Sports Med (2014) 44:67–79
DOI 10.1007/s40279-013-0099-9

SYSTEMATIC REVIEW

Do School-Based Interventions Focusing on Physical Activity, Fitness, or Fundamental Movement Skill Competency Produce a Sustained Impact in These Outcomes in Children and Adolescents? A Systematic Review of Follow-Up Studies

Samuel K. Lai · Sarah A. Costigan · Philip J. Morgan · David R. Lubans · David F. Stodden · Jo Salmon · Lisa M. Barnett

Published online: 12 October 2013

Abstract
Background There is emerging evidence for positive associations between physical activity (PA), fitness, and fundamental movement skill (FMS) competence, for both children and adolescents. Current reviews of interventions to improve these variables note few studies conduct follow-up assessments to assess behavior maintenance.
Objective The aim of this systematic review was to determine whether typically developing children and adolescents (aged 3–18 years) who have participated in school-based interventions have sustained outcomes in PA, fitness, and/or FMS.
Methods A systematic search of six electronic databases (CINAHL® Plus with Full Text, Ovid MEDLINE®, SPORTDiscus™, Scopus, PsycINFO® and ERIC) was conducted from 1995 to 26 July 2012. Included studies were school-based studies (including randomized controlled trials, longitudinal cohort, quasi-experimental, and experimental) that had a positive effect at post intervention in at least one variable and had a follow-up PA, fitness, or FMS assessment at least 6 months after the post-intervention assessment. Risk of bias assessment was guided by the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" statement.
Results The search identified 14 articles, and some studies addressed multiple outcomes: 13 articles assessed PA; three assessed fitness; and two assessed FMS. No study in this review met four key methodological criteria that have been shown to influence results, i.e., clarity on the randomization process, assessor blinding, analyzing participants in their original groups, and retaining sufficient participants through the entire study. Three-quarters (ten of 13) of the studies addressing PA, reported PA behavior change maintenance. The length of follow-up ranged from 6 months to 20 years, and the degree of PA difference reported was between 3 and 14 min per day. Only one of the three studies assessing fitness reported a sustained impact, whilst both studies that assessed FMS reported maintenance of effects.
Conclusion It is likely that PA is a sustainable outcome from interventions in children and adolescents, and there is reasonable evidence that interventions of longer than 1 year and interventions that utilize a theoretical model or framework are effective in producing this sustained impact. It would seem probable that FMS are a sustainable outcome in children and adolescents; however, this finding should be viewed with caution given the lack of studies and the risk of bias assessment. More research is needed to assess the sustainability of fitness interventions as this review only included a handful of studies that addressed fitness and only one of these studies found a sustained impact.

Electronic supplementary material The online version of this article (doi:10.1007/s40279-013-0099-9) contains supplementary material, which is available to authorized users.

S. K. Lai · L. M. Barnett (✉)
Faculty of Health, School of Health and Social Development, Deakin University, Melbourne, VIC, Australia
e-mail: lisa.barnett@deakin.edu.au

S. A. Costigan · P. J. Morgan · D. R. Lubans
Faculty of Education and Arts, Priority Research Centre in Physical Activity and Nutrition, University of Newcastle, Newcastle, NSW, Australia

D. F. Stodden
Department of Physical Education and Athletic Training, University of South Carolina, Columbia, SC, USA

J. Salmon
Faculty of Health, Centre for Physical Activity and Nutrition, Deakin University, Melbourne, VIC, Australia

1 Introduction

Insufficient physical activity (PA) is a global health issue [1, 2]. According to newly collated data from 105 countries, 80 % of youth aged 13–15 years did not meet the recommended public health guidelines of 60 min of PA per day [3]. A recent study of 10- to 12-year-old European children also reported that 83 % of boys and 95 % of girls did not meet recommended PA guidelines (60 min/day) [4]. Similarly, a longitudinal study conducted in the USA found that by age 15, 69 % of adolescents did not meet the recommended guidelines for PA (60 min/day) on weekdays and 83 % did not meet the guidelines on weekends [5]. As PA participation may promote various aspects of physical fitness, and fitness may be a stronger predictor of health than PA [6, 7], there is concern regarding declining youth fitness levels. Data collected between 1958 and 2003 for 6- to 19-year-olds from 27 countries found that aerobic performance had declined substantially since 1970 [8].

An important factor associated with young people's PA and fitness levels is their fundamental movement skill (FMS) competence. As context-specific skill development is another form of PA, particularly in younger children's leisure activity behaviors, it is an important aspect of PA in its own right. There is a growing body of evidence supporting the association between FMS, PA, and various aspects of health-related fitness. Lubans et al. [9] conducted the first systematic review in this area and generally found strong evidence for positive associations between FMS competence, PA, and fitness for both children and adolescents. Other research also supports an association between FMS and PA [10, 11] and FMS and fitness [12, 13]. This suggests that in order to understand how young people's health may be synergistically affected by these three factors, researchers need to understand how amenable they are to change via intervention.

Stodden et al. [14] proposed a developmental model that hypothesizes reciprocal relationships between PA, health-related fitness and actual and perceived FMS competence. The model also hypothesizes that the cumulative effect of factors within the model would be associated with a healthy weight status over time. Recent cross-sectional [15–18] and longitudinal data [19, 20] support this notion. It is hypothesized that synergistic positive trajectories of each factor over time will result in a healthy weight status, whereas a negative trajectory will lead to a higher prevalence of overweight/obesity [13, 14, 20–22]. At the core of the model is the reciprocal nature of the association between PA and the development of FMS competence. In the early childhood years, children who are physically active initially improve their capability to control and coordinate their center of mass and extremities in a gravity-based environment that promotes the attainment of 'motor milestones,' specifically posture-based movement and locomotor skills (e.g., upright posture, crawling, walking, running) [14, 23]. However, as FMS development progresses over time, children's PA levels may be partially attributed to their actual FMS competence and related choices of activities, which are also linked to their perceptions of competence, success, and intrinsic motivation to participate [14, 24]. In effect, actual FMS competence may become a primary determinant of PA [14]. Health-related fitness is described as a mediator to this central relationship as levels of various aspects of fitness (i.e., muscular strength/endurance and cardiorespiratory endurance) are also associated with the development and performance of FMS [13, 14, 25–30].

Thus, it is not surprising that these outcomes have been the focus of numerous preschool and school-based interventions with associated multiple systematic reviews [31–37]. What is notable throughout these reviews is the general consensus that intervention studies need to conduct long-term follow-ups beyond post-intervention testing to assess intervention effect maintenance [9, 31–34, 36, 38]. It is suggested the ultimate goal of any intervention that aims to change behavior and improve outcomes ought to be maintenance, and that evidence of sustained improvements should be compiled. This supposition is supported by health promotion frameworks such as the "Bangkok Charter" [39] and the understanding that achieving long-term outcomes is a key consideration when planning health promotion programs [40]. An intervention that has been proven to be effective in the long-term has implications for policy decisions, government spending, and ultimately the health of children and adolescents as they progress to adulthood [32, 41].

Maintaining PA behavior across childhood is especially important, given the age-related decline that currently occurs during the transition from childhood to adolescence [5, 42]. Of equal concern is that a continued decline in PA during adolescence is then more likely to translate to low PA during adulthood [43]. Taking into account the decline in fitness and the relationship between these factors and FMS [9], sustaining all three outcomes (i.e., PA, fitness, and FMS) in children and adolescents is therefore desirable.

To our knowledge, no published systematic reviews have collated PA, fitness, or FMS intervention studies that have a follow-up assessment that occurs beyond the immediate intervention end point. Therefore, the objective of this systematic literature review was to determine whether PA, fitness, and FMS are sustainable outcomes in typically developing children and adolescents who have participated in school-based interventions measuring one or more of these variables.

2 Methods

2.1 Identification of Studies

A structured electronic literature search was conducted in accordance with standards set forth in the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA) statement [44]. Six electronic databases (CINAHL® Plus with Full Text, Ovid MEDLINE®, SPORTDiscus™, Scopus, PsycINFO® and ERIC) were searched from 1995 to 26 July 2012, in order to identify PA, fitness, or FMS intervention follow-up studies in typically developing children and adolescents. The following search strings were used: (physical activit* OR motor skill* OR exercise* OR movement skill* OR fitness) AND (child* OR adolescen* OR student*) AND (school* OR preschool* OR kindergarten OR education*) AND (intervention* OR program* OR stud*) AND (sustain* OR follow-up OR long term OR long-term). These strings were further limited to those aged 3–18 years and English language. Only articles published in peer-reviewed journals were considered.

In addition to identifying studies through the database search, studies from authors' own bibliographic libraries were assessed for possible inclusion. After duplicate removal, studies were initially assessed by screening titles and abstracts. If suitability could not be determined during this process, full-text articles were accessed and compared against inclusion criteria. The reference lists of retrieved full-text articles and other systematic reviews were also examined for relevant studies.

2.2 Selection Criteria

Four authors (SKL, LMB, SAC, and DRL) independently assessed the eligibility of studies for inclusion using the following criteria:

1. Participants were aged 3–18 years. Studies describing interventions targeting children and/or adolescents with specific diseases or health problems were excluded (e.g., cerebral palsy, obesity).
2. Interventions were primarily preschool or school based. Interventions that were predominantly preschool or school based but had take-home components were included.
3. Interventions aimed to improve and assess PA, fitness, or FMS. Studies that did not aim to improve and assess at least one of these outcomes were excluded.
4. Intervention duration was greater than or equal to 4 weeks.
5. Studies used a control group, as the causal relationship between an intervention and its desired outcomes is best demonstrated using the comparison of a control and intervention group [45].
6. Studies reported a significant intervention effect between intervention and control groups for the outcomes of interest at post-intervention testing.
7. Studies described follow-up intervention and control group PA and/or fitness and/or FMS assessment data. Follow-up assessment was defined as data collection that occurred at least 6 months after post-intervention testing. Previous research has considered this to be adequate time to assess maintenance [32] and the transtheoretical model suggests that maintenance of behavior is achieved after a 6-month period [46].
8. Interventions that solely comprised changes to the school built environment were not included as there was no defined intervention period and therefore it was not possible to distinguish between post-intervention and follow-up assessments.

2.3 Criteria for Risk of Bias Assessment

Two authors (DRL and PJM) independently assessed the risk of bias of the included studies using the methodological items as defined in Table 1. Each item was coded as 'explicitly described and present' (✔), 'absent' (✘), or

Table 1 Methodological quality checklist

A	Randomization (generation of allocation sequence, allocation concealment and implementation) clearly described and adequately completed
B	Valid measures of PA, FI, or FMS (validation in same age group has been published or validation data were provided by the author)
C	Blinded outcome assessment (positive when those responsible for assessing FMS proficiency were blinded to group allocation of individual participants)
D	Participants analyzed in the group they were originally allocated to, and participants not excluded from analyses because of non-compliance to treatment or because of some missing data
E	Covariates accounted for in analyses (e.g., baseline score, group/cluster for cluster RCTs, and other relevant covariates where appropriate, such as age or sex)
F	Power calculation reported for primary outcome (i.e., PA, FI, or FMS)
G	Presentation of baseline characteristics separately for treatment groups (age + sex + at least one outcome measure)
H	Dropout for primary outcome described, with ≤30 % dropout at follow-up
I	Summary results for each group + estimated effect size (difference between groups) + its precision (e.g., 95 % confidence interval)

FI fitness, *FMS* fundamental movement skills, *PA* physical activity, *RCT* randomized controlled trial 'unclear or inadequately described' (?). Inter-rater reliability was calculated on a dichotomous scale (✔ = 1 vs. ✖ or ? = 0) using percentage agreement. Depending on the study design, some items were coded as not applicable (N/A) and were not included in agreement calculations. Disagreements between authors were resolved by discussion.

The risk of bias assessment was guided by recommendations made in the PRISMA statement [47]. As suggested in the PRISMA statement, the methodological items chosen to assess risk of bias were selected on the basis of the type of studies included in the review and empirical evidence [47]. The individual items were not numerically summarized to give a final score, rather each criterion was considered in isolation [47]. Criteria A, C, D, and H were regarded as the most significant items in which bias could have an impact on results [47, 48].

2.4 Categorization of Sustained Impact

Sustained impact was defined as a statistically significant difference in the outcomes of interest (PA, fitness, FMS) between the intervention group and the control group at follow-up. It was still considered a sustained impact if only one of the sub-populations tested (i.e., just females) had a significant difference between the intervention and control groups. Each included study was summarized according to its relevant intervention components, rather than simply a division between those studies with a sustained impact and those without. This allowed for a clear representation of those studies that had two outcomes of interest, but may have only found a sustained impact in one of them. In order to quantify sustained impact, the percentage of studies in which intervention groups still demonstrated significant effects at follow-up was calculated for each outcome of interest.

3 Results

3.1 Overview of Study Characteristics

The identification of studies followed the PRISMA guidelines (Fig. 1). Fourteen studies were included in the final review, and their characteristics are summarized in Table 2. A wide variety of countries were represented in the reviewed studies, including: Australia [49, 50], Canada, [51–53] Crete [54, 55], England [56], Hong Kong [57], Iran [58], Norway [59], Poland [60], and the USA [61, 62]. Baseline sample sizes ranged from 161 [58] to 5,106 participants [62], and the mean participant age at baseline ranged from 6.3 years [54, 55] to 14.8 years [58].

Eleven interventions were conducted with elementary school aged children [49–57, 61, 62] and three with adolescents [58–60]. The majority of studies targeted PA (13/14). Nine studies targeted PA in isolation [52, 53, 55–59, 61, 62], two studies targeted PA in combination with fitness [54, 60], and two studies targeted PA in combination with FMS [49, 50]. One study addressed fitness in isolation [51].

3.2 Overview of Intervention Components and Follow-up Length

Intervention methods and the results of each study at both post-intervention and follow-up data assessment are summarized in the Electronic Supplementary Material, Table S1. Intervention duration ranged from 6 weeks [57] to 6 years [51–55]. The lowest percentage of the original sample retained at follow-up was 24.4 % [51] and the highest was 100 % [58]. Three studies had a follow-up length of 12 months or less [50, 57, 58], and 11 studies had a follow-up length greater than 12 months [49, 51–56, 59–62].

3.3 Risk of Bias Assessment

The risk of bias assessments for the included studies are summarized in Table 3. Inter-rater reliability indicated adequate percentage agreement (94 %) for the 126 items. Nine of the 14 studies used a valid measure for PA, fitness, or FMS [49–51, 54, 56–58, 60, 62], with PA representing the most commonly reported item across the studies. Assessor blinding was reported in two studies [50, 62], and in only three studies, participants were analyzed in their allocated group and not excluded because of missing data or non-compliance [50, 56, 62]. Six studies adequately accounted for covariates in their analysis [50, 54, 56, 59, 61, 62], and only one reported a power calculation for one of the outcomes of interest [57]. One study reported a power calculation for BMI, which was not one of the outcomes of interest, and thus it was not taken into account during the risk of bias assessment [50]. Baseline characteristics were adequately reported in only one study [58], and summary results, effect size, and precision were reported in only one study [62]. Adequate retention ($\leq$30 % dropout at follow-up) was reported in four studies [56–58, 62]. Of the six randomized controlled trials, only two clearly described and adequately completed the randomization process [57, 60].

3.4 Physical Activity

PA was an outcome of interest at follow-up in 13 (93 %) of the included studies [49, 50, 52–62]. A summary of the studies that found a sustained impact at follow-up is found in Table 4.

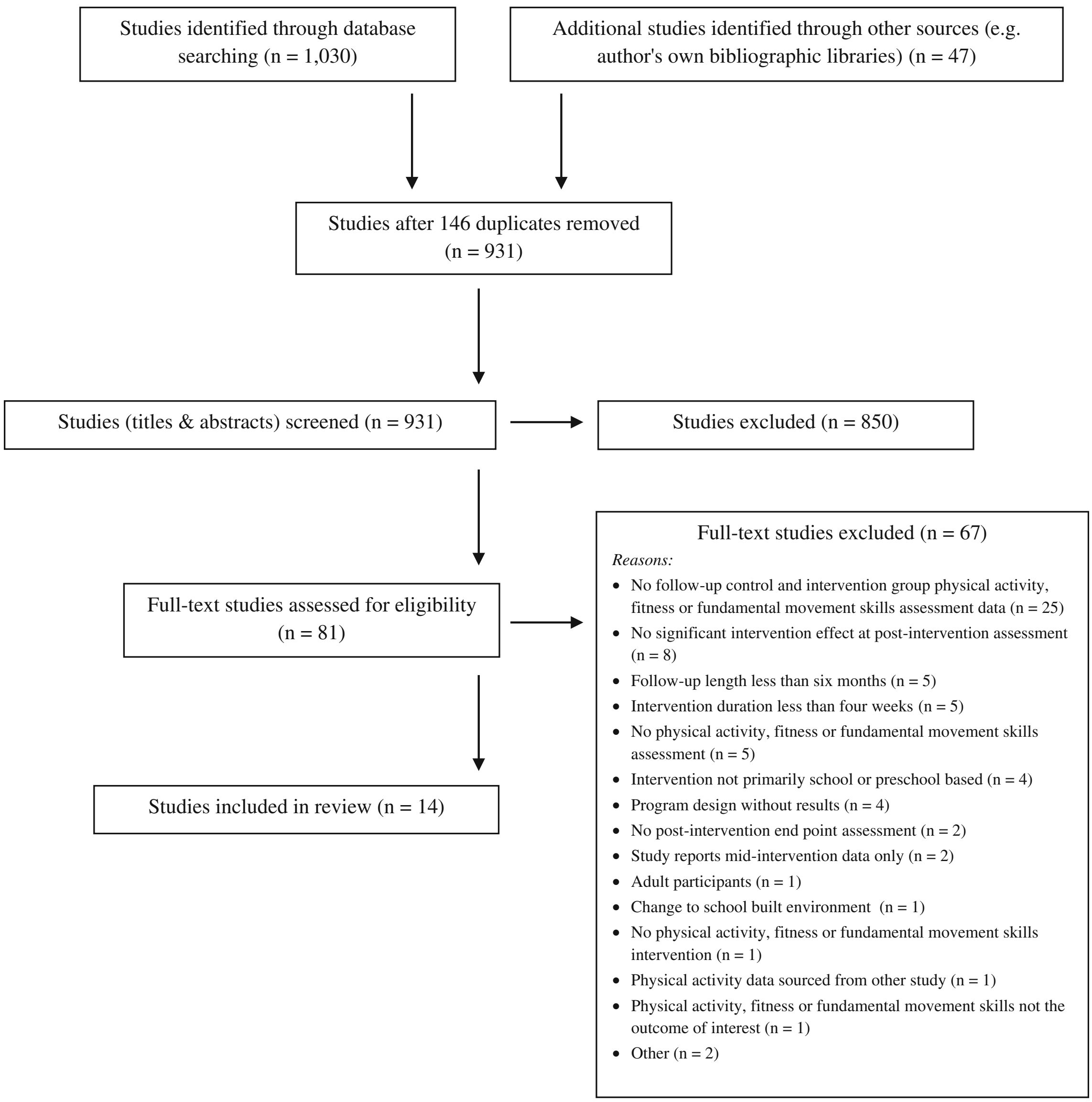

Fig. 1 Study progression during inclusion/exclusion

3.4.1 Sustained Impact

At follow-up data assessment (ranging from 6 months to 20 years), ten (77 %) of the 13 studies that measured PA reported a sustained impact in one or more of the PA variables [50, 52–55, 58–62]. Two studies reported a sustained impact for females only [52, 53] and one study for males only [55]. One study had two different intervention groups, but a sustained impact was only found for one of them [58]. A sustained PA impact was found in the following variables: moderate-to-vigorous PA (MVPA) in minutes per week [54, 55]; frequency of vigorous PA (VPA) in a week [52, 53, 59]; VPA in minutes per day [50, 62]; PA in minutes per day averaged across a 6-day period [58]; moderate PA in minutes per day [50]; number of days per week in which children participated in leisure time PA [60]; out of class exercise hours per week [61]; percentage of participants meeting recommended PA guidelines [55]; and total step counts per day [50]. Nine studies used a self-report method of assessment [52–55, 58–62], and one used accelerometers [50].

The greatest difference for time spent in PA between control and intervention groups at follow-up was a mean value of 14 min per day, averaged across a 6-day period [58]. When averaged across 7 days, Salmon et al. [50] reported mean differences in PA ranging from 3 to 10 min per day at follow-up. Other mean differences averaged across 7 days reported between control and intervention groups included 4 min [54], 5.5 min [61], 7 min [61], and 8 min [62].

Seven of the interventions were based upon a theoretical model or framework [50, 54, 55, 58, 60–62] and the

Table 2 Characteristics of included studies

Study	Sample at baseline (F, M)	Mean age at baseline	Setting	Country	Study design
Barnett et al. [49]	1,045 children (F = 491, M = 554)	10.1 years	School	Australia	Longitudinal cohort
Bronikowski and Bronikowska [60]	369 adolescents (F = 170, M = 199)	13.2 years	School	Poland	Randomized controlled trial
Gorely et al. [56]	589 children (F = 302, M = 287)	8.8 years	School	England	Experimental
Kelder et al. [61]	2,376 children (F = NR, M = NR)	6th grade	School	USA	Longitudinal quasi-experimental
Klepp et al. [59]	827 children and adolescents (F = NR, M = NR)	12.5 years	School	Norway	Randomized controlled trial
Manios and Kafatos [54]	716 children (F = 378, M = 338) [55]	6.3 years [55]	School	Crete	Longitudinal cohort
Manios et al. [55]	716 children (F = 378, M = 338)	6.3 years	School	Crete	Longitudinal cohort
McManus et al. [57]	210 children (F = 105, M = 105)	10.4 years	School	Hong Kong	Randomized controlled trial
Nader et al. [62]	5,106 children (F = 2,461, M = 2,645)	8.8 years	School	USA	Randomized controlled trial
Salmon et al. [50]	311 children (F = 159, M = 152)	10 years 8 months	School	Australia	Randomized controlled trial
Taymoori et al. [58]	161 adolescents (F = all)	14.8 years	School	Iran	Randomized controlled trial
Trudeau et al. [52]	546 children (F = 257, M = 289) [63]	7 years [63]	School	Canada	Quasi-experimental
Trudeau et al. [53]	546 children (F = 257, M = 289) [63]	7 years [63]	School	Canada	Quasi-experimental
Trudeau et al. [51]	546 children (F = 257, M = 289) [63]	7 years [63]	School	Canada	Quasi-experimental

F female, *M* male, *NR* not reported

strategies utilized included health education [58, 59, 61], physical education [52, 53, 60], a combination of health education and physical education [54, 55, 62] and health education and FMS lessons [50]. Intervention duration ranged from 6 months [58] to 6 years [52–55].

3.4.2 No Sustained Impact

Three studies did not find a sustained impact for the outcome of PA at follow-up (ranging from 6 months to 6 years) in any variable assessed [49, 56, 57]. The methods of assessment utilized were self-report [49], heart rate monitors [57], and a combination of pedometers and accelerometers [56]. All three of the interventions were based on a theoretical model or framework [49, 56, 57], and the specific intervention strategies utilized were multi-component [49, 56] and an intervention that provided feedback about heart rate after participating in PA [57]. Intervention duration ranged from 6 weeks [57] to 12 months [49].

3.5 Fitness

Fitness was an outcome of interest at follow-up in three (21 %) of the included studies [51, 54, 60]. A summary of the studies that found a sustained impact at follow-up is found in Table 4.

3.5.1 Sustained Impact

At follow-up data assessment, one of the three studies that addressed fitness reported a sustained impact [60]. This study had an intervention duration of 15 months and a follow-up of 15 months. It involved a physical education program based upon Hellison's theoretical model [64], and the fitness variables assessed included cardiovascular endurance, muscular power, and muscular endurance.

3.5.2 No Sustained Impact

Two studies did not find a sustained impact for the outcome of fitness at follow-up (ranging from 4 to 20 years) [51, 54]. The fitness variables assessed in these studies included cardiovascular endurance [54], and physical work capacity, handgrip strength, flexibility, and abdominal muscular endurance [51]. One of the interventions was based on a theoretical model or framework [54], and the strategies utilized included physical education [51] and a combination of health education and physical education [54].

3.6 Fundamental Movement Skills

FMS were the outcome of interest in two (14 %) of the included studies, as shown in Table 4.

Table 3 Summary of risk of bias assessment of included studies

Study	A	B	C	D	E	F	G	H	I
Barnett et al. [49]	N/A	✔ (PA) ✘ (FMS)	✘	✘	✘	✘ (PA) ✘ (FMS)	✘	✘	✘
Bronikowski and Bronikowska [60]	✔	✔ (PA) ✘ (FI)	✘	✘	✘	✘ (PA) ✘ (FI)	✘	✘	✘
Gorely et al. [56]	N/A	✔ (PA)	✘	✔	✔	✘ (PA)	✘	✔	✘
Kelder et al. [61]	N/A	✘ (PA)	?	✘	✔	✘ (PA)	✘	✘	✘
Klepp et al. [59]	✘	✘(PA)	✘	✘	✔	✘ (PA)	?	✘	✘
Manios and Kafatos [54]	N/A	✔ (PA) ✔ (FI)	✘	✘	✔	✘ (PA) ✘(FI)	✘	✘	✘
Manios et al. [55]	N/A	? (PA)	✘	✘	✘	✘(PA)	✘	✘	✘
McManus et al. [57]	✔	✔ (PA)	✘	✘	✘	✔ (PA)	✘	✔	✘
Nader et al. [62]	✘	✔ (PA)	✔	✔	✔	✘ (PA)	✘	✔	✔
Salmon et al. [50]	?	✔ (PA) ? (FMS)	✔	✔	✔	✘ (PA) ? (FMS)[a]	✘	?	✘
Taymoori et al. [58]	✘	✔ (PA)	✘	✘	✘	✘ (PA)	✔	✔	✘
Trudeau et al. [52]	N/A	? (PA)	✘	✘	✘	✘ (PA)	✘	✘	✘
Trudeau et al. [53]	N/A	? (PA)	✘	✘	✘	✘ (PA)	✘	✘	✘
Trudeau et al. [51]	N/A	✔ (FI)	✘	✘	✘	? (FI)	✘	✘	✘

'A,' 'B,' 'C,' 'D,' 'E,' 'F,' 'G,' 'H,' and 'I' are methodological quality checklist criteria. Please refer to Table 1 for their definitions

FI fitness, *FMS* fundamental movement skills, *N/A* not applicable, *PA* physical activity, ✔ explicitly described and present, ✘ absent, *?* unclear or inadequately described

[a] Power calculation was conducted for BMI, which was the primary outcome of this study

3.6.1 *Sustained Impact*

Both studies reported a sustained impact at follow-up (ranging from 6 to 12 months) [49, 50]. A sustained impact was found in the following FMS: kicking [49, 50], throwing [49, 50], catching [49], striking [50], sprinting [50], and jumping [50]. Both interventions were based on a theoretical model or framework [49, 50], and the strategies were multi-component [49] and a combination of health education and FMS lessons [50].

4 Discussion

4.1 Overview of Findings

The purpose of this systematic review was to determine whether there is evidence of a sustained impact in PA, fitness, and FMS as a result of interventions conducted in education settings. Sustained impact was defined as a statistically significant difference in the outcomes of interest (PA, fitness, FMS) between the intervention group and the control group at follow-up. Of the 13 studies that had PA as an outcome of interest at follow-up, ten found a sustained impact. Whilst only one of the three studies that addressed fitness at follow-up reported a sustained impact, both studies that assessed FMS reported a sustained impact.

4.2 Risk of Bias

All included studies in this review were at risk of some bias, as none of the studies met all four of the methodological criteria that have been shown to have the most influence on results: the randomization process, assessor blinding, analyzing participants in their original groups, and retaining participants through the entire study [47, 48]. Adequate retention ($\leq$30 % dropout at follow-up) was only reported in four of the included studies [56–58, 62], and given the focus of the current review, this is of particular concern.

4.3 Major Findings and Potential Contributors to Sustained Impact

A recent review found that even a slight increase in PA is associated with health benefits, especially in high-risk children and adolescents, and may have an important impact at the population level [65]. As such, the mean differences in PA minutes per day from the current review are encouraging, considering the duration of some of the

Table 4 Summary of sustained physical activity, fitness, and fundamental movement skills outcomes at follow-up

Intervention component	Sustained impact	Study	Proportion of studies that addressed this component in which there was a sustained impact
Physical activity	Yes	Bronikowski and Bronikowska [60]	77 % (10/13)
		Kelder et al. [61]	
		Klepp et al. [59]	
		Manios and Kafatos [54]	
		Manios et al. [55]	
		Nader et al. [62]	
		Salmon et al. [50]	
		Taymoori et al. [58]	
		Trudeau et al. [52]	
		Trudeau et al. [53]	
	No	Barnett et al. [49]	
		Gorely et al. [56]	
		McManus et al. [57]	
Fitness	Yes	Bronikowski and Bronikowska [60]	33 % (1/3)
	No	Manios and Kafatos [54]	
		Trudeau et al. [51]	
Fundamental movement skills	Yes	Barnett et al. [49]	100 % (2/2)
		Salmon et al. [50]	
	No		

follow-ups. The greatest mean difference between intervention and control groups was found to be 14 min per day; however, this was averaged over 6 days, rather than 7 days [58]. Whilst this study had one of the shorter follow-up lengths (6 months), it did meet the criteria for adequate retention [58]. Another notable difference found between intervention and control groups was 8 min of PA per day [62]. This study had a follow-up length of 3 years, yet it was the most robust study according to the risk of bias assessment. It met three of the four criteria that can have the greatest effect on results, including adequate retention [62].

Based on a cursory assessment of intervention length and the noted sustainability effects, it is likely that intervention duration is related to sustained PA impact. Eight of the ten studies that found a sustained impact for PA had intervention durations of greater than 1 year [52–55, 59–62]. In comparison, all three of the studies that produced no sustained PA impact had interventions of 1 year or less [49, 56, 57]. This is consistent with previous recommendations that longer intervention duration is required to affect PA behavior in children [32]. This is also consistent with the transtheoretical model and the understanding that a change in behavior must be sustained for at least 6 months for it to be considered behavior maintenance [46].

It is suggested utilizing a theoretical model may have produced a sustained impact in PA. Seven of the interventions that reported a sustained impact on PA were based on a theoretical model or framework [50, 54, 55, 58, 60–62]. For instance, Taymoori et al. [58] reported the sustained impact of their intervention on adolescent girls' PA. In a subsequent paper, they demonstrated that changes in PA were mediated by changes in theoretical constructs from the health promotion and transtheoretical models [66]. This finding is consistent with the adult literature, whereby theory-based PA interventions appear to be more successful than atheoretical approaches [67, 68]. Although, evidence for the importance of theory for guiding youth interventions has been cited as less convincing [69] and all three of the studies in the current review that did not find a sustained impact on PA also cited a theoretical framework [49, 56, 57]. Future research that examines the effectiveness of different theoretical constructs as mediators of change in youth PA, FMS, and fitness, particularly in the long-term, should be a priority.

There is good evidence that FMS are a sustainable outcome, as both studies that addressed FMS reported significant differences between intervention and control groups at follow-up assessment [49, 50]. Motor learning theory proposes that once a skill has been learnt, an individual has acquired a relatively permanent change in their ability to perform that skill [70, 71], and hence maintenance would be expected. Both of the interventions were conducted with elementary school aged children [49, 50], and this supports the notion that the elementary school years are the optimal age to learn FMS [72, 73] and more recent reviews that demonstrate interventions designed to improve motor skill proficiency in children are effective [74, 75]. Both studies also involved direct teaching strategies for the outcome of FMS, and this method has been shown to be successful when targeting FMS in children [31]. However, considering the limited number of studies in the current review and that adequate retention was not demonstrated for follow-ups of 12 months [50] and 6 years [49], these results should be viewed with caution. Additionally, one of these studies did not meet any of the four methodological criteria that have been demonstrated to bias results [49]. Therefore, it is suggested that these findings would be enhanced by further research and that future FMS intervention studies should conduct long-term follow-ups with more rigorous experimental designs, especially in relation to adequate retention.

Given that both studies assessed PA in conjunction with FMS, this does have implications for the proposed strengthening over time of the relationship between FMS and PA [14]. For example, Salmon et al. [50] followed-up their child participants (10- to 11-year-olds) after 12 months and found a sustained impact for both outcomes. Extrapolating from the developmental model, it would be expected that a higher level of PA would also be evident in adolescents with better FMS, and previous research does support this [76]. Barnett et al. [26] did find this relationship between FMS and PA with a longitudinal analysis, not distinguishing between control and intervention participants. Given that this same relationship was not found when examining for intervention and control differences suggests that the Barnett et al. [49] study may not have been adequately powered or the original intervention may not have improved FMS sufficiently to find this relationship.

4.4 Mixed Findings and Future Research Needs

The wide-ranging assessments of PA across studies (e.g., number of days per week in which children participated in leisure time PA [60] and out of class exercise minutes per week [61]) make it difficult to compare PA results across studies. Previous research has found that MVPA is considered health enhancing and beneficial in terms of promoting healthy weight in children and adolescents [35, 77–79]. However, only two studies within the current review that found a sustained impact on PA behavior used this universally recognized variable to assess PA [54, 55]. It is recommended that future studies utilize MVPA as their unit of measurement. It is also worthwhile noting that nine of the ten studies that found a sustained impact for PA used a self-report method of assessment [52–55, 58–62]. The reliance on measurements of a subjective nature (such as self-report) when assessing PA is a concern that has been highlighted by a previous review [80]. In support of that finding, only four of the studies from the current review that found a sustained impact for PA utilized a valid self-report assessment tool according to the risk of bias assessment [54, 58, 60, 62].

It is difficult to discuss the effectiveness of maintaining fitness variables in youth as only one of the three studies found a sustained impact [60]. Fitness is a characteristic that requires on-going training of appropriate specificity to be sustained and improved [81]. As the authors did not provide specific details regarding the fitness content, dose, and intensity of this intervention, it is hard to ascertain what exactly produced the fitness maintenance results [60]. Given the lack of studies assessing fitness at follow-up, reasons for a lack of sustained impact are also unknown. It may be that interventions were not specific enough (e.g., combination of endurance, strength, and power exercises without a focus on a particular dimension) or the dosage, duration, and/or intensity of the exercise intervention was not adequate to elicit statistically significant changes in specific aspects of musculoskeletal fitness when compared with the effect of growth and maturation changes associated with control groups. However, more research is needed to assess the sustainability of fitness interventions.

No PA, fitness, or FMS intervention studies conducted in a preschool met the inclusion criteria of this review. It is suggested that future research aims to determine whether these outcomes are sustainable in preschool aged children.

4.5 Strengths and Limitations

This is the first systematic review of studies examining the sustainability of PA, fitness, and FMS in children and adolescents. A key strength of this review was the use of the PRISMA statement to guide the structured electronic literature search and the risk of bias assessment. Another strength was the wide variety of countries in which the studies were conducted.

However, a number of limitations have been identified. A lack of studies meeting the inclusion criteria of this review limit the conclusiveness of these results, especially in the area of FMS and fitness interventions. The number of included studies at risk of bias, especially in regard to adequate retention, was also a concern. It is recommended that in the future, experimentally designed studies adhere to guidelines such as the "Consolidated Standards of Reporting Trials" (CONSORT) [82] and "Transparent

Reporting of Evaluations with Nonrandomized Designs" (TREND) [83] statements. The reliance on measurements of a subjective nature in the included studies assessing PA is another weakness, as suggested in a previous review [80]. It has been argued that at least 12 months is required to detect maintenance effects [34]. Had this more stringent criterion been adopted, one study that found a sustained impact would have been excluded from the current review [58]. There was a theoretical basis for using the 6-month maintenance criterion applied in the current review. The transtheoretical model suggests that maintenance of behavior change is achieved after a 6-month period [46]. As time and budget constraints often make longitudinal studies less feasible, the number of studies eligible for the final review may also have been limited by a stricter inclusion criteria.

5 Conclusion

It is highly likely that PA is a sustainable outcome from interventions in children and adolescents, with mean differences of up to 14 min per day found between intervention and control groups. There is reasonably strong evidence that interventions of longer than 1 year and interventions that utilize a theoretical model or framework are effective in producing sustained impact. It would seem probable that FMS are a sustainable outcome in children and adolescents; however, this finding should be viewed with caution given the lack of studies and the high risk of bias in previous studies. More research is needed to assess the sustainability of fitness interventions as this review only included a handful of studies that addressed fitness and only one of these studies found a sustained impact. Future PA interventions should utilize an objective measure of MVPA as their unit of measurement, and more PA, fitness, and FMS studies with long-term follow-ups should be conducted, specifically focusing on preschool-aged children.

Based on our findings and the lack of studies meeting our inclusion criteria, there are a number of implications for researchers, department of education authorities, and healthcare providers. While a number of included studies reported positive findings for a sustained impact on PA, fitness, and FMS, a key challenge is ensuring the adoption of programs within the school setting for the long term, which is evidenced by the lack of follow-up studies assessing these outcomes. Strategies to ensure promising interventions are translated and sustained without researcher support should be considered as well. However, schools face considerable barriers to delivering quality PA programs [84, 85]. For example, many countries employ classroom teachers to deliver PE in elementary schools [86] who lack the competence and confidence to deliver programs, despite believing in the benefits of PA and PE [87]. Given the primary school years are considered an optimal time to develop FMS [72, 73], are a critical period for PA behaviors [5, 42], and many studies do not conduct post-intervention follow-ups, training, support, and resources may need to be prioritized in the post-intervention phase so interventions are implemented as intended and benefits are consequently sustained and assessed.

Overall, it is important to understand whether PA, fitness, and FMS interventions can have sustained effects, not only on their respective attributes, but also in promoting sustained trajectories of these factors across childhood, adolescence, and even into adulthood. In addition, what is it about interventions that may lead to these sustained effects? As suggested by Stodden et al. [14], FMS competence may be a key determinant of PA behavior across time and the proposed synergistic relationships among FMS, PA, and fitness may strengthen over time. It would be important to investigate causal mechanisms relating to the development of these factors, their influence on maintenance effects across time and also how they may impact obesity [20–22], which is a major health issue associated with each of these factors. If we can develop a better understanding of how to develop and sustain adequate PA, fitness, and FMS concomitantly, it would seem to be an optimal strategy to promote positive and sustainable health outcomes.

Acknowledgments No sources of funding were used to assist in the preparation of this review. The authors have no potential conflicts of interest that are directly relevant to the content of this review. LMB is supported by a National Health and Medical Research Council Early Career Fellowship (APP 1013507). JS is supported by a National Health and Medical Research Council Principal Research Fellowship (APP1026216).

References

1. World Health Organization. Global health risks: mortality and burden of disease attributable to selected major risks. 2009 (online). http://www.who.int/healthinfo/global_burden_disease/GlobalHealthRisks_report_full.pdf. Accessed 30 Apr 2012.
2. Kohl HW 3rd, Craig CL, Lambert EV, et al. The pandemic of physical inactivity: global action for public health. Lancet. 2012;380(9838):294–305.
3. Hallal PC, Andersen LB, Bull FC, et al. Global physical activity levels: surveillance progress, pitfalls, and prospects. Lancet. 2012;380(9838):247–57.
4. Verloigne M, Van Lippevelde W, Maes L, et al. Levels of physical activity and sedentary time among 10- to 12-year-old boys and girls across 5 European countries using accelerometers: an observational study within the ENERGY-project. Int J Behav Nutr Phys Act. 2012;9(1):34–41.
5. Nader PR, Bradley RH, Houts RM, et al. Moderate-to-vigorous physical activity from ages 9 to 15 years. JAMA. 2008;300(3):295–305.

6. Rizzo NS, Ruiz JR, Hurtig-Wennlof A, et al. Relationship of physical activity, fitness, and fatness with clustered metabolic risk in children and adolescents: the European youth heart study. J Pediatr. 2007;150(4):388–94.
7. Williams PT. Physical fitness and activity as separate heart disease risk factors: a meta-analysis. Med Sci Sports Exerc. 2001;33(5):754–61.
8. Tomkinson GR, Olds TS. Secular changes in pediatric aerobic fitness test performance: the global picture. Med Sport Sci. 2007;50:46–66.
9. Lubans DR, Morgan PJ, Cliff DP, et al. Fundamental movement skills in children and adolescents: review of associated health benefits. Sports Med. 2010;40(12):1019–35.
10. Kambas A, Michalopoulou M, Fatouros IG, et al. The relationship between motor proficiency and pedometer-determined physical activity in young children. Pediatr Exerc Sci. 2012;24(1):34–44.
11. Lopes VP, Rodrigues LP, Maia JAR, et al. Motor coordination as predictor of physical activity in childhood. Scand J Med Sci Sports. 2011;21(5):663–9.
12. Hands B, Larkin D, Parker H, et al. The relationship among physical activity, motor competence and health-related fitness in 14-year-old adolescents. Scand J Med Sci Sports. 2009;19(5):655–63.
13. Stodden D, Langendorfer S, Roberton MA. The association between motor skill competence and physical fitness in young adults. Res Q Exerc Sport. 2009;80(2):223–9.
14. Stodden DF, Goodway JD, Langendorfer SJ, et al. A developmental perspective on the role of motor skill competence in physical activity: an emergent relationship. Quest. 2008;60(2):290–306.
15. Castetbon K, Andreyeva T. Obesity and motor skills among 4 to 6-year-old children in the United States: nationally-representative surveys. BMC Pediatr 2012;12(1):28.
16. D'Hondt E, Deforche B, Vaeyens R, et al. Gross motor coordination in relation to weight status and age in 5- to 12-year-old boys and girls: a cross-sectional study. Int J Pediatr Obes. 2011;6(2 Pt 2):E556–64.
17. Zhu Y-C, Wu SK, Cairney J. Obesity and motor coordination ability in Taiwanese children with and without developmental coordination disorder. Res Dev Disabil. 2011;32(2):801–7.
18. Lopes VP, Stodden DF, Bianchi MM, et al. Correlation between BMI and motor coordination in children. J Sci Med Sport. 2012;15(1):38–43.
19. Lopes VP, Maia JAR, Rodrigues LP, et al. Motor coordination, physical activity and fitness as predictors of longitudinal change in adiposity during childhood. Eur J Sport Sci. 2012;12(4):384–91.
20. Rodrigues LP, Leitão R, Lopes VP. Physical fitness predicts adiposity longitudinal changes over childhood and adolescence. J Sci Med Sport. 2013;16(2):118–23.
21. D'Hondt E, Deforche B, Gentier I, et al. A longitudinal analysis of gross motor coordination in overweight and obese children versus normal-weight peers. Int J Obes. 2013;37(1):61–7.
22. Martins D, Maia J, Seabra A, et al. Correlates of changes in BMI of children from the Azores islands. Int J Obes. 2010;34(10):1487–93.
23. Clarke JE, Metcalfe JS. The mountain of motor development: a metaphor. In: Clarke JE, Humphrey JH, editors. Motor development: research and reviews, vol. 2. Reston: National Association for Sport and Physical Education; 2002. p. 163–90.
24. Barnett LM, Morgan PJ, van Beurden E, et al. Perceived sports competence mediates the relationship between childhood motor skill proficiency and adolescent physical activity and fitness: a longitudinal assessment. Int J Behav Nutr Phys Act. 2008;5:1–12.
25. Barnett LM, Van Beurden E, Morgan PJ, et al. Does childhood motor skill proficiency predict adolescent fitness? Med Sci Sports Exerc. 2008;40(12):2137–44.
26. Barnett LM, van Beurden E, Morgan PJ, et al. Childhood motor skill proficiency as a predictor of adolescent physical activity. J Adolesc Health. 2009;44(3):252–9.
27. Behringer M, vom Heede A, Matthews M, et al. Effects of strength training on motor performance skills in children and adolescents: a meta-analysis. Pediatr Exerc Sci. 2011;23(2):186–206.
28. Haga M. The relationship between physical fitness and motor competence in children. Child Care Health Dev. 2008;34(3):329–34.
29. Hands B. Changes in motor skill and fitness measures among children with high and low motor competence: a five-year longitudinal study. J Sci Med Sport. 2008;11(2):155–62.
30. Stodden DF, True LK, Langendorfer SJ, Gao Z. Associations among selected motor skills and health-related fitness: indirect evidence for Seefeldt's proficiency barrier in young adults? Res Q Exerc Sport. 2013;84(3):397–403.
31. Dudley D, Okely A, Pearson P, et al. A systematic review of the effectiveness of physical education and school sport interventions targeting physical activity, movement skills and enjoyment of physical activity. Eur Phys Educ Rev. 2011;17(3):353–78.
32. Dobbins M, DeCorby K, Robeson P, et al. School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6–18. Cochrane Database Syst Rev 2009;CD007651.
33. Kriemler S, Meyer U, Martin E, et al. Effect of school-based interventions on physical activity and fitness in children and adolescents: a review of reviews and systematic update. Br J Sports Med. 2011;45(11):923–30.
34. Salmon J, Booth ML, Phongsavan P, et al. Promoting physical activity participation among children and adolescents. Epidemiol Rev. 2007;29(1):144–59.
35. Strong WB, Malina RM, Blimkie CJR, et al. Evidence based physical activity for school-age youth. J Pediatr. 2005;146(6):732–7.
36. Timperio A, Salmon J, Ball K. Evidence-based strategies to promote physical activity among children, adolescents and young adults: review and update. J Sci Med Sport. 2004;7(1 Suppl.):20–9.
37. van Sluijs EMF, McMinn AM, Griffin SJ. Effectiveness of interventions to promote physical activity in children and adolescents: systematic review of controlled trials. BMJ. 2007;335(7622):703–7.
38. National Institute for Health and Clinical Excellence. Promoting physical activity, active play and sport for pre-school and school-age children and young people in family, pre-school, school and community settings. 2009 (online). http://www.nice.org.uk/nicemedia/live/11773/42883/42883.pdf. Accessed 29 Mar 2012.
39. World Health Organization. The Bangkok charter for health promotion in a globalized world 2005 (online). http://www.who.int/healthpromotion/conferences/6gchp/hpr_050829_%20BCHP.pdf. Accessed 30 Jul 2013.
40. Jones RA, Sinn N, Campbell KJ, et al. The importance of long-term follow-up in child and adolescent obesity prevention interventions. Int J Pediatr Obes. 2011;6(3/4):178–81.
41. Veugelers PJ, Fitzgerald AL. Effectiveness of school programs in preventing childhood obesity: a multilevel comparison. Am J Publ Health. 2005;95(3):432–5.
42. Pate RR, Freedson PS, Sallis JF, et al. Compliance with physical activity guidelines: prevalence in a population of children and youth. Ann Epidemiol. 2002;12(5):303–8.
43. Matton L, Thomis M, Wijndaele K, et al. Tracking of physical fitness and physical activity from youth to adulthood in females. Med Sci Sports Exerc. 2006;38(6):1114–20.
44. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. J Clin Epidemiol. 2009;62(10):1006–12.

45. Burns N, Grove SK. The practice of nursing research: conduct, critique, and utilization. 5th ed. St Louis: Elsevier/Saunders; 2005.
46. Prochaska J, Redding C, Evers K. The transtheoretical model and stages of change. In: Glanz K, Rimer B, Viswanath K, editors. Health behavior and health education: theory, research and practice. 4th ed. San Francisco: Wiley; 2008. p. 97–121.
47. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. J Clin Epidemiol. 2009;62(10):E1–34.
48. Higgins JPT, Altman DG, Gøtzsche PC, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ. 2011;343(7829):889–97.
49. Barnett LM, van Beurden E, Morgan PJ, et al. Six year follow-up of students who participated in a school-based physical activity intervention: a longitudinal cohort study. Int J Behav Nutr Phys Act. 2009;6:48–55.
50. Salmon J, Ball K, Hume C, et al. Outcomes of a group-randomized trial to prevent excess weight gain, reduce screen behaviours and promote physical activity in 10-year-old children: switch-play. Int J Obes. 2008;32(4):601–12.
51. Trudeau F, Espindola R, Laurencelle L, et al. Follow-up of participants in the Trois–Rivières growth and development study: examining their health-related fitness and risk factors as adults. Am J Hum Biol. 2000;12(2):207–13.
52. Trudeau F, Laurencelle L, Tremblay J, et al. A long-term follow-up of participants in the Trois–Rivieres semi-longitudinal study of growth and development. Pediatr Exerc Sci. 1998;10(4): 366–77.
53. Trudeau F, Laurencelle L, Tremblay J, et al. Daily primary school physical education: effects on physical activity during adult life. Med Sci Sports Exerc. 1999;31(1):111–7.
54. Manios Y, Kafatos A. Health and nutrition education in primary schools in Crete: 10 years follow-up of serum lipids, physical activity and macronutrient intake. Br J Nutr. 2006;95(3):568–75.
55. Manios Y, Kafatos I, Kafatos A. Ten-year follow-up of the Cretan health and nutrition education program on children's physical activity levels. Prev Med. 2006;43(6):442–6.
56. Gorely T, Morris JG, Musson H, et al. Physical activity and body composition outcomes of the GreatFun2Run intervention at 20 month follow-up. Int J Behav Nutr Phys Act. 2011;8(1):74–84.
57. McManus AM, Masters RSW, Laukkanen RMT, et al. Using heart-rate feedback to increase physical activity in children. Prev Med. 2008;47(4):402–8.
58. Taymoori P, Niknami S, Berry T, et al. A school-based randomized controlled trial to improve physical activity among Iranian high school girls. Int J Behav Nutr Phys Act. 2008;5:1–13.
59. Klepp K-I, Øygard L, Tell G, et al. Twelve year follow-up of a school-based health education programme. Eur J Publ Health. 1994;4(3):195–200.
60. Bronikowski M, Bronikowska M. Will they stay fit and healthy? A three-year follow-up evaluation of a physical activity and health intervention in Polish youth. Scand J Publ Health. 2011;39(7):704–13.
61. Kelder S, Perry CL, Klepp K-I. Community-wide youth exercise promotion: long-term outcomes of the Minnesota Heart Health Program and the class of 1989 study. J Sch Health. 1993;63(5):218–23.
62. Nader PR, Stone EJ, Lytle LA, et al. Three-year maintenance of improved diet and physical activity: the CATCH cohort. Arch Pediatr Adolesc Med. 1999;153(7):695–704.
63. Shephard RJ, Lavallée H. Impact of enhanced physical education in the prepubescent child: Trois Rivières revisited. Pediatr Exerc Sci. 1993;5(2):177–89.
64. Hellison D. Teaching responsibility through physical activity. 2nd ed. Champaign: Human Kinetics; 2003.
65. Janssen I, LeBlanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. Int J Behav Nutr Phys Act. 2010;7:40–55.
66. Taymoori P, Lubans DR. Mediators of behavior change in two tailored physical activity interventions for adolescent girls. Psychol Sport Exerc. 2008;9(5):605–19.
67. Michie S, Abraham C. Interventions to change health behaviours: evidence-based or evidence-inspired? Psychol Health. 2004;19(1): 29–49.
68. Rhodes RE, Pfaeffli LA. Mediators of physical activity behaviour change among adult non-clinical populations: a review update. Int J Behav Nutr Phys Act. 2010;7:37–47.
69. Lubans DR, Foster C, Biddle SJH. A review of mediators of behavior in interventions to promote physical activity among children and adolescents. Prev Med. 2008;47(5):463–70.
70. Shumway-Cook A, Woollacott MH. Motor control: translating research into clinical practice. 3rd ed. Philadelphia: Lippincott Williams & Wilkins; 2007.
71. McMorris T. Acquisition and performance of sports skills. Chichester: Wiley; 2004.
72. Branta C, Haubenstricker J, Seefeldt V. Age changes in motor skills during childhood and adolescence. Exerc Sport Sci Rev. 1984;12(1):467–520.
73. Gallahue D, Ozmun J. Understanding motor development: infants, children, adolescents, adults. 6th ed. Boston: McGraw-Hill; 2006.
74. Logan SW, Robinson LE, Wilson AE, et al. Getting the fundamentals of movement: a meta-analysis of the effectiveness of motor skill interventions in children. Child Care Health Dev. 2012;38(3):305–15.
75. Riethmuller AM, Jones RA, Okely AD. Efficacy of interventions to improve motor development in young children: a systematic review. Pediatrics. 2009;124(4):E782–92.
76. Barnett LM, Morgan PJ, Van Beurden E, et al. A reverse pathway? Actual and perceived skill proficiency and physical activity. Med Sci Sports Exerc. 2011;43(5):898–904.
77. Australian Government Department of Health and Ageing. Physical activity. 2010 (online). http://www.health.gov.au/internet/main/publishing.nsf/content/health-pubhlth-strateg-phys-act-guidelines. Accessed 19 May 2012.
78. Mark AE, Janssen I. Influence of movement intensity and physical activity on adiposity in youth. J Phys Act Health. 2011;8(2):164–73.
79. World Health Organization. Global recommendations on physical activity for health. 2010 (online). http://whqlibdoc.who.int/publications/2010/9789241599979_eng.pdf. Accessed 27 Apr 2012.
80. Metcalf B, Henley W, Wilkin T. Effectiveness of intervention on physical activity of children: systematic review and meta-analysis of controlled trials with objectively measured outcomes (EarlyBird 54). BMJ. 2012;345(e5888):1–11.
81. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise and physical fitness: definitions and distinctions for health-related research. Publ Health Rep. 1985;100(2):126–31.
82. Moher D, Schulz KF, Altman DG. The CONSORT statement: revised recommendations for improving the quality of reports of parallel-group randomized trials. Ann Intern Med. 2001;134(8):657–62.
83. Des Jarlais DC, Lyles C, Crepaz N. Improving the reported quality of nonrandomized evaluations of behavioral and public health interventions: the TREND statement. Am J Publ Health. 2004;94(3):361–6.
84. Morgan P, Hansen V. Recommendations to improve primary school physical education: classroom teachers' perspective. J Educ Res. 2007;101(2):99–111.

85. Morgan PJ, Hansen V. Classroom teachers' perceptions of the impact of barriers to teaching physical education on the quality of physical education programs. Res Q Exerc Sport. 2008;79(4):506–16.
86. Fletcher T, Mandigo J. The primary schoolteacher and physical education: a review of research and implications for Irish physical education. Irish Educ Stud. 2012;31(3):363–76.
87. Morgan PJ, Hansen V. Physical education in primary schools: classroom teachers' perceptions of benefits and outcomes. Health Educ J. 2008;67(3):196–207.