Physically active lessons as physical activity and educational interventions: A systematic review of methods and results

Norris, E[a,*]., Shelton, N[a.,] Dunsmuir, S[b]., Duke-Williams, O[c]., Stamatakis, E[a,d].

[a]Department of Epidemiology & Public Health, University College London, 1-19 Torrington Place, London, WC1E 7HB, UK

[b]Department of Clinical, Educational and Health Psychology, University College London, 26 Bedford Way, London, WC1H 0DS, UK

[c]Department of Information Studies, University College London, Foster Court, London, WC1E 6BT, UK

[d]Exercise & Sport Sciences, Faculty of Health Sciences, University of Sydney, Australia.

* Corresponding author Tel +44 20 7679 1704. Email address: e.norris.11@ucl.ac.uk

Word Count: 3923 (excluding references and in-text citations)

Physically active lessons as physical activity and educational interventions: A systematic review of methods and results

Abstract

Objective

Physically active lessons aim to increase children's physical activity (PA) whilst maintaining academic time. This systematic review aimed to investigate the methods used in such interventions and their effects on PA and educational outcomes.

Methods

In March 2014; PubMed, Web of Science, PsycINFO and ERIC electronic databases were searched. Inclusion criteria were: 1. Classroom lessons containing both PA and educational elements; 2. Intervention studies featuring a control group or within-subjects baseline measurement period; 3. Any age-group; 4. English language. Studies assessing physically active lessons within complex interventions were excluded. Data were extracted onto a standardised form. Risk of bias was assessed using the Effective Public Health Practice Project (EPHPP) tool.

Results

Eleven studies were identified: five examined PA outcomes only, three examined educational outcomes only and three examined both PA and educational outcomes. All studies found improved PA following physically active lessons: either in the whole intervention group or in specific demographics. Educational outcomes either significantly improved or were no different compared to inactive teaching. Studies ranged from low to high risk of bias.

Conclusions

Encouraging evidence of improved PA and educational outcomes following physically active lessons is provided. However, too few studies exist to draw firm conclusions. Future high-quality studies with longer intervention periods are warranted.

Introduction

Physical activity is associated with improved cardiovascular risk factors (Andersen et al., 2011; Cesa et al., 2014) and mental health in children (Biddle and Asare, 2011). However, the typical classroom is currently inherently sedentary, with obligatory seated lessons contributing greatly to the 7-8 hours a day spent sedentary in children (Esliger and Hall, 2009; Mantjes et al., 2012). Despite ever-increasing demands on teaching time and school space, no such rigid demands have been made for improved child physical activity (PA) levels (Weiler et al., 2013). National frameworks to secure time for physical education are currently absent in both the UK (Weiler et al., 2013) and USA (Slater et al., 2012).

There is evident efficacy for school-based physical activity interventions (Dobbins et al., 2013). School environments provide a unique opportunity to ensure physical activity in a maximum number of children over lengthy periods of time (Donnelly and Lambourne, 2011; Rasberry et al., 2011). A recent Cochrane review analysis found school-based interventions to significantly increase pupils' VO_2 max and their moderate and vigorous physical activity (MVPA) during school hours (Dobbins et al., 2013). However, authors noted that studies typically found small effects and featured moderate or high risk of bias: proposing a need for further research into school-based PA interventions (Dobbins et al., 2013). Although teachers may support physical activity interventions, insufficient time is often available to implement them with preference given to academic tasks (Erwin et al., 2012; Ward et al., 2006).

Physically active lessons are a novel teaching technique that introduces PA into the school learning environment (Centers for Disease Control and Prevention, 2010; Kibbe et al., 2011). These teacher-led sessions aim to incorporate physical activity into the teaching of academic content (Bartholomew and Jowers, 2011). Physically active lessons are hence distinct from 'activity-' or 'brain breaks' which facilitate bouts of classroom-based PA without educational features (Bartholomew and Jowers, 2011). The accumulation of short PA intervals during physically active lessons may be more feasible in helping reach recommended guidelines compared to extending recess or physical education (Barr-Anderson et al., 2011).

The combination of movement and learning via physically active lessons follows well-supported associations between physical activity and learning outcomes (Tomporowski et al., 2011). A significant positive relationship between physical activity and cognition in children has been identified in meta-analytic study, with significant effect sizes of 0.32 (Sibley and Etnier, 2003). Such findings align with the Executive Function Hypothesis: finding executive function tasks of goal-directed planning to be improved with physical activity (Best, 2010; Diamond and Lee, 2011; Tomporowski et al., 2011). Physically active lessons also follow the principals of Experiential

Learning theory: learning through action and experience as opposed to via rote (Kolb, 1984; Kolb et al., 2001).

Intervention studies have implemented physically active lessons into various school environments. However, a review of the effects of these programmes on physical activity and educational outcomes accompanied by detailed quality assessment is yet to be performed. It is important to assess the range of strategies used and results found in this relatively novel area. This systematic review aimed to: 1) assess the current methods used to measure i) physical activity and ii) educational outcomes in physically active lesson interventions, 2) assess observed effects of physically active lessons on i) physical activity and ii) educational outcomes and 3) evaluate the risk of bias in these identified interventions.

Methods

Search strategy & information sources

In March to April 2014, a systematic search for original research articles was conducted using ERIC, PubMed, PsycINFO and Web of Science electronic databases. Abstracts and titles were searched with three separate strings representing: 1) physical activity, 2) class or lesson and 3) children. Figure 1 provides a full search strategy for PubMed which was revised according to the requirements of each database. Researchers' own work and reference lists of included papers were searched. Grey literature was also searched from the websites of two UK and two US organisations involved in child physical activity research:

Play England: http://www.playengland.org.uk/

Active Living Research (US): http://activelivingresearch.org/

Institute of Education, University of London: http://www.ioe.ac.uk/index.html

Active Academics (US): http://www.activeacademics.org/?pid=20&homepage

The PRISMA guidelines for systematic review reporting were followed (Moher et al., 2009).

Inclusion/exclusion criteria

Randomised and non-randomised intervention studies were sought that evaluated the effects of implemented physically active lessons on physical activity and/or educational outcomes.

1) Physically active lessons: Classroom-based sessions containing both physical activity and educational elements were included. Physical education, physical activity breaks without educational content, after-school and recess interventions were excluded.

2) Complex interventions: Physically active lessons as part of complex interventions were excluded to isolate the effects of these lessons alone.
3) Study design: Intervention studies that either featured a control group or a baseline comparison phase were included. Studies also featured baseline and post-intervention pupil outcome measurement. Reviews and protocol studies providing no intervention results were excluded.
4) Sample: Child and adolescent samples were included regardless of age. Studies solely investigating special populations (such as disabled or obese children) were excluded as such conditions may have impacted physical activity and educational outcomes differently.
5) English language papers were included.

Papers in press were included. Authors were contacted for full-text papers when related conference proceeding titles or abstracts were found.

Data Extraction

Data extraction and assessment took place between March and April 2014. Paper characteristics including study design, sample characteristics and findings were extracted by one reviewer (EN). Confirmation was sought from a second reviewer where study inclusion was uncertain. Reported results were assessed in terms of their statistical association ($p<0.05$) of physically active lessons and physical activity or educational outcomes. Tables of results were developed and presented according to outcomes assessed.

Methodological quality and risk of bias assessment

The Effective Public Health Practice Project (EPHPP) tool (National Collaborating Centre for Methods and Tools, 2008) was used to assess study quality and risk of bias. This six-component rating scale for interventions assesses selection bias, study design, assessment of confounders (e.g gender), data collection methods (reliability and validity) and reporting of blinding, withdrawals and dropouts. Weak, moderate or strong scores were awarded in each category, with an overall rating then applied according to the tool's accompanying instructions. Inter-rater reliability was gained from a second reviewer. Where discrepancies existed, deliberation occurred until consensus was reached.

Results

In total, 8,021 citations were identified from electronic database records, 16 from reference searches and 2 from grey literature (Figure 2). Of the included studies, 9 were held in the USA, 1 in China and 1 in New Zealand. Four studies were specifically described as either feasibility (Oliver et al., 2006; Trost et al., 2008) or pilot studies (Erwin et al., 2011a; Graham et al., 2014).

Sample sizes and demographics

Study sizes ranged from N=21 (Graham et al., 2014) to N=753 (Liu et al., 2008). A total of N=2137 were tested across the eleven included studies, with N=1544 tested for physical activity levels. Overall N=657 were tested for educational outcomes, including academic achievement (N=358), on-task behaviour (N=184), intelligence (N=155), reading comprehension (N=130) and session knowledge recall (N=21).

Most interventions were held in elementary schools, except for one held in a pre-school (Trost et al., 2008) and one in Junior High Schools (Helgeson, 2014). Participant ages ranged from 3 (Trost et al., 2008) to 14 years (Helgeson, 2014). Gender proportions ranged from 29.25% males (Erwin et al., 2011b) to 58.7% males (Erwin et al., 2011a). One study did not report gender (Mahar et al., 2006). Proportions of Caucasian participants ranged from 69% (Helgeson, 2014) to 92% (Reed et al., 2010). Six studies did not report ethnicity (Erwin et al., 2011b; Graham et al., 2014; Liu et al., 2008; Mahar et al., 2006; Oliver et al., 2006; Trost et al., 2008).

Study design

Eight studies used a controlled trial design (Donnelly et al., 2009; Erwin et al., 2011b; Graham et al., 2014; Helgeson, 2014; Liu et al., 2008; Mahar et al., 2006; Reed et al., 2010; Trost et al., 2008). Of these, five randomised individual classes to either intervention (physically active lessons) or control groups (Donnelly et al., 2009; Helgeson, 2014; Mahar et al., 2006; Reed et al., 2010; Trost et al., 2008). Three studies used a pre/post-test design, where all participants undertook a baseline, intervention and post-intervention period (Erwin et al., 2011a; Grieco et al., 2009; Oliver et al., 2006) (Tables 1, 2 & 3).

Intervention structure

Most intervention periods ran from 13 days to 3 months (Erwin et al., 2011a; Erwin et al., 2011b; Helgeson, 2014; Mahar et al., 2006; Oliver et al., 2006; Reed et al., 2010; Trost et al., 2008). Two studies featured only one physically active lesson (Graham et al., 2014; Grieco et al., 2009), with other interventions extending to 9 months (Liu et al., 2008) and 3 years (Donnelly et al., 2009). One study did not report the length of its respective baseline, intervention and post-intervention periods (Erwin et al., 2011b). The target frequency of physically active lessons during interventions also varied. Some recommended a set number of sessions each week: ranging from one (Erwin et al., 2011a; Erwin et al., 2011b; Mahar et al., 2006) or two sessions every school day (Liu et al., 2008; Trost et al., 2008), to once a day three days a week (Reed et al., 2010). Donnelly and colleagues (2009) recommended MVPA time rather than session numbers: seeking 90 minutes of MVPA a week during physically active lessons. Helgeson (2014) provided a set range of ten Energizers sessions to be carried out at teachers' discretion over four weeks. One study did not report the length of frequency of its intervention session (Oliver et al., 2006). Two studies were published as part of larger physically active lesson studies: one from the Texas I-CAN study (Grieco et al., 2009; see Kibbe et al., 2011 for programme review) and another from the Physical Activity Across the Curriculum study (PAAC; Donnelly et al., 2009; see DuBose et al. (2008) for protocol).

Intervention content

Content of physically active lessons varied. Most featured age-appropriate content based on maths, language arts and social sciences (Donnelly et al., 2009; Erwin et al., 2011a; Erwin et al., 2011b; Graham et al., 2014; Grieco et al., 2009; Helgeson, 2014; Liu et al., 2008; Mahar et al., 2006; Reed et al., 2010; Trost et al., 2008). One study featured virtual walks as the basis for physical activity and educational content (Oliver et al., 2006): with students recording their steps to simulate travel to cities around New Zealand. Seven studies hosted physically active sessions independent from other lessons (Erwin et al., 2011b; Grieco et al., 2009; Helgeson, 2014; Liu et al., 2008; Mahar et al. 2006; Oliver et al., 2006; Trost et al., 2008), whereas four modified existing lessons to be more physically active (Donnelly et al., 2009; Erwin et al., 2011a; Graham et al., 2014; Reed et al., 2010). Accompanying additional equipment for physically active lessons was provided to teachers in some studies. Resources of activity cards (Erwin et al., 2011b) and notebooks (Donnelly et al., 2009) were provided to provide teachers with ideas for physically active lessons. Tracking posters and stickers were provided in one study to enable pupils to record their activity during the physically active lesson programme (Liu et al., 2008). Another used developed 'Jump In!' mats with 2x2 coloured squares for pupils to jump on corresponding correct answers during physically active sessions (Graham et al., 2014). Two studies featured sport equipment such as balls or hula-hoops which were already owned by participating schools (Oliver et al., 2006; Trost et al., 2008).

Six studies provided detailed examples of intervention activities to allow replication (Erwin et al., 2011a; Erwin et al., 2011b; Graham et al., 2014; Helgeson, 2014; Oliver et al., 2006; Trost et al., 2008). One instead provided a free website link to resources used (Mahar et al., 2006). To increase intervention compliance; one study charged participating intervention schools $180 to participate (Erwin et al., 2011b), whilst another rewarded pupils with a free sports centre pass and teachers with unspecified payment (Erwin et al., 2011a)

Only two studies featured a notable theoretical rationale for their physically active lesson interventions. Erwin (et al. 2011a) discuss the Ecological Model (Sallis and Owen, 1997; Sallis et al., 2000), which describes the importance of social and physical environments on individual behaviour. The authors hypothesise that teachers can engage students in additional physical activity via its integration into curriculum content. Helgeson (2014) vaguely describes physically active lessons as applicable to 'Brain-based learning theory' (Caine and Caine, 1991), which stresses teaching techniques should be grounded in the neuroscience of learning. No studies featured theoretical justifications for their choice of outcomes.

Teacher training and intervention implementation

Most studies described training teachers in the principles of their respective physically active lessons programmes. Training length ranged from weekly timing of unspecified length (Helgeson, 2014) to six hours each school year (Donnelly et al., 2009). Training was not described in two studies (Liu et al., 2008; Oliver et al., 2006). Only two studies involved teachers in the development of their interventions (Erwin et al., 2011a; Graham et al., 2014).

Teacher records of intervention implementation were used to evaluate processes in four studies. Trost (et al., 2008) used a structured checklist, completed by teachers each day. They reported 93% of physically active lessons completed, with 74% meeting the 10 minute activity requirement. Helgeson (2014) also provided a teacher intervention implementation checklist for each of the ten sessions provided. However although sessions were nominally coded as implemented or not implemented; no rates of implementation were provided. Erwin (et al., 2011b) reported daily physically active lesson completion rates of 55%, analysing intervention results into 'compliance' (classes who completed the recommended one session a day at follow-up and post-follow-up) and 'noncompliance' groups. No significant differences in steps taken were found between control and non-compliance groups, whereas significantly more steps were taken in the intervention compliance than control groups (p<0.001). Donnelly (et al., 2009) found target activity rates of between 50-83% in its active curriculum programme. Average active minutes were reported by teachers as lower at the start of each semester, with increases within each school year and across years from baseline to year 3 (p<0.0001). Reasons for classes completing less than the target number of sessions were not provided. Teachers who reported themselves as more physically active in class, had pupils who were also more active (Donnelly et al., 2009). Two studies did not feature process evaluations as they featured one-off lessons closely monitored by researchers (Graham et al., 2014; Grieco et al., 2009).

Use of sub-groups

Four studies featured sub-groups to analyse outcomes. Only one of these described the selection of these sub-group participants as via random selection (Mahar et al., 2006), whereas two others described biased selection by class teachers (Erwin et al., 2011a; Liu et al., 2008). Donnelly and colleagues (2009) assessed physical activity via accelerometers in a sub-sample of N=167, reporting no significant differences between these and total study participants. Differences between sub- and total groups were not reported in the other studies using sub-groups for activity monitors (N=80; Liu et al. 2008, N=11; Erwin et al. 2011a) or on-task behaviour (N=87; Mahar et al. 2006).

Physical activity outcomes

Differences in physical activity between physically active lesson intervention and control groups were assessed in eight of the eleven identified studies (Tables 1 & 3). Although Reed and colleagues (2010) assessed educational outcomes in both intervention and control groups (see educational outcomes section), they only assessed activity in intervention group participants and so are not included in this PA outcome report. Five studies assessed PA only (Erwin et al., 2011a; Erwin et al., 2011b; Liu et al., 2008; Oliver et al., 2006; Trost et al., 2008) and three assessed PA alongside educational outcomes (Donnelly et al., 2009; Grieco et al., 2009; Mahar et al., 2006).

Four studies assessed PA with pedometers only (Erwin et al., 2011b; Grieco et al., 2009; Mahar et al., 2006; Oliver et al., 2006), one with accelerometers only (Donnelly et al., 2009), one study with accelerometers and a developed self-report PA questionnaire (Liu et al., 2008; Liu et al., 2003), one with accelerometers and observation (Trost et al., 2008) and one with accelerometers and pedometers (Erwin et al., 2011a).

Activity monitors were worn for four (Donnelly et al., 2009; Erwin et al., 2011b) or five consecutive days (Grieco et al., 2009) or for school time throughout the study's duration (Erwin et al., 2011a; Mahar et al., 2006; Oliver et al., 2006; Trost et al. 2008). All but one study (Donnelly et al., 2009) assessed PA with devices during school time only, with another assessing activity during physically active lessons only (Liu et al., 2008). When described, studies reported hip placement for PA devices (Grieco et al., 2009; Liu et al., 2008; Mahar et al., 2006; Oliver et al., 2006; Trost et al., 2008). Cut-points and epoch lengths were reported in three out of four studies using accelerometers (not in Donnelly et al., 2009). Cut-points used were all child-calibrated and suitable for their respective sample populations (Puyau et al., 2002; Sirard et al., 2005). One study used separate pedometers to measure total school activity and physically active Maths lesson activity to enable easier analysis (Erwin et al., 2011a). The Observational System for Recording Activity in Preschoolers system (OSRAP; Brown et al., 2006) was additionally used in the study of Trost and colleagues (2008) to code types of activity elicited during physically active lessons.

Of the seven studies assessing intervention group changes, six found physical activity levels across all intervention group participants to significantly improve following physically active lessons (Donnelly et al., 2009; Erwin et al., 2011a; Erwin et al., 2011b; Liu et al., 2008; Mahar et al., 2006; Trost et al., 2008). However, one study did not provide statistics to support these claims (Liu et al., 2008). Of the four studies able to measure activity intensity with accelerometers, two found increased MVPA during the intervention period (Donnelly et al., 2009; Trost et al., 2008). One study found an improvement of PA levels during the intervention in the least active girls only (Oliver et al., 2006) and was the only study to assess intervention effects on gender. Grieco (et al. 2009) only compared PA between BMI groups: finding significantly more steps in normal weight, compared to at-risk or overweight groups. A post-intervention follow-up was only present in one study (Erwin et al., 2011b): finding increased activity to be maintained in physically active lesson participants after a 3-month period ($p<0.001$). One study assessed weekend physical activity changes between intervention group participants, finding 17% more weekend activity in intervention versus control participants (Donnelly et al., 2009).

Educational outcomes

Six studies assessed the effect of physically active lessons on educational outcomes. Three assessed educational outcomes alongside PA (Donnelly et al., 2009; Grieco et al., 2009; Mahar et al., 2006) (Table 3) and three assessed educational outcomes only (Graham et al., 2014; Helgeson, 2014; Reed et al., 2010) (Table 2).

On-task behaviour was assessed in two studies (Grieco et al., 2009; Mahar et al., 2006), both testing pre- and post-physically active lessons. Both studies used momentary time sampling with trained researchers observing pupil behaviours for fixed intervals (5 seconds; Grieco et al. 2009, 1 minute; Mahar et al. 2006). Inter-rate reliability of 80% (Mahar et al., 2006) and 90% (Grieco et al., 2009) was expected of researchers during training to ensure observation accuracy. Grieco and colleagues (2009) used a binary on-or off-task recording system, whereas Mahar (et al. 2006) used a four point system recording behaviour as on-task, motor off-task, noise off-task and passive/other off-task. One study found day on-task behaviour to improve by 20% following physically active lessons compared to before ($p<0.05$; Mahar et al. 2006). Grieco and colleagues found no significant differences in pre- and post- on-task behaviour in the physically active lesson intervention group, whereas on-task behaviour decreased following typical teaching in the control group.

Academic achievement was assessed in two studies (Donnelly et al., 2009; Reed et al., 2010), with both assessing achievement via standardised tests. Donnelly and colleagues (2009) used the well-validated 2nd edition Wechsler Individual Achievement Test (WIAT-II-A; The Psychological Corporation, 2001), taking 30 minutes to complete per pupil. This produces age-based scores in maths, reading, spelling and composite areas that can be compared to show trends over time. Physically active lesson intervention pupils scored significantly higher in test sections compared to controls ($p<0.01$): improving over time in all fields whereas controls only improved in maths. Reed and colleagues assessed academic achievement via mandatory, Palmetto Achievement Challenge Tests (PACT) in maths, language arts, science and social studies (Buckendahl et al., 2003). Achievement was only assessed post- intervention, with physically active lesson participants receiving significantly higher scores in social sciences ($p=0.004$) but no other topics.

Fluid intelligence (the ability to reason quickly and solve abstract problems) was also assessed by Reed and colleagues (2010). Diagrammatic puzzles comprising the Standard Progressive Matrices tests were administered (Raven et al., 1998), with sufficient participant data available for post-intervention testing only. Significantly higher overall fluid intelligence scores were found in physically active lesson intervention pupils ($p<0.05$), with no significant differences between demographic groups.

Helgeson (et al. 2014) measured changes in reading comprehension between intervention groups via grade-level ‘easy CBM®’ assessments (Alonzo and Tindal, 2009). This involved provision of a reading passage and twenty multiple-choice questions pre- and post ‘Energizers’ programme. No differences were found between physically active and control groups. Finally, one study assessed knowledge of content shown during a one-off ‘Jump In!’ physically active session (Graham et al., 2014). Again, no difference in knowledge was found between intervention groups. However, authors stress caution over these early findings given the very small, feasibility sample.

Risk of Bias assessment

Of the eleven identified studies, three were assessed to have low (Donnelly et al., 2009; Oliver et al., 2006; Trost et al., 2008), three to have moderate (Erwin et al., 2011b; Grieco et al., 2009; Reed et al., 2010) and five to have high overall risk of bias (Erwin et al., 2011a; Graham et al., 2014; Helgeson, 2014; Liu et al., 2008; Mahar et al., 2006)(Table 4). Selection bias was likely in many studies. Authors mostly did not report the rationale behind their selected participating schools, nor the rate of school or participant study participation (Donnelly et al., 2009; Erwin et al., 2011b; Graham et al., 2014; Oliver et al., 2006; Reed et al., 2010). The selection processes of classes from larger study cohorts were also absent (Donnelly et al., 2009; Grieco et al., 2009), with no clear, valid selection processes reported for sub-group participants (Erwin et al., 2011a; Liu et al., 2008). Some studies did not report potential demographic confounders or account for them in their analysis (Erwin et al., 2011a; Grieco et al., 2009; Helgeson, 2014; Liu et al., 2008; Mahar et al., 2006). In all studies, blinding for either participants or researchers was unclear. Physical activity and educational outcome measures used were shown to be valid and reliable with supporting previous research in most studies (Donnelly et al., 2009; Erwin et al., 2011a; Erwin et al., 2011b; Grieco et al., 2009; Mahar et al., 2006; Oliver et al., 2006; Reed et al., 2010; Trost et al., 2008). Studies provided a range of detail on participant attrition, with some providing full numbers and reasons (Trost et al., 2008) and others not discussing drop-outs at all (Helgeson, 2014; Liu et al., 2008; Mahar et al., 2006).

Discussion

A systematic search of the literature found eleven studies assessing classroom physically active lesson interventions and either a control group or baseline comparison phase. Physically active lessons featured a variety of content, ranging from age-appropriate content based on maths, language arts and social sciences (Donnelly et al., 2009; Erwin et al., 2011a; Erwin et al., 2011b; Graham et al., 2014; Grieco et al., 2009; Helgeson, 2014; Liu et al., 2008; Mahar et al., 2006; Reed et al., 2010; Trost et al., 2008) to virtual walks (Oliver et al., 2006).

Positive associations between physically active lessons and physically activity were found in all seven studies assessing this relationship: either in all participants (Donnelly et al., 2009; Erwin et al., 2011a; Erwin et al., 2011b; Liu et al., 2008; Mahar et al., 2006; Trost et al., 2008) or in least active girls only

(Oliver et al., 2006). Limited evidence was provided of MVPA increases with physically active lessons, including from the longest identified intervention of 3 years (Donnelly et al., 2009). As MVPA is especially important for improving health outcomes (Cesa et al., 2014), these limited findings suggest that physically active lessons may well have the ability to provide associated health benefits. Although this body of emerging evidence seems promising, the methods used to collect this data must be considered to assess their validity. The majority of studies assessed physical activity primarily with pedometers (Erwin et al., 2011a; Erwin et al., 2011b; Grieco et al., 2009; Mahar et al., 2006; Oliver et al., 2006), providing step-count data only. Although providing an insightful early evidence base here and being useful as inexpensive devices, pedometers cannot detect activity intensity (Corder et al., 2008). Devices such as accelerometers in future studies would allow measurement of the intensity of activity initiated during physically active lessons (de Vries et al., 2006). Habitual physical activity could not be determined from the majority of studies, as only one measured activity both in and outside of school (Donnelly et al., 2009). Objective recording of between three to seven full days is recommended to better assess changes in children’s habitual activity levels (Reilly et al., 2008). Only one study assessed the effects of physically active lesson interventions on gender (Oliver et al., 2006). More research is needed to see if these novel interventions can improve activity in specific demographic groups such as girls: commonly found to be less physically active (Griffiths et al., 2013). Future studies should also assess the effects of such lessons on physical activity beyond the school environment, with assessments over both weekday and weekends (as in Donnelly et al., 2009).

Tentative, positive associations were also found in studies assessing the effects of physically active lessons on educational outcomes. Outcomes assessed varied from assessing student on-task behaviour to more curriculum-orientated academic outcomes of achievement and knowledge. Results were either significantly improved following interventions (Donnelly et al., 2009; Mahar et al., 2006), sustained compared to control group (Grieco et al., 2009) or were no different to control groups (Graham et al., 2014; Helgeson, 2014). This suggests that learning and attention may be improved following bouts of educational physically active lessons. Such findings are in line with numerous previous studies finding learning capacity to increase following exercise (Barr-Anderson et al., 2011; Centers for Disease Control and Prevention, 2010; Tomporowski et al., 2011). Although results identified in this review seem aligned with educational associations in wider physical activity interventions, findings are still in their infancy. The wide range of educational assessments used across studies makes firm conclusions impossible from this limited number of studies.

Findings from this systematic review must be interpreted with caution for a number of reasons. Firstly, nine out of eleven studies featured no consideration of theory in their development or analysis. This is unfortunately typical of many interventions, with common-sense development used instead of formal analysis of target behaviours or the mechanisms of action behind them (Michie et al., 2009). Ensuring the embedding of theory or Behaviour Change Techniques (Michie et al., 2009) into future physically active lesson interventions will ensure a grounded and valid basis for their development. Secondly, the majority of studies had a relatively short follow-up time preventing longer term assessment. This is understandable given the infancy of physically active lesson research, with some studies identifying themselves specifically as pilot or feasibility tests. However, findings drawn from such short interventions of one day in some instances (Graham et al., 2014; Grieco et al., 2009), should be treated with caution. School physical activity interventions of 12 weeks and over have been recommended and systematically assessed elsewhere (Dobbins et al., 2013) and should be the target for future physically active lesson work. Thirdly, the generalizability of the findings in identified studies is questionable, given that nine out of eleven studies are based in the USA. Additionally, there is great diversity in the assessed risk of bias of included studies, suggesting room for improvement in physically active lesson intervention study designs. Even in studies with low risk of bias there are often issues with insufficient intervention or demographic details. For example, although the paper of Oliver and colleagues (2006) was assessed to have low risk of bias, the frequency and length of their virtual walk intervention sessions were absent. As with any intervention, full detail of physically active lesson procedures is required to allow replication. Only six included studies gave detailed examples of intervention sessions. Given that physically active lessons are still relatively novel (Centers for Disease Control and Prevention, 2010); it is vital that full intervention descriptions are provided to allow reproduction by researchers and teachers.

Insufficient detail of teacher intervention implementation records was also common. Three studies reported execution rates of between 50% (Donnelly et al., 2009) to 93% (Trost et al., 2008) but no studies sought details on what barriers prevented teachers from reaching target levels. The importance of such process evaluations was especially emphasised in findings of Erwin and colleagues (2011b): where step results would have been inaccurate without accounting for their collected compliance data. Future physically active lesson studies will need to assess potential difficulties as part of their development and process evaluation phases (Kibbe et al., 2011) to allow potential barriers to be tackled. Relatedly; only two studies included teachers in the intervention development process (Erwin et al., 2011b; Graham et al., 2014). Teachers will need to be included at the heart of future physically active lesson development to ensure content is both fun and relevant in the teaching environment (Active Living Research, 2013). Without this co-operation at the development stage; physically active lessons will be less likely to have the support of teachers and hence less likely to be introduced at curriculum level.

Conclusions

From eleven identified studies, a range of interventions were described to provide a number of ideas for researchers and teachers to adapt or replicate. This review has identified a need for further, larger and more rigorous research in order to firmly ascertain the effects of physically active lessons. Future interventions in this area must be developed with teachers and the school environment at their core: working to reduce school sedentary time whilst maintaining educational value.

Acknowledgements

This research was funded by a UCL Crucible PhD Studentship of EN.

Conflict of Interest statement

No authors have any conflict of interest related to this paper.

References

Active Living Research, 2013. Do Short Physical Activity Breaks in Classrooms Work?, Active Living Research. University of California, San Diego.
Alonzo, J., Tindal, G., 2009. Alternate Form and Test-Retest Reliability of easyCBM Reading Measures, Behavioral Research and Teaching, University of Oregon.
Andersen, L.B., Riddoch, C., Kriemler, S., Hills, A., 2011. Physical activity and cardiovascular risk factors in children. British journal of sports medicine 45, 871-876.
Barr-Anderson, D.J., AuYoung, M., Whitt-Glover, M.C., Glenn, B.A., Yancey, A.K., 2011. Integration of short bouts of physical activity into organizational routine a systematic review of the literature. American journal of preventive medicine 40, 76-93.
Bartholomew, J.B., Jowers, E.M., 2011. Physically active academic lessons in elementary children. Preventive medicine 52 Suppl 1, S51-54.
Best, J.R., 2010. Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise. Developmental Review 30, 331-351.
Biddle, S.J., Asare, M., 2011. Physical activity and mental health in children and adolescents: a review of reviews. British journal of sports medicine.

Brown, W.H., Pfeiffer, K.A., McIver, K.L., Dowda, M., Almeida, J.M., Pate, R.R., 2006. Assessing preschool children's physical activity: the Observational System for Recording Physical Activity in children-preschool version. Research quarterly for exercise and sport 77, 167-176.
Buckendahl, C.W., Nebelsick-Gullet, L., Bandalos, D., Benson, J., Irwin, P., 2003. Palmetto Achievement Challenge Tests and End-of-Course Examination Program, Buros Institute for Assessment Consultation and Outreach,. University of Nebraska, Lincoln.
Caine, R.N., Caine, G., 1991. Making connections: Teaching and the human brain.
Centers for Disease Control and Prevention, 2010. The Association Between School-Based Physical Activity, Including Physical Education, and Academic Performance. U.S. Department of Health and Human Services, Atlanta, GA.
Cesa, C.C., Sbruzzi, G., Ribeiro, R.A., Barbiero, S.M., de Oliveira Petkowicz, R., Eibel, B., Machado, N.B., Marques, R.d.V., Tortato, G., dos Santos, T.J., Leiria, C., Schaan, B.D.A., Pellanda, L.C., 2014. Physical activity and cardiovascular risk factors in children: meta-analysis of randomized clinical trials. Preventive medicine 69, 54-62.
Corder, K., Ekelund, U., Steele, R.M., Wareham, N.J., Brage, S., 2008. Assessment of physical activity in youth. Journal of Applied Physiology 105, 977-987.
de Vries, S.I., Bakker, I., Hopman-Rock, M., Hirasing, R.A., van Mechelen, W., 2006. Clinimetric review of motion sensors in children and adolescents. Journal of clinical epidemiology 59, 670-680.
Diamond, A., Lee, K., 2011. Interventions shown to aid executive function development in children 4 to 12 years old. Science 333, 959-964.
Dobbins, M., Husson, H., DeCorby, K., LaRocca, R.L., 2013. School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6 to 18. The Cochrane database of systematic reviews 2, CD007651.
Donnelly, J.E., Greene, J.L., Gibson, C.A., Smith, B.K., Washburn, R.A., Sullivan, D.K., DuBose, K., Mayo, M.S., Schmelzle, K.H., Ryan, J.J., Jacobsen, D.J., Williams, S.L., 2009. Physical Activity Across the Curriculum (PAAC): A randomized controlled trial to promote physical activity and diminish overweight and obesity in elementary school children. Preventive medicine 49, 336-341.
Donnelly, J.E., Lambourne, K., 2011. Classroom-based physical activity, cognition, and academic achievement. Preventive medicine 52 Suppl 1, S36-42.
DuBose, K.D., Mayo, M.S., Gibson, C.A., Green, J.L., Hill, J.O., Jacobsen, D.J., Smith, B.K., Sullivan, D.K., Washburn, R.A., Donnelly, J.E., 2008. Physical activity across the curriculum (PAAC): Rationale and design. Contemporary clinical trials 29, 83-93.
Erwin, H., Fedewa, A., Beighle, A., Ahn, S., 2012. A Quantitative Review of Physical Activity, Health, and Learning Outcomes Associated With Classroom-Based Physical Activity Interventions. Journal of Applied School Psychology 28, 14-36.
Erwin, H.E., Abel, M.G., Beighle, A., Beets, M.W., 2011a. Promoting children’s health through physically active math classes: a pilot study. Health promotion practice 12, 244-251.
Erwin, H.E., Beighle, A., Morgan, C.F., Noland, M., 2011b. Effect of a low-cost, teacher-directed classroom intervention on elementary students' physical activity. The Journal of school health 81, 455-461.
Esliger, D., Hall, J., 2009. Accelerometry in Children, Health Survey for England 2008. The Information Centre, Leeds.
Graham, D.J., Lucas-Thompson, R.G., O'Donnell, M.B., 2014. Jump In! An Investigation of School Physical Activity Climate, and a Pilot Study Assessing the Acceptability and Feasibility of a Novel Tool to Increase Activity during Learning. Frontiers in public health 2, 58.
Grieco, L.A., Jowers, E.M., Bartholomew, J.B., 2009. Physically active academic lessons and time on task: the moderating effect of body mass index. Medicine and science in sports and exercise 41, 1921-1926.
Griffiths, L.J., Cortina-Borja, M., Sera, F., Pouliou, T., Geraci, M., Rich, C., Cole, T.J., Law, C., Joshi, H., Ness, A.R., Jebb, S.A., Dezateux, C., 2013. How active are our children? Findings from the Millennium Cohort Study. BMJ Open 3, e002893

Helgeson, J.L., Jr., 2014. The impact of physical activity on academics in English classes at the junior high school level. Dissertation Abstracts International Section A: Humanities and Social Sciences 74.
Kibbe, D.L., Hackett, J., Hurley, M., McFarland, A., Schubert, K.G., Schultz, A., Harris, S., 2011. Ten Years of TAKE 10!: Integrating physical activity with academic concepts in elementary school classrooms. Preventive medicine 52, S43-S50.
Kolb, D.A., 1984. Experiential learning: Experience as the source of learning and development. Prentice-Hall Englewood Cliffs, NJ.
Kolb, D.A., Boyatzis, R.E., Mainemelis, C., 2001. Experiential learning theory: Previous research and new directions. Perspectives on thinking, learning, and cognitive styles 1, 227-247.
Liu, A., Hu, X., Ma, G., Cui, Z., Pan, Y., Chang, S., Zhao, W., Chen, C., 2008. Evaluation of a classroom-based physical activity promoting programme. Obesity reviews : an official journal of the International Association for the Study of Obesity 9 Suppl 1, 130-134.
Liu, A.L., Ma, G.S., Zhang, Q., Ma, W.J., 2003. Reliability and validity of a 7-day physical activity questionnaire for elementary students. Zhonghua Liu Xing Bing Xue Za Zhi. 24, 901-904.
Mahar, M.T., Murphy, S.K., Rowe, D.A., Golden, J., Shields, A.T., Raedeke, T.D., 2006. Effects of a classroom-based program on physical activity and on-task behavior. Medicine and science in sports and exercise 38, 2086-2094.
Mantjes, J.A., Jones, A.P., Corder, K., Jones, N.R., Harrison, F., Griffin, S.J., van Sluijs, E., 2012. School related factors and 1yr change in physical activity amongst 9–11 year old English schoolchildren. The international journal of behavioral nutrition and physical activity 9, 153.
Michie, S., Fixsen, D., Grimshaw, J.M., Eccles, M.P., 2009. Specifying and reporting complex behaviour change interventions: the need for a scientific method. Implement Sci 4, 1-6.
Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., 2009. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Annals of internal medicine 151, 264-269.
National Collaborating Centre for Methods and Tools, 2008. Quality Assessment Tool for Quantitative Studies. Hamilton, ON, McMaster University.
Oliver, M., Schofield, G., McEvoy, E., 2006. An Integrated Curriculum Approach to Increasing Habitual Physical Activity in Children: A Feasibility Study. Journal of School Health 76, 74-79.
Puyau, M.R., Adolph, A.L., Vohra, F.A., Butte, N.F., 2002. Validation and calibration of physical activity monitors in children. Obesity research 10, 150-157.
Rasberry, C.N., Lee, S.M., Robin, L., Laris, B.A., Russell, L.A., Coyle, K.K., Nihiser, A.J., 2011. The association between school-based physical activity, including physical education, and academic performance: A systematic review of the literature. Preventive medicine 52, Supplement, S10-S20.
Raven, J., Raven, J., C., Court, J.H., 1998. Standardised Progressive Matrices. Harcourt, San Antonio.
Reed, J.A., Einstein, G., Hahn, E., Hooker, S.P., Gross, V.P., Kravitz, J., 2010. Examining the impact of integrating physical activity on fluid intelligence and academic performance in an elementary school setting: a preliminary investigation. J Phys Act Health 7, 343-351.
Reilly, J.J., Penpraze, V., Hislop, J., Davies, G., Grant, S., Paton, J.Y., 2008. Objective measurement of physical activity and sedentary behaviour: review with new data. Archives of disease in childhood 93, 614-619.
Sallis, J.F., Owen, N., 1997. Ecological Models, in: Glanz., K., Lewis., F.M., Rimer., B.K. (Eds.), Health behavior and health education, 2nd ed. Jossey-Bass, San Francisco.
Sallis, J.F., Prochaska, J.J., Taylor, W.C., 2000. A review of correlates of physical activity of children and adolescents. Medicine and science in sports and exercise 32, 963-975.
Sibley, B.A., Etnier, J.L., 2003. The relationship between physical activity and cognition in children: a meta-analysis. Pediatric Exercise Science 15, 243-256.
Sirard, J.R., Trost, S.G., Pfeiffer, K.A., Dowda, M., Pate, R.R., 2005. Calibration and evaluation of an objective measure of physical activity in preschool children. Journal of physical activity and health 2, 345.

Slater, S.J., Nicholson, L., Chriqui, J., Turner, L., Chaloupka, F., 2012. THe impact of state laws and district policies on physical education and recess practices in a nationally representative sample of us public elementary schools. Archives of Pediatrics & Adolescent Medicine 166, 311-316.
The Psychological Corporation, 2001. WIAT-II-A: Wechsler Individual Achievement Test - Second Edition, San Antonio.
Tomporowski, P.D., Lambourne, K., Okumura, M.S., 2011. Physical activity interventions and children's mental function: An introduction and overview. Preventive medicine 52, Supplement, S3-S9.
Trost, S.G., Fees, B., Dzewaltowski, D., 2008. Feasibility and Efficacy of a "Move and Learn" Physical Activity Curriculum in Preschool Children. Journal of Physical Activity & Health 5, 88-103.
Ward, D., Saunders, R., Felton, G., Williams, E., Epping, J., Pate, R., 2006. Implementation of a school environment intervention to increase physical activity in high school girls. Health education research 21, 896-910.
Weiler, R., Allardyce, S., Whyte, G.P., Stamatakis, E., 2013. Is the lack of physical activity strategy for children complicit mass child neglect? British journal of sports medicine.

Figure 1. Search strategy used in PubMED.

1. physical activity or activit* or exercise (title and abstract)

2. class* or lesson* or learning* (title and abstract)

3. child* or young* (title and abstract)

4. 1 and 2 and 3

Figure 2
Click here to download Figure: Re-RevisedFigure 2 - Preventive Medicine.docx

Figure 2. Record flow of systematic review.

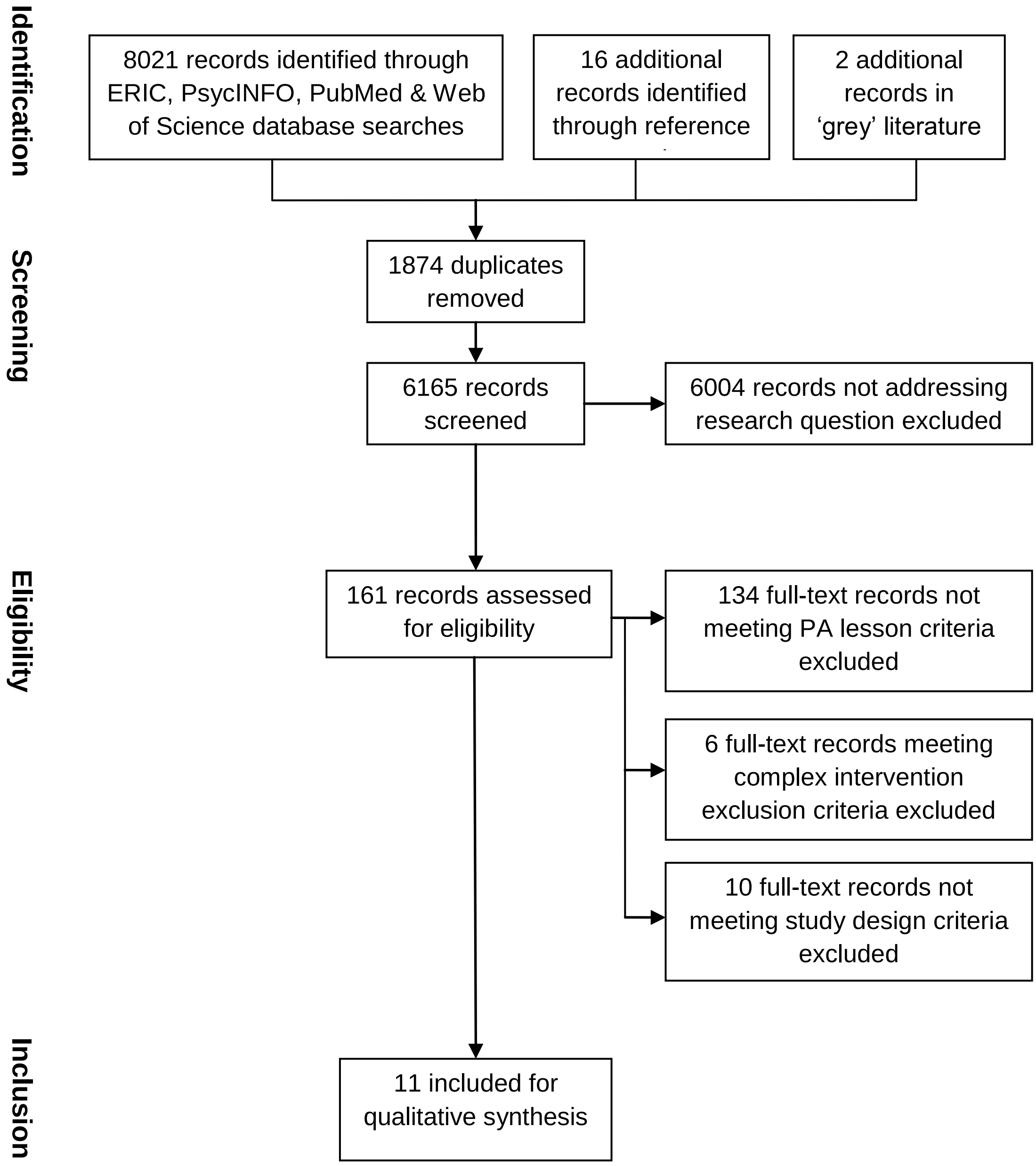

Table 1

Table 1. Physically active lesson interventions assessing physical activity only.

Paper	Country	Intervention	Intervention period	Study design	Sample	Outcome	Result
Erwin et al. (2011a)	USA	Physically active Maths classes = 10 min once a day	13 days	Pre- and post-intervention testing	1 school N=75, 8-12 years Subgroup: N=7	1) Pedometer (Walk4Life, LS 2505) Sub-group: 2) Accelerometer (Actigraph GT1M)	1) + Significantly more steps in intervention classes than baseline ($p<0.001$) 2) + Significantly greater activity counts ($p<0.01$), light activity ($p<0.01$) than baseline 2) No difference in MVPA pre- and post-intervention
Erwin et al. (2011b)	USA	Physically active breaks with some educational content = 5-10 min once a day	1 academic year (8 months)	Non- randomised Controlled Trial; pre- during- and post-test	2 schools N=106, (N in intervention group not given) 8-11 years	Pedometer (Walk4Life, LS 2500)	+ Only in 'compliant' classes adhering to recommended 1 physically active lesson a day, recorded 33% more steps compared to control ($p<0.001$)
Liu et al. 2008	China	'Happy 10' = 10 min activities, at least 1x a day	1 academic year (9 months)	Non-randomised Controlled Trial; pre- and post-test	2 schools N=753, N=328 intervention group	1) Developed questionnaire + BMI Sub-group:	1) - BMI increased in both groups 2) + 'Significantly' more energy expenditure and duration (figures not given)

					6-12 years Sub-group: N=80	2) Zhi-Ji UX-01 activity monitor	
Oliver et al. 2006	New Zealand	Virtual walk around New Zealand = length & frequency not given	4 weeks	Pre- and post-intervention testing	1 school N=61, 8-10 years	Pedometer (Yamax SW-200 Digiwalker)	No difference in steps between intervention and baseline periods in whole sample + Least active girls significantly increased steps during intervention (p=0.02; 131.4% increase compared to baseline)
Trost et al. 2008	USA	'Move and Learn' = 10 min activities, 2x a day	8 weeks	Cluster randomised controlled trial; pre- and post-test	1 pre-school centre N=42, N=20 intervention group 3-5 years	1) Accelerometer (Actigraph 7164) 2) Observation – OSRAP tool	1) + Significantly more MVPA during class time but only in latter half of intervention period (p<0.05) 2) + Significantly more MVPA during interventions in circle time (OR=2.6), free-choice outdoor time (OR=1.4) & free-choice indoor time (OR=1.2, p<0.05) than equivalent control time

Table 2

Table 2. Physically active lesson interventions assessing educational outcomes only.

Paper	**Country**	**Intervention**	**Intervention period**	**Study design**	**Sample**	**Outcome**	**Result**
Graham et al. 2014	USA	Jump In! = One 10 min Maths session on designed mat	1 day	Non- randomised Controlled Trial;	1 class N=21, N=13 intervention group 7-8 years	Post-session knowledge questionnaire	No differences between groups
Helgeson, 2014	USA	Energizers = 10 min activities, 10 across study period	4 weeks	Cluster randomised controlled trial; pre- and post-test	6 classes N=130, N=86 intervention group 11-14 years	EasyCBM® reading comprehension assessment test	No differences between groups
Reed et al. 2010	USA	Activity integrated into core curriculum = 30mins a day, 3 days a week	3 months	Cluster randomised controlled trial; pre- and post-test	1 school N=155, N=80 intervention group 9-11 years	1) Fluid intelligence: SPM Test 2) Academic Achievement: PACT Tests	1) + Intervention group had significantly higher average fluid intelligence ($p<0.05$) 2) + Intervention significantly higher Social Studies scores ($p=0.004$) No diffs in Maths, Science or English

Table 3

Table 3. Physically active lesson interventions assessing physical activity and educational outcomes.

Paper	**Country**	**Intervention**	**Intervention period**	**Study design**	**Sample**	**Outcome**	**Result**
Donnelly et al. 2009	USA	PAAC: Physical Activity Across the Curriculum = 2-10 min activities each day	3 years	Cluster randomised controlled trial; pre- and post-test	24 schools N=454, (N in intervention group not given) 7-9 years Sub-groups: PA: N= 167 Academic: N=203	Sub-groups: 1) PA: Accelerometer (Actigraph 7164) 2) Academic: WIAT-II-A standardised academic achievement test 3) All pupils: BMI	1) + intervention group more active overall (13%, p=0.007), sig more activity during school day (12% p=0.01), weekends (17%, p=0.001), more MVPA (27%, p<0.001) 2) + intervention group sig better scores in intervention in all areas 3) Dose response relationship – schools with >75 min PAAC/wk sig less increase in BMI at 3 years than schools < 75 min PAAC/ wk
Grieco et al. 2009	USA	Texas ICAN = One 10-15 min activity	1 day	Pre- and post-intervention testing	9 classes N=97, 8-10 years	1) PA: Pedometer (Omron HJ 105) 2) Time-on-task: 5 sec observations	1) + At-risk of overweight (d= -0.43) & overweight (d= -0.65) took fewer steps than normal weight group 2) + No significant increase of TOT after intervention lesson compared to decrease in TOT after control lesson

Mahar et al. 2006	USA	Energizers = 10 min activities, 1 per day	4 or 8 weeks	Cluster randomised controlled trial; pre- and post-test	1 school N=243, N=135 intervention group 5-11 years Sub-group: N=87, 8-11 years	1) PA: Pedometer (Yamax SW-200) Sub-group: 2) On-task behaviour: 10 sec observations	1) + significantly more steps during intervention (p<0.005) 2) + increased by 8% post-intervention (p<0.017)

Table 4

Table 4. Risk of bias of identified studies

Study	**Selection Bias**	**Study Design**	**Confounders**	**Blinding**	**Data Collection Methods**	**Withdrawals & Drop-Outs**	**Overall**
Donnelly et al. 2009	Moderate	Low	Low	Moderate	Low	Low	Low
Erwin et al. 2011a	High	Moderate	High	Moderate	Low	High	High
Erwin et al. 2011b	Moderate	Low	Low	High	Low	Moderate	Moderate
Graham et al. 2014	High	Moderate	Low	High	High	Low	High
Grieco et al. 2009	Moderate	Moderate	High	Moderate	Low	Moderate	Moderate
Helgeson, 2013	Moderate	Low	High	High	Moderate	High	High
Liu et al. 2008	High	Low	High	Moderate	High	High	High
Mahar et al. 2006	Moderate	Low	High	Moderate	Low	High	High
Oliver et al. 2006	Moderate	Moderate	Low	Moderate	Low	Moderate	Low
Reed et al. 2010	Moderate	Low	Low	Moderate	Low	High	Moderate
Trost et al. 2008	Low	Low	Low	Moderate	Low	Low	Low

Note: Assessed using Effective Public Health Practice Project (EPHPP) tool (National Collaborating Centre for Methods and Tools, 2008)