test (>0.05)	42.1 (18.9) (n = 30)	39.0 (19.9) (n = 30)
van Beurden et al. (2003)	Teaching strategies	SOFIT (lesson)	≥Walking	78 weeks	Hierarchical logistic regression (0.09)	39.2 (25.9) (n = 117)	34.7 (25.9) (n = 117)
Verstraete et al. (2007)	Teaching strategies	Accelerometer (student)	≥3 METs	85 weeks	Linear mixed models (0.39)	67.0 (12.58) (n = 190)	60.5 (19.27) (n = 190)
Verstraete et al. (2007)	Teaching strategies	SOFIT (lesson)	≥Walking	85 weeks	Linear mixed models (0.001)	56.3 (9.2) (n = 19)	41.5 (8.5) (n = 19)
Webber et al. (2008)	Teaching strategies	SOFIT (lesson)	≥Walking	104 weeks	Mixed-model regression (0.025)	42.2 (29.1) (n = 215)	38.3 (29.1) (n = 215)
Young et al. (2006)	Teaching strategies	SOFIT (lesson)	≥Walking	35 weeks	ANCOVA (<0.001)	46.9 (23.9) (n = 40)	30.5 (23.9) (n = 41)

Note: MVPA = Moderate-to-Vigorous Physical Activity and SOFIT = System for Observing Fitness Instruction Time.
[a] Estimated value.

2005a; Verstraete et al., 2007), we included data from the objective measurement device only.

The meta-analysis indicated an absolute difference of 10.37% (95% CI = 6.33%–14.41%) of lesson time spent in MVPA in favor of the interventions over controls. The weighted mean across the control groups was 43.45% of lesson time in MVPA. The estimated difference of 10.37% of lesson time corresponds to 24% more active learning time in the intervention groups compared with the control condition (standardized mean difference = 0.62, 95% CI = 0.39–0.84). However, it must be noted that there was a high degree of heterogeneity in the results across the 13 studies ($I^2 = 86.7\%$, $p < .001$).

We also conducted subgroup analyses to determine the effectiveness of interventions based on: (1) 'teaching strategies' ($k = 8$); (2) 'fitness infusion strategies' ($k = 4$); and (3) one 'other' study whose intervention content was not clearly described (Rowlands et al., 2008). Students in the teaching strategies intervention condition were more active than controls (absolute difference = 6.27%, 95% CI = 4.15%–8.40%, standardized mean difference = 0.35, 95% CI = 0.20–0.50). Heterogeneity in the results was low to moderate across these eight studies ($I^2 = 40.3\%$, $p = .11$). The weighted mean of the control groups was 44.54% of lesson time spent in MVPA and, on average, the students in intervention condition spent 14% more lesson time in MVPA relative to controls. Students in the fitness infusion intervention condition spent more time in MVPA compared with controls (absolute difference = 16.15%, 95% CI = 5.25%–27.05%, standardized mean difference = 1.35, 95% CI = 0.25–2.45). Heterogeneity in the results of these four studies was high ($I^2 = 92.8\%$, $p < .001$). The weighted mean MVPA in the control groups was 26.55%, suggesting 61% more time spent in MVPA in the intervention condition relative to controls.

Finally, we conducted sub-group analyses to investigate the effects of age, gender, and intervention duration. However, none of these factors appeared to moderate intervention effects. For complete details of these analyses (including forest plots), contact the first author.

Risk of bias across studies

Examination of the funnel plot (Fig. 3) revealed no evidence of publication bias in the meta-analysis.

Discussion

Summary of evidence

The aim of our study was to systematically review the evidence related to interventions designed to increase students' MVPA within PE lessons. Overall, interventions were associated with 24% more active learning time compared with usual practice (10% more of total lesson time spent in MVPA). Effective intervention strategies included teacher professional learning focusing on class organization, management and instruction, and supplementing usual PE lessons with high-intensity activity (i.e., fitness infusion). There was considerable heterogeneity in

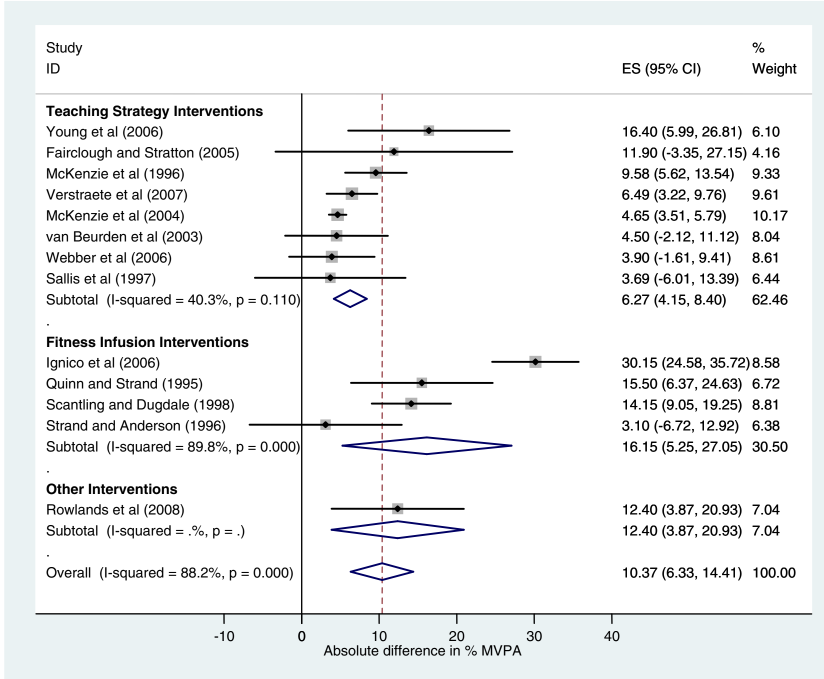

Fig. 2. Forest plot.

terms of study design, duration, and sample size. Therefore, our findings should be interpreted with caution. Since there are so few studies, yet their results are generally positive, there is a need and opportunity to evaluate the effects of interventions to increase active learning time in high-quality cluster randomized controlled trials.

The public health implications of these findings are substantial. For example, in California, where state law mandates that students in Grades 1–6 receive 200 min of PE every 10 days, spending 20 min extra of lesson time in MVPA every 10 days (10% of total lesson time) would represent an additional 6.7 h of MVPA across a 40-week school year. These benefits would be further amplified in schools that devote greater lesson time to PE. For example, a recent high-quality primary school obesity prevention intervention involving 45 min of *daily* PE significantly increased children's within-school physical activity by 11 min/day (Kriemler et al., 2010). However, the intervention did not specifically target improvements in active learning time in PE lessons. By including strategies to maximize MVPA within PE lessons, the benefits of these types of school-based interventions may be further increased. Considering the physical activity decline typically observed during adolescence (Nader et al., 2008) and the challenges faced by parents and teachers attempting to increase children's physical activity outside of the school setting (e.g., lack of access to facilities, unsafe neighborhoods, and attractive sedentary alternatives), increasing active learning time in PE should be a public health priority.

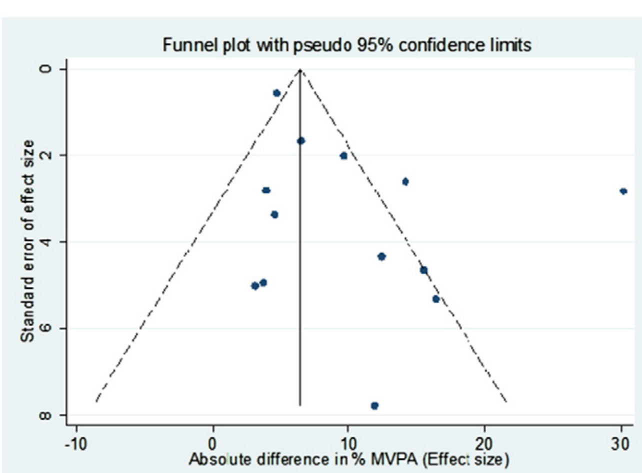

Fig. 3. Funnel plot.

Not surprisingly, the fitness infusion interventions (Ignico et al., 2006; Quinn and Strand, 1995; Scantling and Dugdale, 1998; Strand and Anderson, 1996) were more effective in increasing MVPA than the teaching strategies interventions. Fitness infusion typically involves teachers incorporating high-intensity activity (e.g., jumping, running on the spot, star jumps) into usual PE lessons. This is an appealing strategy for increasing active learning time because it requires minimal organization and creativity from teachers. Unfortunately, the long-term sustainability of this type of intervention is unknown, as fitness infusion intervention studies included in our review only measured MVPA during lessons that took place during the intervention (i.e., no follow-up). In contrast, interventions that include teacher professional learning to improve lesson preparation and management appear to have potential long-term benefits for teachers and students (McKenzie et al., 2004). As such, the lack of focus on teacher professional learning in many school-based PA interventions (Kriemler et al., 2011) is surprising, considering the importance placed on professional learning in the general education literature (Avalos, 2011).

Less than half of the studies included in our review cited a relevant theoretical framework to explain students' behavior. Notable exceptions were the CATCH (McKenzie et al., 1996) and SPARK (Sallis et al., 1997) interventions, which were guided by Social Learning Theory (Bandura, 1977) and M-SPAN, which was also underpinned by Ecological Theory (Bronfenbrenner, 1979). Evidence suggests that interventions developed in reference to a theory of behavior change (e.g., Theory of Planned Behavior, Social Cognitive Theory, Transtheoretical Model) and that target the hypothesized mediators of behavior change are more successful in changing behavior than atheoretical ones (Lubans et al., 2008; Michie and Abraham, 2004). In addition to the above-mentioned theories, researchers seeking to increase active learning time in PE may also wish to consider motivational theories that have proved useful in explaining students' behavior, cognition, and affect (e.g., emotion) in

PE. In particular, Self-Determination Theory (Deci and Ryan, 1985; Deci et al., 1991) and Achievement Goal Theory (Ames and Archer, 1988; Duda, 1996; Nicholls, 1989) have been employed to explain how the 'motivational climate' created by the PE teacher can influence students' experiences in PE. According to these theories, motivational climates that emphasize effort and personal improvement and provide students with opportunities to demonstrate leadership and make decisions (e.g., select task difficulty, timing, and the composition of groups) have a positive impact on PE students' outcomes, including self-reported effort during lessons (Taylor and Lonsdale, 2010). However, to our knowledge, no study has investigated the impact of an intervention based on Self-Determination Theory or Achievement Goal Theory on students' active learning time during lessons. Interventions that enhance motivation towards PE and increase student MVPA during lessons may also increase their leisure time activity (Chatzisarantis and Hagger, 2008) and (Cheon et al., 2012).

Physical education is a valuable source of physical activity for children and adolescents (Tudor-Locke et al., 2006), but perhaps its most important role is to provide students with the knowledge, skills, abilities, and confidence to be active both now and throughout their lifetime (Sallis et al., 2012; Sanchez-Vaznaugh et al., 2012). Indeed, a PE teacher could achieve 100% MVPA in their PE lessons by making students run around a field for the duration of the lesson. While this approach may assist students in meeting their daily PA requirements, it is unlikely that this type of lesson will engage students and prepare them for a lifetime of physical activity. Importantly, PE provides children with opportunities to develop competence in a range of fundamental and specialized movement skills that are necessary for participation in various games and sports (Lubans et al., 2010). Skill mastery requires quality instruction, relevant feedback, and opportunity to practice (Gallahue and Ozmun, 2006). Furthermore, PE is an appropriate setting for learning self-management strategies (e.g., goal setting, self-assessment, and monitoring), as well as the rules, tactics and objectives of various games. For these reasons, high levels of active learning time need to be balanced with opportunities for instruction, feedback, and reflection.

Strengths and limitations

This is the first systematic review and meta-analysis of interventions designed to increase MVPA within PE lessons. The design and reporting of this review were guided by the PRISMA statement (Liberati et al., 2009) and studies were assessed for risk of bias using criteria adapted from the CONSORT statement (Schulz et al., 2010). Despite these strengths, there are some limitations that should be noted. First, only 14 studies met our inclusion criteria. Despite the multitude of school-based physical activity interventions (Kriemler et al., 2011), few have reported their effects on the proportion of PE lessons spent in MVPA. As a result, it was not possible to meaningfully test the potential effects of all confounding factors. For example, studies in this review included a variety of measurement tools to assess MVPA (e.g., SOFIT, accelerometers, and heart rate monitors). While these measures produce MVPA estimates that are correlated with each other (McKenzie et al., 1994) and have been validated against criterion measures (Rowe et al., 1997; Sun et al., 2008), evidence suggests that different measures will produce different estimates (McClain et al., 2008) and it is possible that different measures could be more or less sensitive to change in MVPA. As additional studies emerge, it will be important to update this review and account for potential confounding factors in meta-analyses.

Importantly, the risk of bias was moderate or high in all but one of the studies included in our review (Webber et al., 2008). An additional concern with many studies in this review was the lack of intervention fidelity assessment. As a result, the internal validity of these studies is somewhat difficult to discern. Also, there was a lack of clarity concerning the extent to which the intervention impacted on theoretical mediators of behavior change. This omission limits identification of the effective components of the intervention, as well as those aspects that might be improved in the future. Finally, most of the studies were cluster randomized controlled trials, but few adjusted for the clustered nature of the data. Due to the considerable intra-class correlation coefficients typically observed in school-based studies, a large number of schools and observations are often required to assess the intervention effects with adequate statistical power.

Conclusions

Schools are ideal settings for the promotion of physical activity among youth, and PE is the primary vehicle associated with this objective in schools (Centers for Disease Control and Prevention, 2011; Sallis et al., 2012). Our review suggests that PE-based interventions can increase students' MVPA during lessons by about 24% compared with usual practice, and this increase could have a substantial positive influence on the total amount of physical activity children and adolescents accumulate. Professional learning focused on teacher pedagogy and behavior offers considerable potential for increasing physical activity in youth.

Based on our review, we offer the following recommendations. First, there is a need for additional adequately powered cluster randomized controlled trials to determine the most effective strategies and theoretical frameworks for increasing MVPA in PE. Importantly, these interventions should target and assess effects on hypothesized psycho-social mediators. Second, more transparent reporting of intervention strategies, including details of professional learning for teachers, is needed. Student activity levels in PE are likely dependent upon teacher behavior and there is a need to improve our understanding of how to improve teacher practice. Third, consistency in physical activity assessment (e.g., type of accelerometer and cut-points used) will allow for more meaningful comparisons of intervention effects across studies. In summary, the existing evidence indicates that interventions can increase the proportion of PE lesson time students spend in MVPA, but higher quality trials are needed to determine how best to promote MVPA in PE lessons, and to determine the most effective and sustainable intervention strategies.

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Conflict of interest statement

The authors declare no conflict of interest associated with this study.

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