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The effectiveness of interventions to increase physical activity among young girls: a meta-analysis

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Abstract

Context. Pre-adolescent girls are an important target population for physical activity behaviour change as it may enhance tracking into the crucial period of adolescence. The quantification of intervention effectiveness for this age group of girls has not been previously reported.

Evidence acquisition. Studies published in English up to and including August 2013 were located from computerised (MedLine, PsychInfo, Science Direct, Web of Science, EPPI centre databases, and Cochrane Library database) and manual searches. Intervention studies aimed at promoting physical activity, that included pre-adolescent girls aged 5-11 years, and a non-physical activity control/comparison group, were included.

Evidence synthesis. A random-effects meta-analysis was conducted. The average treatment effect for pre-adolescent girls involved in physical activity interventions was significant but small (g = 0.314, $p < .001$). Moderator analyses showed larger effects for interventions that catered for girls-only and used educational and multicomponent strategies.

Conclusions. Interventions to increase physical activity in pre-adolescent girls show small but significant effects, suggesting that behaviour change may be challenging, but results suggest some strategies that could be successful.

Introduction

Given the well documented health benefits of physical activity and concerns about low levels of physical activity in all age groups, there is a clear need for effective interventions that increase population levels of physical activity (Biddle, Brehm, Hopman-Rock, & Verheijden, 2012). Within the general population, there are sub-groups that warrant particular focus. Pre-adolescent children are the most active segment of society, yet there remains concern that even for this age group many children have physical activity levels lower than those recommended for good health. For example, objective assessment data from England shows that only 34% of 4-10 year olds meet national recommendations (i.e., 60 minutes or more of at least moderate activity on all 7 days of the week), and this figure falls to zero for adolescent girls (Townsend et al., 2012).

Recent studies have shown that the decline in physical activity during early adolescence is greater among girls than boys, and that the decline among girls begins earlier than in boys (Dumith, Gigante, Domingues, & Kohl, 2011). Moreover, given the small-to-moderate strength of tracking of physical activity from pre to during adolescence (Telama, 2009), it may be wise to promote physical activity early in life if maintenance of this health behaviour is desired, even though it is recognised that there are a multitude of influences on physical activity across the lifespan.

Using the behavioural epidemiological framework (Sallis & Owen, 1999), having identified the levels of physical activity in girls and the factors affecting participation (correlates), it is important to appraise the evidence concerning how effective interventions are in this age group. One of the first reviews of the effects of physical activity interventions in young people was reported by Stone et al. (1998). They concluded that the effects were stronger for interventions that used randomised designs, had valid and reliable measures, and included more extensive intervention strategies. However, they recommended that future research involve studies that investigate the success of interventions attempting to prevent the decline in physical activity in females. More recently, a comprehensive review was reported by van Sluijs et al. (2007). In this review, interventions conducted with pre-adolescent children showed no or inconclusive effectiveness when analysed across different settings. However, no distinction was made in the results by gender. Thus it is not possible to conclude whether interventions for girls are successful. For example, while we know that physical activity levels of boys and girls differ, we do not yet know whether targeting girls alone is more effective than mixed interventions. The question about effective strategies to address and increase pre-adolescent girls' PA is an important public health topic that has yet to be adequately explored. How to best address low levels and declines in physical activity in pre-adolescent girls is unclear. The purpose of this meta-analysis, therefore, is to quantify the effect of physical activity interventions for pre-adolescent girls by including intervention studies that provided results for girls separately.

Methods

Search strategy

Search strategies were built around four groups of keywords: population, study design, behaviour, and intervention type. Key words used to guide the searching process included 'girls', 'youth', 'children', 'adolescents', 'teens', 'teenagers', 'young people', 'controlled trial', 'random', 'intervention', 'prospective', 'trial', 'cluster', 'physical activity', 'activities', 'exercise', 'physical education', 'play', 'leisure', 'sport', 'school', 'community', 'family', 'primary health care', 'counselling', 'education'. Science Direct, PubMed, PsychINFO, Web of Science, Cochrane Libraries, and EPPI Centre databases were searched using the key terms. In addition, manual searches of personal files were conducted along with screening of reference lists of previous physical activity reviews (Brown, 2009; Camacho-Minano, LaVoi, & Barr-Anderson, 2011; De Bourdeaudhuij et al., 2011; De Meester, van Lenthe, Spittaels, Lien, & De Bourdeaudhuij, 2009; DeMattia, Lemont, & Meurer, 2007; Foley & Maddison, 2010; Hamel, Robbins, & Wilbur, 2011; Jago & Baranowski, 2004; Lubans, Morgan, & Tudor-Locke, 2009; Ogilvie et al., 2007; Pate & O'Neill, 2009; Salmon, Booth, Phongsavan, Murphy, & Timperio, 2007; Timperio, Salmon, & Ball, 2004; van Sluijs, et al., 2007; Ward, Vaughn, McWilliams, & Hales, 2010) and identified articles for titles that included the key terms.

Inclusion and exclusion criteria

For inclusion, studies were required to (i) be an intervention study in which the main component or one of the components was aimed at promoting physical activity through behaviour change in any setting; (ii) include girls aged 5-11 years (or a mean within these ranges) as subjects of study at baseline; (iii) include a non-physical activity control group or comparison group (randomised or nonrandomised); (iv) include a quantitative outcome assessment of physical activity behaviour; (v) be published in the English Language up to and including May 2013.

Identification of relevant studies

Potentially relevant articles were selected by (i) screening the titles; (ii) screening the abstracts; and (iii) if abstracts were not available or did not provide sufficient data, the entire article was retrieved and screened to determine whether it met the inclusion criteria.

Data extraction and coding

Information extracted from each article included sample characteristics, inclusion criteria, intervention type, setting, and components/description, length of intervention and follow-up, theoretical framework, physical activity outcome, assessment of physical activity, and measures of physical activity (see Tables 1 and 2). Study design information extracted included sampling and group-assignment procedures. The sample size at group assignment

and each assessment point and the number of participants included in the analysis also were recorded. Finally, information about study outcomes, including means and associated SDs and mean change from baseline to post-test, were extracted for use in calculating effect sizes. Data were extracted using a standard data extraction instrument developed specifically for this study.

Risk of Bias

The Cochrane Collaboration tool for Assessing Risk of Bias was used to assess the included studies (Higgins et al., 2011). For each study seven domains were scored with high, low or unclear risk for bias: sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting and 'other' issues (similarity in baseline characteristics and timing of outcome assessment). These seven domains assess the level of risk regarding selection bias, allocation bias, performance bias, detection bias, attrition bias, reporting bias and other bias. The quality assessment was performed independently by two authors and the findings were compared and discussed until consensus was achieved. For the purpose of this meta-analysis, each domain was scored as -1 for high risk, 0 for unclear risk and 1 for low risk. Scores were then summed with a possible range of scores from -6 to 6 ('other' was not scored), with positive values meaning lower risk of bias.

Statistical Procedures

Outlier and publication bias analyses were used to evaluate and manage the influence of extreme values or missing studies on the overall treatment effect. Outliers were considered to be studies with inflated residual values approximately two standard deviations ($z = \pm 1.96$) above or below the average treatment effect. If outliers were present a "one study removed" procedure was performed to determine if study removal from the analysis was appropriate. The two criteria used to evaluate outlier inclusion were based on small changes in the overall treatment effect that remained significant ($p < .05$) and results were within the 95% confidence interval. Publication bias refers to an underrepresentation of non-significant studies from published literature preventing accurate conclusions from being drawn from research (Rothstein, Sutton, & Borenstein, 2005). Three separate methods were used to evaluate publication bias including review of the funnel plot, Duval and Tweedie's (2000a, 2000b) "trim and fill" procedure, and the Fail-Safe *N* calculation. Funnel plots graph studies according the effect size (vertical-axis) and standard error (horizontal-axis) with asymmetrical plots representing publication bias. The "trim and fill" procedure is an iterative statistical process that provides estimates of studies from the right side and replaces an approximation on the left side of a funnel plot readjusting the overall effect size according to a symmetrical graph (Duval & Tweedie, 2000a). A "file-drawer" analysis (Rosenthal, 1979), commonly referred to as the Fail Safe *N*, was the final method used to

evaluate publication bias. This calculates the number of missing studies that would increase results to a non-significant level ($p > .05$).

Effect Size

The effect size metric selected was Hedges' *g.* This provides a correction factor for smaller sample sizes ($k < 20$) as there were only 22 studies in the current investigation (Hedges & Olkin, 1985). Each study was the unit of analysis and contributed a single calculation to the summary treatment effect. When several measures of physical activity were reported (i.e., self-report, pedometer, accelerometer, etc.) an average calculation provided the standardized difference between intervention and control groups. Positive effect sizes were interpreted as intervention groups having higher physical activity scores whereas negative effect sizes indicated control groups had more physical activity. A random effects model was selected to provide a conservative interpretation of data as there was an assumption that the true effect would vary between studies (Borenstein, Hedges, Higgins, & Rothstein, 2010). The calculation of standard error for the combined effect in a random effects model contains two sources of error that factor within-study (sampling error) and between-study variance to adjust overall results. Application of these adjustments to standard error limit the influence of larger studies by using inverse weights plus an additional between-study variance component to provide a more conservative estimate of effect (Borenstein, et al., 2010). The second version of Comprehensive Meta-Analysis software (Borenstein, Hedges, Higgins, & Rothstein, 2005) was used to perform all analyses.

Subgroup Analyses

Heterogeneity represents the dispersion of the true effects between studies and functions to provide an interpretation of differences between studies (Borenstein, Hedges, Higgins, & Rothstein, 2009). Three separate but related statistics were used to evaluate heterogeneity between studies in the current analysis including Q, τ^2, and I^2. The total Q-statistic and corresponding p-value are based on a Chi-squared (χ^2) distribution and are partitioned into within (Q_W) and between (O_B) values to provide a calculation of variation between study effects. Tau-squared (τ^2) reflects the amount of variance between studies and is the more appropriate statistic to report when employing a random effects model. I-squared (I^2) provides an independent scale that is descriptive in nature and reflects the portion of excess dispersion to total dispersion (Higgins, Thompson, Deeks, & Altman, 2003). Larger I^2-values can be interpreted as the observed difference between studies due to heterogeneity and require a moderator or subgroup analysis to explain the variance (Higgins et al., 2003) by using techniques analogous to a t-test or ANOVA (Hedges & Olkin, 1985). When conducting subgroup analyses, small sample sizes ($k < 5$) are problematic as between-study variance (τ^2) will have less precision to draw conclusions (Borenstein, et al., 2009). The authors have selected to report separate treatment effects for all subgroup analyses regardless of sample size and caution readers to apply conservative interpretations when a subgroup has fewer

than five studies. As an additional precautionary measure the alpha level was set at .01 to prevent committing a type I error when interpreting subgroups analyses.

Results

There were a total of 22 studies with as many independent samples that met inclusion criteria (see Figure 1). A total of 1641 girls were exposed to physical activity intervention/treatment conditions compared to 2045 in control or comparison groups. Each of the 22 studies was coded across 10 categories (6 intervention characteristics, 2 sample characteristics, and 2 study characteristics) and can be found in Table 2. Effect sizes for the overall treatment effect and subgroup analyses were interpreted using Cohen's (1988) criteria.

INSERT FIGURE AND TABLE 1 ABOUT HERE

Outliers and Publication Bias

Two studies were identified as outliers with large residual values: Horne et al. (Horne, Hardman, Lowe, & Rowlands, 2009) (z = 2.25) and Huberty et al. (Huberty, Beets, Beighle, & Welk, 2011) (z = -5.24), therefore a sensitivity analysis was conducted. Both studies were retained as results from the sensitivity analysis suggested that removal of either study would have been marginal to results by reducing the treatment effect (g = $\pm$ .05, p < .001) and remaining within the 95th percent confidence interval. Publication bias was assessed and review of the funnel plot indicated questionable symmetrical plot and the "trim and fill" procedure for the random effects model added 9 studies to the left of the mean effect and would reduce the overall treatment effect to a marginal level (g = .06). The Fail Safe *N* value indicated that there needed to be 545 missing studies to reduce the treatment effect to a non-significant level. Based on the contradictory results of these analyses and the directional results suggested in the physical activity literature, along with the conservative approach (α = .01) to interpretation that we adopted, the risk of publication bias was considered small to negligible.

Physical Activity Treatment Effects

There was a significant small positive treatment effect (k = 22, g = 0.314, p < .001) for experimental groups participating in physical activity interventions. The differential score between treatment and control groups indicated there was approximately one third of a standard deviation or the equivalent of 12.17 percent more physical activity for girls participating in the experimental conditions. Heterogeneity statistics indicated that there was significant between-study variance (Q_T = 346.37, p <.001, τ^2 = 0.199) and that a large portion of variance (I^2= 93.94) could be explained by subgroup analyses. Figure 2 summarizes the forest plot for individual study data.

INSERT FIGURE 2 ABOUT HERE

Subgroup Analyses

Based on the significant heterogeneous distribution, category subgroups were analysed to determine if portions of the variance between studies could be explained. Table 2 provides the subgroup analyses for intervention characteristics, sample characteristics, and study characteristics across the physical activity interventions. There were significant results ($p < .01$) for the sample characteristics. The additional subgroup variables produced several trends within groups. As previously stated, conservative interpretations should be applied to subgroup analyses that contain fewer than five studies (Borenstein, et al., 2009).

The subgrouping category for population sample characteristics determined that there were significant differences ($Q_B = 7.52$, $p < .001$) when studies developed interventions for girls only ($k = 6$, $g = .774$) compared to studies involving both boys and girls ($k = 16$, $g = .174$). Other subgroup characteristics that provided moderate to large trends within (not between) subgroups were multicomponent ($k = 9$, $g = .503$, $p < .01$) and educational interventions ($k = 9$, $g = .414$, $p < .01$), interventions focusing on both physical activity and dietary behaviours ($k = 7$, $g = .535$, $p < .01$), interventions randomised at the individual level ($k = 4$, $g = 1.026$, $p < .01$), interventions that were conducted for time periods less than three months ($k = 8$, $g = .636$, $p < .01$), atheoretical interventions ($k = 10$, $g = .526$, $p < .01$), studies not conducting a follow-up ($k = 12$, $g = .542$, $p < .01$), and intervention designs of high quality ($k = 7$, $g = .588$, $p < .01$). The study characteristics that produced a moderate positive trend were interventions using both objective and self-report measures for physical activity ($k = 4$, $g = .578$, $p < .01$). Each of the significant trends for all three categories had large τ^2 and I^2 values which is indicative of a large variance between studies and within some of the subgroups.

INSERT TABLE 2 ABOUT HERE

Discussion

This meta-analysis was conducted to test whether interventions to increase physical activity in pre-adolescent girls were successful. The overall effect size was small but significant, suggesting that behaviour change is possible in this population, but equally may be challenging. The size of effect is slightly smaller though broadly comparable to physical activity intervention effects shown across other age groups and settings (Heath et al., 2012). It is also similar to recent meta-analytic reviews assessing the effectiveness of interventions in young people designed to reduce their sedentary screen time (Biddle, O'Connell, & Braithwaite, 2011; Maniccia, Davison, Marshall, Manganello, & Dennison, 2011).

The small effect shown in the present meta-analysis suggests that behaviour change may be challenging. This could be due to contemporary environmental influences on young people's physical activity, such as greater use of motorised transport, unattractive and perceived dangerous environments for walking, safety concerns (e.g. 'stranger danger'), as well as

increasing pressure on children to do well academically. The latter may lead to a lack of parental encouragement for active play and sports. Moreover, there are many attractive options to be sedentary, such as TV viewing and computer game playing. If indeed these factors are important, the small effect for interventions could be seen as encouraging. That is, we are able to change behaviour, at least in the short term, in the context of unhelpful physical and social environments. However, more work is needed to increase the potency of intervention effects over the short and long term.

The meta-analysis showed that results are heterogeneous. Moreover, despite the small overall effect size, there were trends showing larger effects in certain contexts or groups. There was support for educational interventions, which is not too surprising given the young age being studied, but also there was support for interventions that used multiple components (e.g. education plus environmental change). The latter is an important issue to consider in future studies as some strategies, such as education, maybe more effective when other elements are in place, as consistent with social-ecological theory (Stokols, 1992). For example, educating children about the benefits of walking to school can only be helpful if the local environment near the school is relatively traffic-free, or there are attractive and safe routes to walk to school. However, it will remain a challenge to achieve some changes to the environment in the short term due to logistical or financial difficulties. This means that behaviour change sometimes has to take place without positive changes to the environment, and it is here that further work is needed. Similarly, data showed that there were larger effects for interventions that focussed on diet as well as physical activity. While there is not always agreement on whether single or multiple health behaviours should be targeted, it could be argued that for this age group an approach reaching across health behaviours could help focus the children on mutually beneficial behaviours and provide a stronger focus on behaviour change. Single behaviours may get lost when competing with other behaviours and influences across the day.

Results showed that interventions were more effective when the intervention was quite short. This may be accounted for by the motivation and interest being kept higher for this younger population. Children may get bored with longer interventions or the intensity of the intervention may be unsustainable over longer periods. But a challenge here is to maintain initial changes in behaviour.

Stronger effects were noted for studies that were of higher quality but also were atheoretical. The results for higher quality studies is encouraging as it suggests that the significant overall effect size is unlikely to be an artefact of other study characteristics or confounders. However, why atheoretical studies should be more effective than those using a theory is contrary to expectation. While theory is often advocated as an essential element in intervention design (Bartholomew, Parcel, Kok, & Gottlieb, 2006), it may be the case that specific behaviour change techniques (Michie et al., 2011) can be successful without being

planned within a theoretical framework. This needs further testing. Moreover, some interventions may be simply environmental changes, or provision of extra physical activity opportunities – factors that may lead to behaviour change without reference to theory. Indeed, trends in psychology suggest that often we make changes to our behaviour with less cognitive processing than previously thought. Such 'automatic' processing effects may account for successful behaviour change yet will not fit with the typical theoretical frameworks of social-cognitive psychology.

An important finding was that showing a higher effect size for interventions that targeted just girls rather than boys and girls together. While one might expect such a finding for adolescent girls, due to self-presentation issues such as body image, it appears to be also the case for younger girls. If this finding is confirmed (the effect size is only derived from 6 studies so some caution is required), organising physical education and other structured physical activity contexts might require greater use of single sex provision.

Finally, the interventions reviewed used different methods to assess physical activity. While most studies had some objective assessment, the effect size for interventions using both objective and self-report methods was higher. One reason for this may be that outcomes are more precisely assessed with the objective monitoring tools, and hence having less measurement error, and at the same time maybe triggering behaviour change through creating greater awareness of physical activity by using the self-report instruments. This needs further testing.

Overall, the meta-analysis shows that physical activity interventions for pre-adolescent girls are effective but show a small effect. Analyses show greater effectiveness for interventions that are educational, multi-component, atheoretical but high quality, target physical activity and diet together, last less than 12 weeks, and are with girls only. Future studies should aim to strengthen the evidence base for interventions among young girls with rigorous designs, longer follow-ups, use of objective measures, and assessment of potential mediators of behaviour change. Furthermore, although the decline of physical activity in young girls is well-documented, there are girls whose physical activity does not follow this pattern. Future studies should target such girls in an effort to understand the motives and facilitators of being and remaining physically active in different contexts and settings.

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Table 1. Intervention characteristics of included studies aiming to increase physical activity among adolescent girls (k=22)

Author (year), country	Intervention name	Design	Setting	Participants	Description of intervention and control conditions
(Baranowski et al., 2003), US	GEMS Fun, Food and Fitness Project (FFFP)	Pilot RCT	Community	n=35 (child and family), aged 8 years. N=19 intervention and n=16 control	Intervention group: summer camp for 4 weeks plus 8 weeks of internet programme at home. Camp mixed usual activities with interactive activities to promote intake of fruit and vegetables and physical activity, including decision making, problem solving, and goal setting. Participants asked to log on to internet programme once a week after summer camp. Control group: summer camp for 4 weeks, containing usual camp activities only. Internet programme contained links to general health and homework websites. Participants asked to log on once a month.
(Beech et al., 2003), US	Memphis GEMS	Pilot RCT	Community / Family	n=60 African-American girls, mean age 8.9 years. N=21 in intervention 1 (child targeted); n=21 in intervention 2 (parent targeted); n=18 in control.	Intervention group 1: child targeted: 12 weeks' duration. Focus on nutrition and physical activity. Weekly 90 minute session covering aerobics, reducing sedentary activity, and promoting intake of fruit and vegetables and other healthy diet practices. Intervention group 2: parent targeted: 12 weeks' duration. Weekly 90 minute session. Physical activity component focused on dancing; other components included nutrition, food preparation, and nutrition related games. Control group: 12 weeks' duration. 3× 90 minute sessions per month. Focus on self-esteem; neutral for diet and physical activity.
(Bergh et al., 2012), Norway	Health In Adolescents study (HEIA)	Group RCT	School plus	N=129 girls in intervention group and n=263 girls in the control group. Mean age: 11.2	The intervention was designed to increase environmental opportunities for PA at school, improve social support, self-efficacy and enjoyment in order to enhance overall level of PA. The PA components included: active commuting campaigns, sports equipment for recess activities, posters in

				(SD 0.3) years	classrooms, one class-room lesson including PA in relation to energy-balance, weekly activity breaks during lessons, 2 inspirational courses for physical education teachers presenting instructional material for PE lessons based on the SPARK Program, a computer tailoring program including PA behaviour, fact sheets for parents and yearly kick-off meetings for the teachers.
(Bugge et al., 2012), Denmark	Copenhagen School Child Intervention Study (CoSCIS)	Controlled study	School only	N=148 girls in the intervention group and n=119 in the control group. Mean age: 6.7 (SD: 0.4) years.	The program consisted of four constituent parts. First, an increase in the amount of PE lessons from 90 to 180 min/wk, given as two double sessions each week. The extra PE session was administered by the normal PE teachers, and the content was not controlled or supervised by the researchers. The goal of the PE sessions was to make fun activities with a high level of intensity and incorporating both strength and cardiovascular training. The final planning and execution of the lessons were done by the PE teachers; thus, the situation resembles ‘‘a real-world scenario.’’ Second, the children were given lessons in health education, focusing on the importance of PA and healthy eating. Third, the PE teachers received three to four full days a year of supplementary training focused on didactic tools to enhance the children’s motivation for and enjoyment of PA and, at the same time, keeping the intensity in PE lessons moderate to vigorous. Fourth, indoor and outdoor PE and playing facilities were upgraded

					in all intervention schools. Control schools: usual curriculum.
(Ernst & Pangrazi, 1999), US	PLAY	Treatment control repeated measures design	School only	28 classes (14 intervention and 14 control) of children in 4th, 5th and 6th Grade elementary school	Intervention PLAY. Step 1 (4-weeks): students participate in a 15-minute activity break during each school day. Teachers would prompt students to move (week 1), during weeks 2-4 teachers taught and participated in a variety of games and activities. Step 2 (8-weeks) students were no longer given activity breaks, they were asked to record all activity in a log book and meet goals: spend at least 30 mins daily being active outside of school; be active at least 5 times a week; record daily activity in log book. Controls had a modified version of PLAY, step 1 had activity breaks, but teachers were not encouraging activity. Step 2 students were asked to log their TV time rather than activity.
(French et al., 2005), US	Cal-Girls	RCT	Community	322 girls aged 10.5 years (15 groups in intervention and 15 groups in control)	Intervention group: 2 years' duration, ten 90 minute sessions in each year at troop meetings. Focus on developing behavioural skills to choose calcium rich foods and engage in weight-bearing physical activity. Included group goal setting, interactive web based programme, and summer camp for one week. Parents also targeted through web based programme. Troop leaders received training and delivered intervention. Control group: usual troop meeting activities
(Gentile et al., 2009), US	Switch what you Do, View and Chew	RCT	Community, school and family	224 girls, mean age 9.6 years. (84 girls in intervention schools, and 140 in control schools)	The specific Do, View and Chew goals were to be active for 60 minutes or more per day, to limit total screen time to less than 2 hours per day, and to eat five FV or more per day. Community component of awareness (advertising). School component designed to re-inforce Switch messages and facilitate family component. Family component designed to provide parents and children with materials and resources to

					facilitate the adoption of healthy target behaviours. Control families/schools received no materials.
(Goran & Reynolds, 2005), US	IMPACT	RCT	Classroom and home	36 girls in control group (mean age 9.5 (0.4 years) and 35 in intervention group (mean age 9.3 (0.4) years)	The intervention consisted of eight CD-ROM interactive animated lessons (45 minutes per lesson), four classroom lessons (45 minutes per lesson), and four family-based assignments (45 minutes per assignment), for a total of 12 hours of contact delivered over 8 weeks. The classroom and family components allowed students to enact behaviour, skills, knowledge, and attitudes learned while using the interactive computer program. The control group did not receive the IMPACT CD-ROM, they received a control intervention consisting of a variety of popular educational CD-ROMSs not relating to health topics
(Horne, et al., 2009), UK	No name	RCT	School only	26 girls in intervention school and 24 girls in control school. Aged 9-11 years.	Intervention (weeks 1-2): letter read out to all participants to encourage them to be active. Each child received daily step target and a personalised letter from the Fit n' Fun Dudes. Targets were determined by baseline level of PA and required an increase of 1500 steps per day. Participants also received a CD with the theme song and lyrics. On each day participants needed to reach or exceed their targets to qualify for the daily reward. Maintenance (weeks 3-14) phase aimed to support participants in maintaining their increases activity levels. Participants recorded daily steps in a diary and were sent letters during weeks 3, 9 and 13 with encouragement.
(Huberty, et al., 2011), US	Ready for Recess	Controlled study	School only	141 girls (n=23 in 'equipment and staff training (EQ+ST)' group;	Before the Ready for Recess intervention, all recess staff, teachers associated with recess, school nurses/health aides, and school principals from EQ+ST and ST schools attended a staff

				n=37 in 'staff training (ST)' group; n=45 in 'equipment only' group; and n=36 in the control group). Children were in 3rd-6th grade of elementary school.	training session (half day), which consisted of 1) introduction and overview of Ready for Recess and responsibilities of recess activity aides, 2) education on working with youth in an activity setting (maximizing PA, addressing misbehavior, motivating children for PA, and organizing activity zones were addressed), and 3) exposure to and participation in activity zone activities. Trainers provided tips for organizing games and fostering maximal activity during recess. EQ+ST and EQ schools were provided recreational equipment (balls, hula hoops, nets etc.) and asked to contact the research assistants if they had any questions about how to use the equipment. Staff from the control school did not attend any training sessions. They received all equipment and materials that the other schools received at the end of post-intervention data collection.
(Klesges et al., 2010), US	Memphis GEMS	RCT	Community	230 girls (110 intervention, mean age 9.3 (0.9) years and 120 alternative intervention, mean age 9.3 (0.9) years)	Intervention: weekly meetings for 14 weeks and then monthly for 20 months (34 sessions over 2 years). Sessions lasted 90 minutes. Girls and their parents participated in the intervention through a combination of separate and joint sessions. Girls developed behavioural goals (e.g. increase MVPA). Behavioural strategies included skill building, self-monitoring etc. Parents were encouraged to make changes in the home food environment. Alternative intervention was designed to improve self-esteem and social efficacy (no focus on PA, diet or

					weight).
(Loucaides, Jago, & Charalambous, 2009), Cyprus	No name	RCT	School only	36 girls in intervention school 1, 39 girls in intervention school 2 and 39 girls in control group. Mean age 11.1 (0.3) years.	Intervention1: the school's courts were allocated to different children on alternate days of the week, playground markings were painted in the school's yard and jump ropes were provided. Children were divided into teams and played the games of their choice. They were taught rules and were assigned to collect an distribute balls. Intervention 2: the school's courts were allocated to different children on alternate days of the week, no playground markings or jump ropes. Control: no games were organised or equipment handed out.
(Manios, Kafatos, Kafatos, & Preventive Med Nutrition Clinic, 2006), Greece	No name	Controlled study	School and parents	223 females (97 control and 126 intervention). Mean age 6.3 (0.4) years for total sample at baseline.	Intervention group: 6 years' duration. Health and nutrition component (13-17 hours over academic year), physical fitness, and activity component (2×45 minute physical education sessions per week and 4-6 hours of classroom sessions per year), and homework. Parents given booklets on nutrition and physical activity. Control group: standard physical education classes.

(Pangrazi, Beighle, Vehige, & Vack, 2003), US	PLAY	Controlled study	School only	149 girls aged 9.8 years (0.6). 93 intervention and 56 in control groups.	Intervention group 1 (PLAY + PE): impact of promoting lifestyle activity for youth (PLAY) programme and physical education: 12 weeks' duration. Usual physical education programme plus daily sessions, with class teachers facilitating 15 minutes of physical activity. Focus moved from teachers prompting activity to encouraging children to be self-directed. Students kept log book of physical activity outside school. Intervention group 2 (PLAY only): as above but did not include physical education programme. Control group 1 (PE only): usual physical education programme only, for 12 weeks. Students kept log book of activities outside school (sedentary and physical activities). Control group 2: no treatment: no PLAY or physical education programme. Students kept log book as above.
(Ridgers, Stratton, Fairclough, & Twisk, 2007), UK	No name	Controlled study	School only	126 girls in intervention group (mean age 8.1(1.7) years) and 112 controls (mean age 8.1(1.5) years)	Intervention schools received £20,000 to re-design their playground environment based on sporting playground zonal design. The physical activity structures that the school received included goal posts, hoops and fencing around sports and seating areas. Equipment was also made available. Control schools received no funding.
(Rosenkranz, Behrens, & Dzewaltowski, 2010), US	SNAP (Scouting Nutrition and Activity Program)	RCT	Girl scouts and parents	33 intervention girls aged 10.6 (1.1) years and 39 control girls aged 10.5(1.3) years.	Intervention had three main components: (1) an interactive educational curriculum delivered by troop leaders (8 modules delivered over 4 months); (2) Troop meeting policies implemented by troop leaders; (3) Badge assignments completed at home with parental assistance. Control: standard care intervention
(Sallis et al., 1997), US	SPARK	RCT	School plus home	124 girls in intervention group 1; 156 girls	Intervention group 1: 2 years' duration (grades 4 and 5). Specialist led physical education classes three 30 minute sessions per week and weekly self-

				in intervention group 2; 169 girls in control group. Aged between 9.49-9.62 years.	management session (30 minutes) to teach behaviour change skills to help generalise to regular physical activity outside school. Included homework and monthly newsletters. Specialists received on-going training and supervision from investigators. Intervention group 2: as above but teacher led. Teachers received extensive in-service training programme, which decreased in frequency over the intervention group period. Also had consultations with physical education specialists, ranging from biweekly to bimonthly during the intervention group period. Control group: usual physical education programmes but schools provided with sufficient physical education equipment to carry out sports, play, and active recreation for kids (SPARK) programme, as with intervention.
(Salmon, Ball, Hume, Booth, & Crawford, 2008), Australia	Switch Play	RCT	School only	Girls aged 10 years. 28 girls in BM group; 36 in BM/FMS group; 30 in FMS group; 25 in control group.	There were two intervention components: a behavioural modification (BM) condition and an FMS condition. These intervention components were delivered in addition to the usual physical education and sports classes. Each of the intervention conditions consisted of 19 lessons (40–50 min each), which were delivered by one qualified physical education teacher from March to November 2002 (1 school year in Australia). Classes were randomly allocated to a BM only condition, an FMS only condition, a combined BM/FMS condition (2 19 lessons) or a control (usual curriculum) group. Children in the BM/FMS condition received both the BM and FMS lessons, therefore receiving double the dose of the other intervention groups. The BM lessons were delivered in the classroom and incorporated: self-monitoring (increasing children's

					awareness of time spent in physical activity and screen behaviours); the health benefits of physical activity; awareness of the home and community physical activity, and sedentary behaviour environments; decision-making and identifying alternatives to screen behaviours that included designing their own physical activity games; intelligent TV viewing and reducing viewing time; advocacy of reduced screen time through poster displays and role plays; use of pedometers; and group games including all children in the BM condition at each of the schools . From Lessons 11 to 14, children completed a weekly contract undertaking to switch off one television programme per week over the 4-week period (that is, they switched off one programme for the week of Lesson 11, two programmes for Lesson 12 and so on). A newsletter was sent home to parents of children in the BM or combined BM/FMS condition asking them to sign their child's switch-off contracts each week to confirm that the nominated programme was turned off, and after Lesson 14 parents were encouraged to help their child maintain the switch-off. The FMS lessons were delivered either in the indoor or outdoor physical activity facilities at each school (dependent on the weather and accessibility). Through games and activities developed for this intervention, these lessons focused on mastery of six FMS. The interventionist taught the skills with an emphasis on enjoyment and fun through games and maximum involvement for all the children. Most lessons focused on at least two skills. The six skills

					were selected on the basis that they are commonly used in children's games, sports and physical activities.
(Stevens et al., 2003), US	Pathways	RCT	School	357 girls in intervention and 329 in control) mean age 7.6 years	Intervention group: 3 years' duration (grades 3-5). Included classroom curriculum (two lessons per week for 12 weeks in grades 3 and 4, 8 weeks in grade 5), physical activity (minimum of three 30 minute sessions per week of MVPA), family involvement (nine events at school plus information sent home), and changes to food service (to promote healthy eating). Control group: usual curriculum
(Story et al., 2003), US	Girlfriends for KEEPS (part of GEMS)	RCT	School plus family	53 girls (26 intervention and 27 control) aged 9.3(0.9) years	Intervention group: 12 weeks' duration. Two after school club sessions per week, focusing on healthy eating; increasing frequency of physical activity; decreasing time in sedentary activity; and experiencing feeling enjoyment, competence, and confidence; also had weekly take home packs for family, two family nights, and two phone calls a week. Control group: after school club, with no diet or physical activity information (three sessions over 12 weeks)
(Verstraete, Cardon, De Clercq, & De Bourdeaudhuij, 2006), Belgium	No name	RCT	School only	47 girls in intervention group and 67 in control group. Children aged 10.8-10.9 years	Intervention group: 3 months' duration. Classes provided with game equipment and activity cards with examples of games and activities. Teachers asked to encourage children daily to play with equipment during morning, lunch, and afternoon breaks. Control group: no provision of equipment or cards
(Wright, Giger, Norris, & Suro, 2013), US	Kids N Fitness	Parallel-group RCT	School plus	N=70 girls in intervention group and n=80 in the control	Intervention schools received two components, a school-level environmental intervention and the KNF intervention. The lifestyle intervention program, Kids N Fitness (KNF), that was used in this study is

				group. Mean age range 8.3 (SD: 1.1) years to 9.0 (SD: 1.6) years.	a 6-week afterschool program with weekly 90-min sessions conducted by registered nurse, trained community health workers and a physical education specialist. Sessions consisted of three components: physical activity, nutrition education/behaviour modification, and family involvement. The physical activity component lasted 45 min and was taught by a physical education specialist. The major focus was on reducing sedentary behaviors that may compete with activity. In addition, students learned creative ways to exercise in a non-structured exercise program, including culturally and developmentally appropriate approaches including, warm-up and stretching, basketball, soccer, Hip Hop and Salsa dancing, relay race activities, jump rope, power walking, and running. During the exercise portion parents were taught the implications of obesity in children and adults, and the importance of healthy lifestyles to prevent obesity. In addition parents participated in a parent support group, moderated by a registered nurse where they were able to discuss their challenges and success stories regarding diet and exercise modification. Following the exercise, children and parents were given a 45-min nutrition education/behavioral modification session. Environmental interventions at the school-level included: School Wellness Policy involving dietary

					changes, staff professional development; at the community-level included, establishing partnerships with local community clinics for health and mental health services; and, home-level activities included parental outreach via bi-monthly educational newsletters mailed to their homes. Control group: usual practice.

Table 2. Coding Information for Studies (K=22) meeting Inclusion Criteria

	Intervention Characteristics							Sample Characteristics			Study Characteristics	
Study	**Type**	**Focus**	**Level**	**Time**	**Follow-up**	**Theory**	**Quality**	**Population**	**N**	**Country**	**Setting**	**Measure**
(Baranowski, et al., 2003)	ED	PAD	I	1	N	T	H	G	35	US	C	O
(Beech, et al., 2003)	ED	PAD	I	1	N	T	H	G	60	US	C+	M
(Bergh, et al., 2012)	M	PA	S	2	N	T	L	BG	736	W	S+	O
(Bugge, et al., 2012)	M	PA	S	2	Y	A	L	BG	260	W	S	O
(Ernst & Pangrazi, 1999)	M	PA	C	1	N	A	M	BG	644*	US	S	O
(French, et al., 2005)	ED	PAD	G	2	N	T	L	BG	296	US	C	S
(Gentile, et al., 2009)	M	O	S	2	Y	T	H	BG	1323	US	S	O
(Goran & Reynolds, 2005)	M	PA	S	1	N	T	M	BG	209	US	S+	O
(Horne, et al., 2009)	M	PA	S	2	Y	A	M	BG	100	W	S	O
(Huberty, et al., 2011)	EN	O	PA	2	N	T	L	BG	45	US	S	O
(Klesges, et al., 2010)	EN	O	I	2	N	A	H	G	303	US	C	O
(Loucaides, et al., 2009)	EN	PA	S	1	Y	A	M	BG	247	W	S	O
(Manios, et al., 2006)	ED	PA	A	2	Y	T	L	BG	425	W	S+	S
(Pangrazi, et al., 2003)	ED	PA	S	1	N	A	L	BG	606	US	S	O
(Ridgers, et al., 2007)	EN	PA	S	2	Y	A	M	BG	470	W	S	M
(Rosenkranz, et al., 2010)	ED	PAD	G	2	N	T	H	G	76	US	C+	M
(Sallis, et al., 1997)	M	PA	S	2	N	A	M	BG	955	US	S+	M
(Salmon, et al., 2008)	ED	O	C	2	Y	T	H	BG	268	W	S	O
(Stevens, et al., 2003)	ED	PAD	S	2	N	T	M	BG	1447	US	S	S
(Story, et al., 2003)	ED	PAD	I	1	N	T	H	G	54	US	S+	O
(Verstraete, et al., 2006)	EN	PA	S	2	N	A	M	BG	235	W	S	O
(Wright, et al., 2013)	M	PAD	S	1	Y	A	M	BG	190	US	S+	O

Note. Type (Intervention Type): ED = Educational, EN = Environmental, M = Multicomponent. Focus (Intervention Focus): O = Obesity-Related Behaviors, PA = Physical Activity Only, PAD = Physical Activity AND Diet. Level (Level of Randomization). C = Class, I = Individual, S = School, G = Intact Group. Time (Intervention Length): 1 = less than or equal to 12 weeks, 2 = greater than 12 weeks. Follow-up (Intervention Follow-Up AFTER Post Test): N = No, Y = Yes. Theory (Theoretical Foundation): T = Theoretical, A = Atheoretical. Quality (Study Quality): L = Low Delphi score < 3, M = Moderate Delphi score between 4 and 6, H = High Quality Delphi Score > 6. Population (sample composition) BG = Boys and Girls, GO = Girls Only. Country (Participants Country of Origin): US = United States, W = Rest of World. Setting (Study Setting): C = Community, C+= Community and Family, S = School-Based, S+ = School and Outside of School. Measure (Study Outcome Measures) O = Objective, M = Objective & Self-Report, S = Self Report. *minimum estimate of sample size.

Table 3. Children's Physical Activity Subgroup Analyses

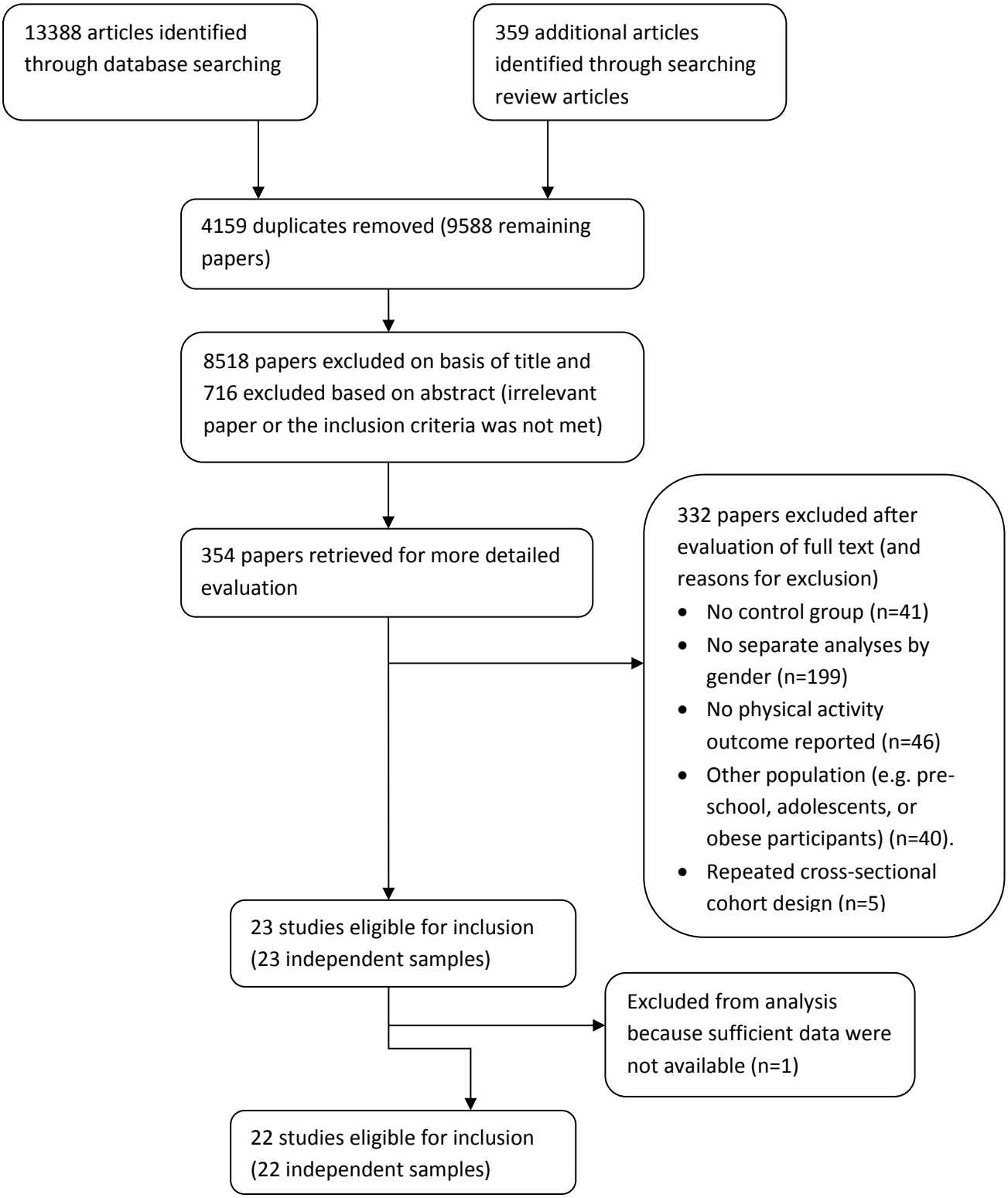
	Effect Size Statistics					Null Test	Heterogeneity Statistics			Publication Bias
Subgroup Variables	***k***	***g***	***SE***	s^2	***95% C.I.***	***Z***	***Q***	τ^2	I^2	**Fail Safe *N***
Random Effects Model [A]	22	0.314	0.103	0.011	(0.112, 0.516)	3.050*	346.37*	0.199	93.94	545
Intervention Characteristics [B]										
Intervention Type							7.502 [B]			
Educational	9	0.414	0.176	0.031	(0.070, 0.759)	2.357*		0.067	82.43	
Environmental	4	-0.301	0.252	0.064	(-0.795, 0.194)	-1.191		1.174	98.11	
Multicomponent	9	0.503	0.169	0.028	(0.172, 0.833)	2.980*		0.174	93.17	
Intervention Focus							1.857 [B]			
Obesity Related	3	0.413	0.301	0.090	(-0.177, 0.889)	1.002		0.414	97.78	
PA and Diet	7	0.535	0.217	0.047	(0.111, 0.959)	2.471*		0.088	73.38	
PA Only	12	0.183	0.155	0.024	(-0.121, 0.742)	1.179		0.263	95.04	
Randomisation Level							10.54 [B]			
Area	1	0.147	0.417	0.174	(-0.671, 0.964)	0.352		0.000	0.000	
Class	2	0.262	0.318	0.101	(-0.362, 0.885)	0.822		0.376	89.77	
Girl Scout	2	0.215	0.357	0.127	(-0.484, 0.913)	0.602		0.000	0.000	
Individual	4	1.026	0.241	0.058	(0.554, 1.499)	4.258*		0.000	0.000	
School	13	0.165	0.120	0.014	(-0.069, 0.400)	1.384		0.172	94.53	
Intervention Time							4.969 [B]			
≤12 weeks	8	0.636	0.177	0.031	(0.290, 0.983)	3.598*		0.026	40.94	
> 12 weeks	14	0.155	0.124	0.015	(-0.088, 0.398)	1.251		0.214	95.76	
Intervention Follow-up							0.001 [B]			

No	14	0.313	0.139	0.019	(0.042, 0.585)	2.261*		0.329	95.64	
Yes	8	0.321	0.173	0.030	(-0.018, 0.659)	1.855		0.066	84.93	
Theoretical Approach							3.892 [B]			
Atheoretical	10	0.526	0.149	0.022	(0.235, 0.817)	3.540*		0.154	91.82	
Theoretical	12	0.120	0.142	0.020	(-0.158, 0.399)	0.848		0.232	94.38	
Intervention Quality							8.090 [B]			
High	7	0.588	0.198	0.039	(0.200, 0.976)	2.970*		0.348	94.15	
Low	6	-0.170	0.206	0.042	(-0.573, 0.233)	-0.828		0.404	97.16	
Moderate	9	0.448	0.169	0.029	(0.116, 0.781)	2.646*		0.049	79.01	
Sample Characteristics [B]										
Population							7.522* [B]			
Boys and Girls	16	0.174	0.103	0.011	(-0.028, 0.377)	1.685		0.150	93.01	
Girls Only	6	0.774	0.193	0.037	(0.396, 1.152)	4.016*		0.143	72.35	
Country							0.791 [B]			
World	6	0.351	0.156	0.024	(0.045, 0.657)	2.248*		0.115	88.44	
US	12	0.525	0.119	0.014	(0.293, 0.758)	4.431*		0.129	89.91	
Study Characteristics [B]										
Setting							4.490 [B]			
Community	3	0.776	0.293	0.086	(0.201, 1.351)	2.643*		0.192	71.22	
Community + Family	2	0.585	0.343	0.118	(-0.088, 1.258)	1.705		0.201	77.59	
School	10	0.147	0.142	0.020	(-0.131 0.425)	1.035		0.265	96.08	
School + Outside	7	0.326	0.171	0.029	(-0.009, 0.662)	1.905		0.019	60.07	
Measure							1.124 [B]			
Objective	13	0.239	0.151	0.023	(-0.057, 0.535)	1.585		0.356	96.23	
Objective & Self-Report	4	0.578	0.282	0.080	(0.025, 1.130)	2.049*		0.226	85.17	
Self-Report	5	0.249	0.248	0.062	(-0.152, 0.822)	1.350		0.011	44.25	

Note. *k* = number of effect sizes. *g* = effect size (Hedges g). *SE* = standard error. S^2 = variance. 95% *C. I*. = confidence intervals (lower limit, upper limit). *Z* = test of null hypothesis.τ^2 = between study variance in random effects model. I^2 = total variance unexplained by moderator. *

indicates $p < .01$. A = Total *Q*-value used to determine heterogeneity. B = Between *Q*-value used to determine significance between subgroups ($\alpha < 0.01$).

Figure 1. Flow chart describing the study-identification process



Study name	Subgroup within study	Comparison	Outcome	Hedges's g	p-Value
Horne et al. 2007	Combined	Combined	Steps (pedometers)	1.406	0.000
Story et al. 2003	Intervention	Control	Combined	1.160	0.000
Klesges et al. 2010	Combined	Combined	Combined	1.140	0.000
Beech et al. 2003	Combined	Control	Combined	0.929	0.000
Ernst and Pangrazi 1999	Combined	Combined	PAQC PA	0.772	0.004
Baranowski et al. 2003	Intervention	Control	Combined	0.723	0.054
Pangrazi et al. 2003	Combined	Control	steps	0.545	0.000
Wright et al. 2013	Intervention	Control	PA	0.411	0.005
Goran and Reynolds 2005	Intervention	Control	Combined	0.388	0.169
Verstraete et al. 2006	Intervention	Control	Combined	0.349	0.067
Ridgers et al. 2007	Combined	Combined	Combined	0.291	0.002
Loucaides et al. 2009	Combined	Control	Combined	0.273	0.090
Rosenkranz et al. 2010	Intervention	Control	days per week of 60 mins MVPA	0.225	0.337
Gentile et al. 2009	Combined	Combined	Steps (pedometers)	0.217	0.026
French et al. 2005	Intervention	Control	Weight-bearing PA score	0.191	0.591
Stevens et al. 2003	Combined	Combined	Physical activity score	0.181	0.000
Manios et al. 2006	Combined	Combined	Combined	0.146	0.125
Bergh et al. 2012	Intervention	Control	PA counts	0.124	0.131
Sallis et al. 1997	Combined	Control	Combined	0.110	0.175
Bugge et al. 2012	Combined	Combined	Combined	0.090	0.264
Salmon et al. 2008	Combined	Combined	MVPA	-0.119	0.195
Huberty et al. 2011	Combined	Combined	MVPA	-2.137	0.000
				0.312	0.002

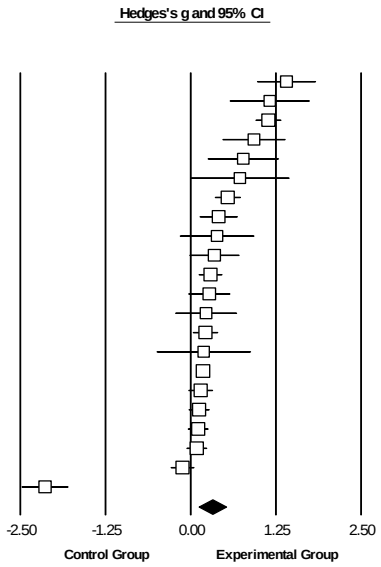


Figure 2: Forrest Plot for Adolescent Girls Physical Activity Interventions