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REVIEW PAPER

Systematic review of physical activity and exercise interventions on body mass indices, subsequent physical activity and psychological symptoms in overweight and obese adolescents

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Abstract

Aims. To examine the effects of physical activity and exercise interventions on body mass index, subsequent physical activity and psychological symptoms for overweight and obese adolescents (12-18 years).

Background. Overweight and obesity have increased among adolescents globally and physical activity has decreased. Healthcare systems face challenges promoting physical activity and in treating obesity. Promotion of physical activity must be effective and school nurses should be equipped with the information and resources required to implement counselling for overweight and obese adolescents.

Design. A systematic review of randomized controlled trials was conducted according to procedures by the Centre for Reviews and Dissemination and the Joanna Briggs Institute.

Data sources. Research studies published between 1950–2013 were identified from the following databases. CINAHL, MEDLINE (Ovid) and PsycINFO.

Review methods. Selected studies were reviewed for quality and a risk-of-bias assessment was conducted for the included studies. A narrative synthesis was used to report results, while a fixed-effect meta-analysis was used to analyse the interventions effects on physical activity and body mass index.

Results. Fourteen published studies were included to this review. Supervised exercise interventions most affected adolescents' body mass index. The interventions effect on adolescents' physical activity was small and heterogeneous. Two interventions positively affected psychological symptoms.

Conclusion. Interventions were complex, with more than one component and the aspect that effectively promotes physical activity in obese adolescents was not clear. However, it seems that exercise interventions affect the body mass index of overweight or obese adolescents. Interventions that include a component for

promoting physical activity with or without supervised exercise can affect subsequent physical activity and body mass index.

Keywords: adolescent health, exercise, intervention, obesity, overweight, physical activity, systematic review and meta-analysis

Why is this research or review needed?

- In nursing science there is a need to clarify the evidence on improving overweight and obese adolescent's health.
- This article systematically reviews the effect of physical activity and exercise interventions involving overweight and obese adolescents.
- This review synthesizes the effects of interventions on BMI, subsequent physical activity and psychological symptoms for overweight and obese adolescents and adds new information on healthcare practices.

What are the key findings?

- Interventions that include supervised exercise most affected the BMI of overweight or obese adolescents.
- Our systematic review suggest that complex interventions that include a component for promoting physical activity with or without supervised exercise can affect the subsequent physical activity of overweight or obese adolescents.
- Interventions that include supervised exercise and promotion of physical activity can affect the psychological symptoms of overweight or obese adolescents.

How should the findings be used to influence policy/practice/research/education?

- The findings can be used to develop health promotion interventions for overweight and obese adolescents in nursing research and practice.
- Nurse educators should take into account in their teaching that promotion of physical activity among obese and overweight adolescents is multifaceted and challenging
- At the policy level, complex interventions with more than one component for overweight and obese adolescent should be considered.

Introduction

The rising prevalence of overweight is recognized as a serious global health problem (Hurt *et al.* 2010). Physical inactivity is fourth on the list of leading risk factors for global mortality, while overweight and obesity are fifth (WHO 2010). Responding to these problems requires individual lifestyle changes and concerted policies from multiple ranks of healthcare organizations, including changes in physician practices (Lake & Townshed 2006, WHO 2013). Obesity, high blood pressure and physical inactivity are all implicated in non-communicable diseases (WHO 2009). Obese adolescents experience a lower health-related quality of life and more symptoms of depression than their overweight or normal-weight counterparts (Schwimmer *et al.* 2003, Goldfield *et al.* 2010). The reasons behind the increased prevalence of overweight and obesity are thought to include changes to our living environment, physical inactivity and eating habits that do not align with recommendations for a healthy diet (Gordon-Larsen *et al.* 2002, Lake & Townshed 2006, Roseman *et al.* 2011, Ng *et al.* 2014). Targeting childhood and adolescence for the prevention and treatment of obesity is wholly appropriate so as to establish a healthy weight moving forward into the adult years (Lloyd 2012).

The International Obesity Task Force (IOTF) defines overweight and obesity using body mass index (BMI) cut-offs, which are also widely used to assess the prevalence of overweight or obese children and adolescents. An adolescent is overweight when the individual curve cut-off BMI is at 25 kg/m^2 (85th-95th percentiles for adolescents of the same age and sex) and obese at BMI cut-off of 30 kg/m^2 (≥95th percentile) (Cole & Lobstein 2012). Based on IOTF cut-offs, the prevalence of overweight and obesity among children and adolescents (2-19 years old) in developed countries is over 22% and is approximately 13% in developing countries (Ng *et al.* 2014). Adolescence obesity has adverse consequences for health in adulthood (Reilly & Kelly 2011).

At puberty, adolescents may create a good foundation for healthy adulthood by participating in a range of physical activities (Tammelin *et al.* 2003). The recommended level of physical activity for a 5-17-year old is 60 minutes per day at moderate-to-vigorous intensity (Strong *et al.* 2005, WHO 2010). Most of the daily physical activity should be aerobic. Vigorous activities should be incorporated, including those that strengthen muscle and bone, at least three times per week (WHO 2010). The terms physical activity and exercise are widely used to describe human movement, but their definitions differ. Physical activity is defined as any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure. Exercise or exercise training is a subcategory of physical activity that

is planned, structured and repetitive and purposive with the objectives of improving or maintaining physical fitness, physical performance, or health (Physical Activity Guidelines Advisory Committee 2008). These terms are often used interchangeably. In many countries, more than 30% of 15-year-old adolescents are insufficiently physically active. Levels of physical activity significantly decrease from childhood to adolescence, increasing the risk of developing obesity and chronic diseases later in life (Ortega *et al.* 2013). Besides its well-known health benefits, regular and sufficient physical activity positively influences adolescents' psychological factors like self-esteem and improves quality of life (Neumark-Sztainer *et al.* 2003, Ekeland *et al.* 2005, Penedo & Dahn 2005, Warburton *et al.* 2006, Biddle & Asare 2011). Physical activity is also positively associated with academic performance (Strong *et al.* 2005, Kantomaa *et al.* 2013).

WHO (2013) has pronounced a global, voluntary target to stop the rise in obesity by 2025 and to reduce insufficient physical activity. Prevention and treatment efforts against obesity have focused on pharmacological, educational and behavioural interventions (Lake & Townshed 2006). Childhood and adolescence weight management programs should have multiple components, including core components of a healthy diet, physical activity, reduced sedentary behaviour and strategies for changing the behaviours of the child or adolescent and close family members (National Institute for Health and Care Excellence (NICE) 2013). Lifestyle counselling, which includes these core components, is an essential part of treating overweight and obese adolescents (Barlow 2007, Oude Luttikhuis *et al.* 2009). School nurses are key persons for promoting health and preventing obesity among adolescents and they also meet more and more adolescents who are overweight, obese, or at risk of being overweight (Wilson 2007). Therefore, they should be provided with effective strategies for promoting physical activity and healthy diets among overweight and obese adolescents. Barriers to effective lifestyle counselling are insufficient knowledge and resources for school nurses and a lack of motivation on the part of adolescents, although some adolescents are willing to exercise more (Wilson 2007, Tompkin *et al.* 2009, Steele *et al.* 2011). Thus, it is important to synthesize evidence from studies on physical activity interventions for overweight and obese adolescents to develop effective lifestyle counselling interventions for their health care.

Earlier systematic reviews have targeted interventions that either promote physical activity among adults and normal-weight adolescents or that prevent childhood obesity (Flodmark *et al.* 2004, Foster *et al.* 2005, Hamel *et al.* 2011, Waters *et al.* 2011). Conducting a systematic review of studies including normal-weight children is considered obesity prevention (Waters *et al.* 2011). Strong evidence in the literature corroborates the value of interventions with multiple components in helping overweight and obese adolescents reduce weight (Kelly & Melnyk 2008). To our knowledge, there is a lack of evidence confirming the effectiveness of physical activity or exercise interventions for increasing physical activity and improving BMI and psychological symptoms among overweight or obese adolescents aged 12–18 years.

The review

Aim

The aim of this systematic review is to examine the effects of physical activity and exercise interventions. More specifically, our goal is to examine the effects of randomized controlled trials (RCTs) on BMI, subsequent physical activity and psychological symptoms in overweight and obese 12-18 years old adolescents who experienced interventions. This review introduces evidence-base practices for health care that promote physical activity among overweight and obese adolescents.

Design

This systematic review is a quantitative review of effects and was conducted according to the guidelines of the Centre for Reviews and Dissemination (CRD 2008) and the Joanna Briggs Institute User guide (JBI 2014). Our report is based on the principles of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement (Moher *et al.* 2009, CRD 2008).

Search strategy

We searched the electronic databases Medline, PsycInfo and Cinahl studies published during the period January 1950–August 2013. Key search terms included 'physical activity', 'exercise', 'motor activity', 'obese', 'overweight', 'adolescent', 'teen' and 'youth.' A strategy, terms and limits for the search were selected with the aid of an information specialist (CRD 2008). A sample of the full search strategy is included as a supplementary information file (See supplementary information Table S1). All studies included in this review were original and were published in peer-reviewed journals. The studies had to meet all of the following criteria for inclusion in the review:

Population

Participants had to be overweight or obese adolescents (age range 12-18 (±1) years). Studies that addressed adolescents with long-term disease, mental health problems, intellectual disabilities or eating disorders were excluded.

Intervention

The intervention must have consisted solely of physical activity or exercise, or of physical activity/exercise along with counselling or dietary practices.

Comparators

The study design included at least one control group that did not have any treatment in addition to standard care; the control condition must not have any treatment related to physical activity/exercise.

Outcomes

The study examined physical activity, BMI or psychological symptoms as outcome variables and postintervention outcome measures where available.

Study design

Studies had to be randomized controlled trials (RCT). Other study designs (e.g. qualitative, surveys, studies without a control group) were not included in this review.

Search outcome

The electronic database search produced 7384 studies. The selection process is described by way of a PRISMA flow diagram in Figure 1 (Moher *et al.* 2009). During the first phase, duplicate publications (n = 177) from the three databases were eliminated to reduce publication bias (CRD 2008). In the second phase, two independent reviewers (HR, MK) screened the studies by evaluating their titles (n = 7207) and abstracts (n = 1540) according to the predetermined inclusion criteria (CRD 2008, JBI 2014). In the last phase, full texts (n = 259) were read and screened to determine whether the studies met the inclusion criteria. Disagreement between reviewers regarding eligibility was resolved through discussion. If the manuscript was unavailable in familiar languages (English, Finnish or Swedish), the study was excluded (n = 14). The systematic selection process (Figure 1) was performed in four phases to minimize bias and to ensure that all relevant studies were included.

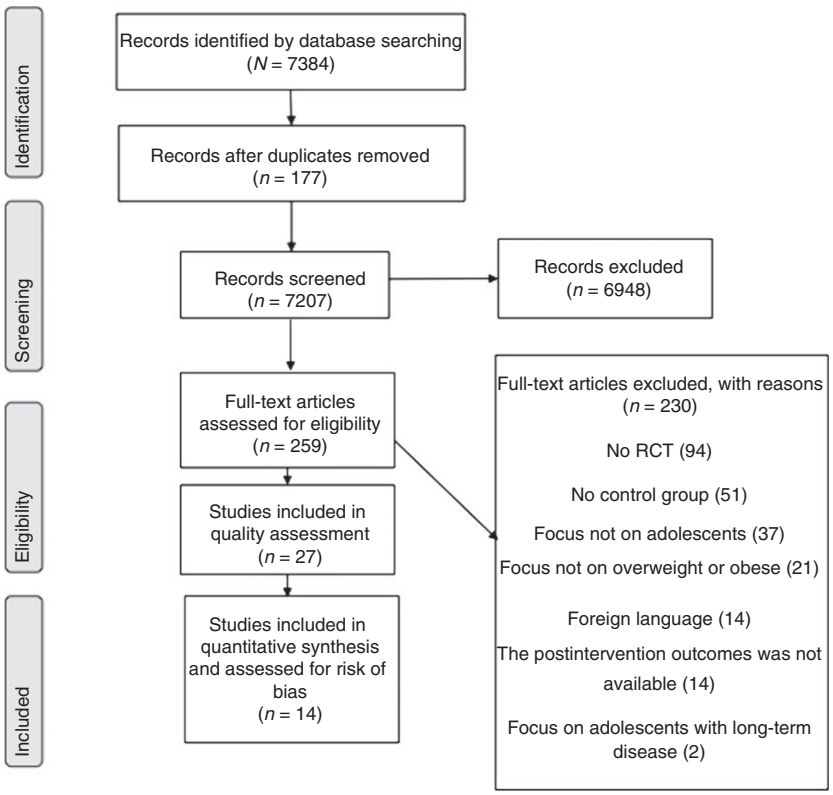

Figure 1 Flow diagram of the study selection process.

To ensure reproducibility, the selection of studies was carefully documented using RefWorks® (CRD 2008).

Quality appraisal and assessing the risk of bias

Two reviewers (HR, HK) with methodological and content expertise (Higgins & Green 2011) independently assessed the quality of the 27 studies emerging from the previously described selection process. They used the Joanna Briggs Institute's critical appraisal checklist for randomized and pseudo-randomized studies (JBI 2014) (see Supplementary information Table S2). Quality was quantified by assigning scores of either 0-1 point per criterion. One point was assigned if the item was mentioned in the study and zero if the item was not mentioned, or was unclear. The total quality score ranged from 0–10 points. If the study was allocated at least five points out of 10, it was included in the review. The quality scores of the two studies reviewed varied from two to eight. Based on this quality assessment, 14 studies were eligible for inclusion in this review. To ensure the quality of the selected studies, we used the risk-of-bias assessment tool recommended by the Cochrane Collaboration to evaluate the following six domains: sequence generation, allocation concealment, blinding, incomplete data, selective outcome reporting and other sources of bias (Higgins & Green 2011) (Table 1).

Data extraction and synthesis

The following characteristics of the studies were collated during the data extraction phase: authors, publication year, country where study was performed, study participants, entry criteria and outcome measures. Table 2 provides a description of participants, intervention setting or recruitment, theories, duration and intervention components, while the supplementary information file includes more specific information on the studies included (See supplementary information Table S3). Postintervention results are reported in Table 3. Two reviewers crosschecked the extracted data and disagreements were resolved through discussion (CRD 2008, JBI 2014). Data synthesis was initially conducted by the primary reviewer, but discussed regularly with the review team. For continuous data on BMI and physical activity (self-reported or objectively measures), we extracted the means and standard deviations (SD) or standard errors plus sample size for both the control and intervention group. If the SD was not reported, but SE was, we calculated the SD using a formula (JBI 2014).

The included studies for this systematic review were analysed with a narrative synthesis and a meta-analysis. The meta-analysis was used to analyse intervention effects on physical activity and BMI (Figures 2 and 3). The software used was STATA 11.2 (Egger *et al.* 2001). Standardized mean differences (Cohen′s d) for each study were calculated from postintervention outcomes measures or average changes in the means and standard deviations, when these were available. In the meta-analysis, we classified different studies to subgroups according to whether the intervention included: (1) supervised exercise; (2) supervised exercise and promotion of physical activity; or (3) promotion of physical activity. Summary effect sizes were estimated for each of these subgroups. Analyses were carried out using fixed-effect meta-analysis. An overall standardized mean

Table 1 Assessing risk of bias in included studies (n = 14).

	Adequate sequence generation	Allocation concealment	Blinding of participants personnel or outcome assessors	Incomplete outcome data	Selective outcome data reporting	Free of other bias
Black *et al.* (2010)	+	+	–	?	+	–
Daley *et al.* (2006)	+	+	–	?	+	+
Davis *et al.* (2011)	?	+	+	–	+	–
DeBar *et al.* (2012)	+	+	+	+	+	+
Doyle *et al.* (2008)	+	+	+	+	+	+
Elloumi *et al.* (2010)	?	?	?	+	?	+
Hagströmer *et al.* (2009)	?	?	?	+	+	+
Lee *et al.* (2012)	+	+	?	+	+	+
Maddison *et al.* (2011)	+	+	–	+	+	+
Ounis *et al.* (2010)	?	?	?	+	?	+
Reinehr *et al.* (2010)	+	?	–	+	?	+
Saelens *et al.* (2002)	+	+	?	+	+	+
Tsiros *et al.* (2008)	+	?	?	+	?	+
White *et al.* (2004)	?	?	?	+	+	–

+, low risk of bias; ?, unclear risk of bias; –, high risk of bias.

Table 2 Description of participants and intervention setting or recruitment, theory, duration and components.

Author & year of publication	Participants	Mean age	Mean BMI	Setting or recruitment	Theory	Duration weeks	Supervised exercise	Behavioural management skills	Material and informational support	Motivational interviewing	Social support	Dietary regimen or restriction
Black *et al.* (2010)	119 males 116 females	13·3	0·68*	Home- and community based	Social cognitive theory	12		x		x	x	
Daley *et al.* (2006)	67 males 14 females	13·1	3·23†	Recruitment from Hospital	Trans-theoretical model	8	x	x	x		x	
Davis *et al.* (2011)	45 females	15·7	34·5	Recruitment from high schools	Motivational interviewing	16	x	x		x		
DeBar *et al.* (2012)	208 females	14·1	31·9	Primary care	Behavioral based	20	x	x	x		x	
Doyle *et al.* (2008)	30 males 50 females	14·5	34·2	Web-base	Cognitive behavioral theory	16		x	x		x	
Elloumi *et al.* (2010)	28 males	13·0	30·3	School setting	Unclear	8	x					x
Hagströmer *et al.* (2009)	17 males 14 females	13·7	32·7	Obesity clinic setting	Unclear	13	x					
Lee *et al.* (2012)	45 males 0 females	14·8	35	Hospital-based	Unclear	12	x					x
Maddison *et al.* (2011)	235 males 87 females	11·6	25·7	Home-based	Unclear	Unclear			x			
Ounis *et al.* (2010)	15 males 17 females	13·3	30·95	Recruitment from schools	Unclear	8	x					
Reinehr *et al.* (2010)	28 males 38 females	11·4	23·9	Recruitment by newspaper and radio	Unclear	24	x	x			x	
Saelens *et al.* (2002)	26 males 18 females	14·2	30·85	Pediatric primary-care clinical setting	Unclear	16		x	x		x	
Tsiros *et al.* (2008)	16 males 31 females	14·5	30·85	Clinical and home setting	Cognitive behavioral therapy	20		x	x		x	
White *et al.* (2004)	0 males 57 females	13·1	36·3	Family-based home setting	Unclear	24		x	x		x	

*Z-BMI.
†BMI SD-Score.
BMI, body mass index.

Table 3 Postintervention outcomes (n = 14).

Postintervention outcomes	Author & year of publication													
	Black *et al.* (2010)	Daley *et al.* (2006)	Davis *et al.* (2011)	DeBar *et al.* (2012)	Doyle *et al.* (2008)	Elloumi *et al.* (2010)	Hagströmer *et al.* (2009)	Lee *et al.* (2012)	Maddison *et al.* (2011)	Ounis *et al.* (2010)	Reinehr *et al.* (2010)	Saelens *et al.* (2002)	Tsiros *et al.* (2008)	White *et al.* (2004)
BMI or BMI-Z scores	NS	NS	NS	*	*	***†	NS	*‡	*	*	***	*	*	**
Physical activity														
Physical activity, objectively measured	**	0	NS	0	0	0	–	0	NS	0	0	0	NS	0
Sedentary activity, self-reported	0	0	0	NS	0	0	0	0	0	0	NS	NS	0	0
Physical activity, self-reported	0	NS	0	NS	0	0	0	0	0	0	NS	NS	0	0
Playing active video games	0	0	0	0	0	0	0	0	***	0	0	0	0	0
Psychological outcome														
Eating disorder or problematic eating attitudes	0	0	0	0	*	0	0	0	0	0	0	*	0	0
Physical self-perception or body satisfaction	0	*	0	*	0	0	0	0	0	0	0	0	0	0
Attitudes about appearance	0	0	0	*	0	0	0	0	0	0	0	0	0	0
Satisfaction with life or quality of life	0	0	0	NS	0	0		0	0	0	0	0	0	0
Depression	0	NS	0	0	0	0	0	0	0	0	0	0	0	0
Self-perception or self-esteem	0	NS	0	NS	0	0	0	0	0	0	0	0	0	0

*P < 0·05; **P < 0·01, ***P < 0·001.

†In favour of energy restriction/training group.

‡In favour of resistance exercise group.

–, significant difference in favour of the control group; NS, no significant change between groups; 0, not measured or reported.

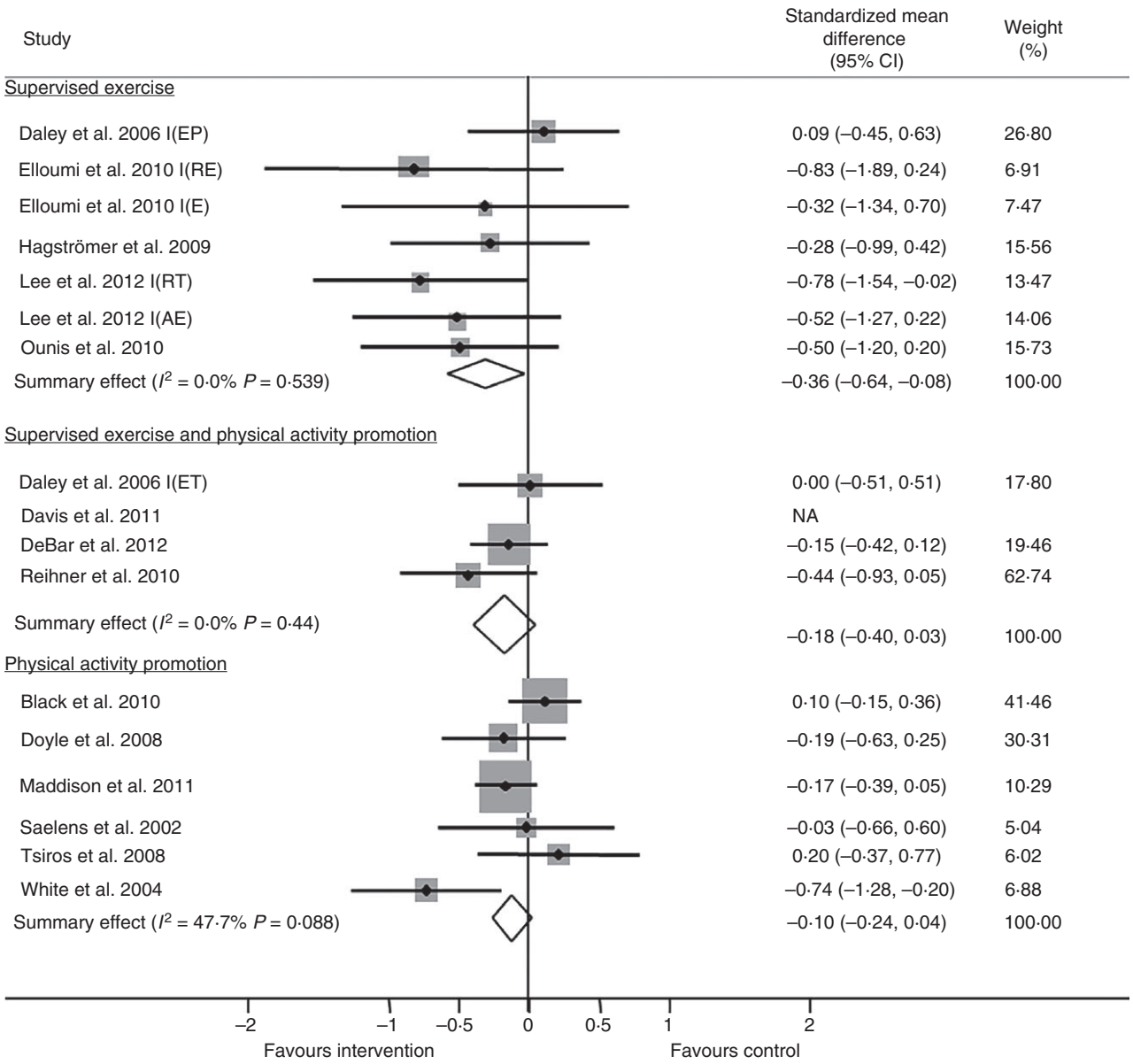

Figure 2 Forest plot showing standardized mean difference in change in body mass index between intervention and control group. Weight (%) is reported from fixed-effect meta-analysis by subgroup. I(EP), exercise placebo intervention; I(RE), energy restriction and exercise training intervention; I(E), exercise training at maximum lipid-oxidation intervention; I(RT), resistant exercise training intervention, I(Ae), aerobic exercise training intervention; NA, data not available.

difference of 0·2-0·5 was considered small, 0·5-0·8 moderate and over 0·8 a large effect (Cohen 1992). In one study (Davis *et al.* 2011) results were not reported, so it was not possible to include it in meta-analysis. Heterogeneity was assessed through I^2 values, ranging from 0-100% (Higgins *et al.* 2003). Intervention characteristics (mode of delivery, setting, theoretical basis, duration, intervention components and moderator) were gathered from the studies and a narrative synthesis was applied (Table 2).

Results

General description of studies included

Years of publication ranged from 2002–2012. The ages of the participants ranged from 10-18 years (mean age 13·6, median 13·5 years). One study focused on a low-income population (Black *et al.* 2010). Study populations were ethnically diverse, with Caucasian, Black, Hispanic and oth-

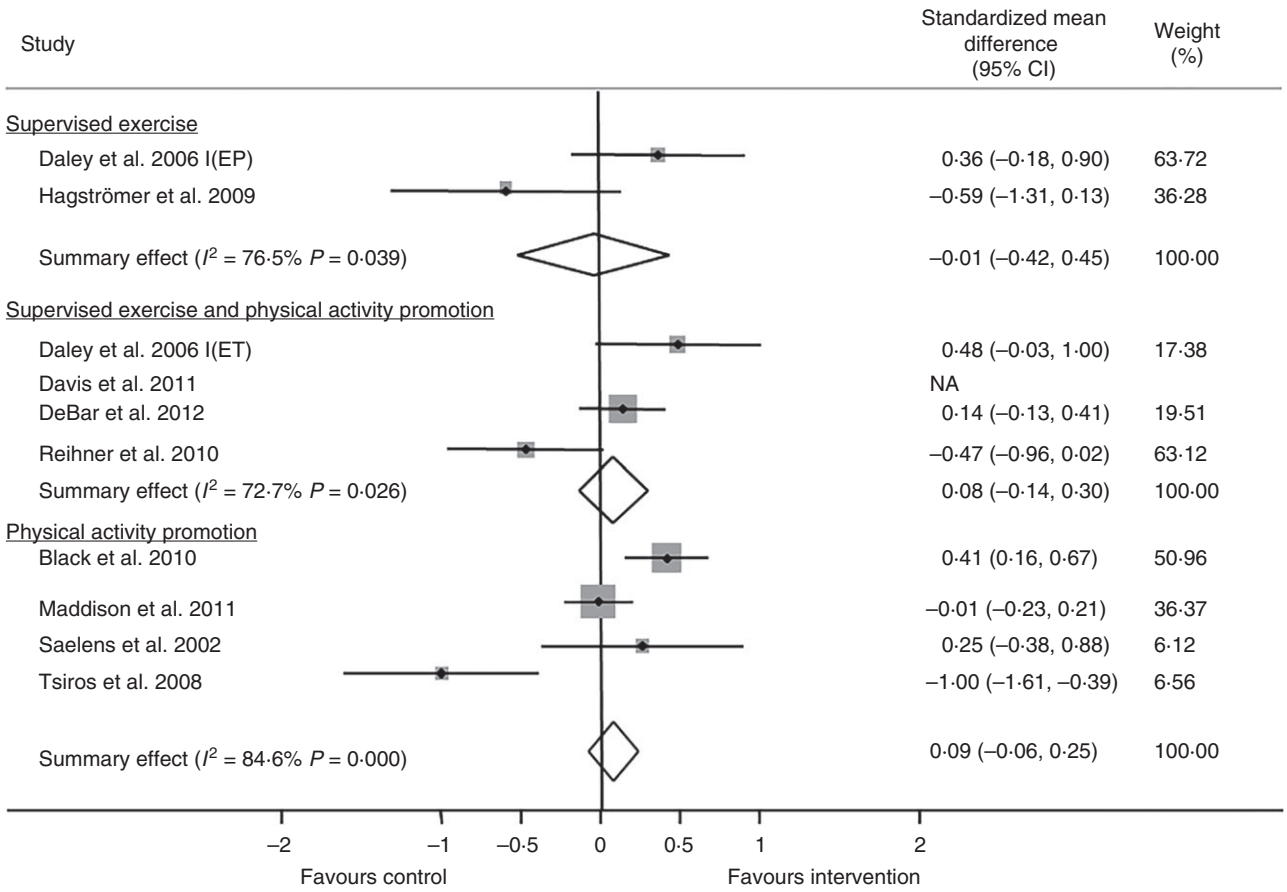

Figure 3 Forest plot showing standardized mean difference in change in physical activity between intervention and control group. Weight (%) is reported from fixed-effect meta-analysis by subgroup. I(EP), exercise placebo intervention; I(RE), energy restriction and exercise training intervention; NA, data not available.

ers well represented (Saelens *et al.* 2002, Doyle *et al.* 2008). Sample sizes ranged from 28-322 (mean 94 and median 52).

Inclusion criteria for entry into an intervention study were based on different definitions of the terms 'overweight' or 'obese'. Three studies (White *et al.* 2004, Doyle *et al.* 2008, Davis *et al.* 2011) set a BMI threshold greater than the 85th percentile of the population, while Saelens *et al.* (2002) used a BMI cut-off of 20-100% higher than the 50th percentile (average) in adolescents. Three studies used the IOTF cut-off points for determining obesity (Tsiros *et al.* 2008, Hagströmer *et al.* 2009, Maddison *et al.* 2011). Other studies included adolescents if their BMI was greater than the 90th (Reinehr *et al.* 2010, DeBar *et al.* 2012), 95th (Lee *et al.* 2012), 97th (Elloumi *et al.* 2010, Ounis *et al.* 2010), or 98th percentiles (Daley *et al.* 2006). In one study, the inclusion criterion was not whether an individual was overweight or obese; instead adolescents from low-income homes were selected and 38% of these participants were overweight or obese. Results pertaining to these participants were reported separately (Black *et al.* 2010). The mean BMI of adolescents who participated in all these studies was 31·3 and the studies reported absolute BMIs (n = 12) ranging from 23·2-36·6. However, BMIs from the studies by Black *et al.* (2010) and Daley *et al.* (2006) are not included in this average since they reported Z-BMI and BMI SD-Scores.

Quality of Methodology

A risk-of-bias analysis was conducted, following quality appraisal (JBI 2014), on 14 selected studies in accordance with the Cochrane handbook (Higgins & Green 2011) (Table 1, Risk of Bias analysis). The sequence-generation processes for randomization were clearly described in these studies and the methods were adequate (Saelens *et al.* 2002, Daley *et al.* 2006, Doyle *et al.* 2008, Tsiros *et al.* 2008, Black *et al.* 2010, Reinehr *et al.* 2010, Maddison *et al.*

2011, DeBar *et al.* 2012, Lee *et al.* 2012). Other studies mentioned that randomization was performed, but the methods were unclear (White *et al.* 2004, Hagströmer *et al.* 2009, Elloumi *et al.* 2010, Ounis *et al.* 2010, Davis *et al.* 2011). Adequate allocation concealment was performed in eight studies (Saelens *et al.* 2002, Daley *et al.* 2006, Doyle *et al.* 2008, Black *et al.* 2010, Davis *et al.* 2011, Maddison *et al.* 2011, DeBar *et al.* 2012, Lee *et al.* 2012). However, in six studies, the allocation concealment remained unclear (White *et al.* 2004, Tsiros *et al.* 2008, Hagströmer *et al.* 2009, Elloumi *et al.* 2010, Ounis *et al.* 2010, Reinehr *et al.* 2010).

Blinding the participants, personnel and outcome assessors was not entirely possible for any of the included studies because of the behavioural nature of the intervention. However, blinding of key personnel or the outcome assessors was possible (Doyle *et al.* 2008, Davis *et al.* 2011, DeBar *et al.* 2012). Seven studies did not address this characteristic (Saelens *et al.* 2002, White *et al.* 2004, Tsiros *et al.* 2008, Hagströmer *et al.* 2009, Elloumi *et al.* 2010, Ounis *et al.* 2010, Lee *et al.* 2012). Four reported that blinding was impossible for their study (Daley *et al.* 2006, Black *et al.* 2010, Reinehr *et al.* 2010, Maddison *et al.* 2011).

Generally, the number of withdrawals of study participants was described in the publications and few authors reported that they carried out an intention-to-treat analysis (Saelens *et al.* 2002, Reinehr *et al.* 2010, Maddison *et al.* 2011, DeBar *et al.* 2012). Also, in some of the studies, missing data were computed using appropriate statistical methods (Doyle *et al.* 2008, Tsiros *et al.* 2008). In one study the missing data were analysed but it was not reported statistically, although they mentioned it did not differ from the data of those who completed the study (Hagströmer *et al.* 2009). Two studies (Elloumi *et al.* 2010, Ounis *et al.* 2010) had no dropouts and one study did not include withdrawals in the analysis (Davis *et al.* 2011). Action taken regarding participants who withdrew was not reported in two studies (Daley *et al.* 2006, Black *et al.* 2010).

All studies reported the statistical difference between groups after the intervention, but in the Hagströmer *et al.* (2009) study, the baseline differences between group outcomes were not reported clearly. The primary and secondary outcomes are reported clearly in most of these studies (Saelens *et al.* 2002, White *et al.* 2004, Daley *et al.* 2006, Doyle *et al.* 2008, Black *et al.* 2010, Reinehr *et al.* 2010, Davis *et al.* 2011, Maddison *et al.* 2011, DeBar *et al.* 2012). Some of the studies analysed multiple outcomes and so the primary outcome was unclear (Tsiros *et al.* 2008, Hagströmer *et al.* 2009, Elloumi *et al.* 2010, Ounis *et al.* 2010, Lee *et al.* 2012).

Description of the intervention

Interventions were complex and are described in Table 2. Settings where interventions were conducted varied between studies, with some authors clearly stating this study characteristic. The interventions investigated in four studies were conducted in a hospital or clinical setting (Saelens *et al.* 2002, Hagströmer *et al.* 2009, DeBar *et al.* 2012, Lee *et al.* 2012), two in home- and community settings (White *et al.* 2004, Black *et al.* 2010) and one in a combined hospital- and home-based setting (Tsiros *et al.* 2008). The settings were not explained clearly in the remainder of the studies selected, but the authors reported recruiting participants from a hospital (Daley *et al.* 2006), from schools (Elloumi *et al.* 2010, Ounis *et al.* 2010, Davis *et al.* 2011, Maddison *et al.* 2011), from both hospitals and schools (Doyle *et al.* 2008), or via the media (Reinehr *et al.* 2010).

Some authors mentioned the theoretical basis for their intervention, such as: social cognitive theory (Black *et al.* 2010), cognitive behavioural theory (Doyle *et al.* 2008), behavioural theory (DeBar *et al.* 2012), the trans-theoretical model (Daley *et al.* 2006) and motivational interviewing (Davis *et al.* 2011). The seven other studies did not record any theoretical basis for the intervention (Saelens *et al.* 2002, Hagströmer *et al.* 2009, Elloumi *et al.* 2010, Ounis *et al.* 2010, Reinehr *et al.* 2010, Maddison *et al.* 2011, Lee *et al.* 2012).

There were a variety of intervention delivery methods, but most were delivered face-to-face (Daley *et al.* 2006, Hagströmer *et al.* 2009, Black *et al.* 2010, Elloumi *et al.* 2010, Ounis *et al.* 2010, Reinehr *et al.* 2010, Davis *et al.* 2011, DeBar *et al.* 2012, Lee *et al.* 2012). Two studies used the Internet (White *et al.* 2004, Doyle *et al.* 2008), computers (Saelens *et al.* 2002), game consoles (Maddison *et al.* 2011) and telephone calls (Saelens *et al.* 2002, Tsiros *et al.* 2008) as part of the delivery method.

The duration of the series of interventions ranged from 12-24 weeks. Five of the studies reported postintervention follow-ups ranging from 4-24 months (Saelens *et al.* 2002, Daley *et al.* 2006, Doyle *et al.* 2008, Black *et al.* 2010, Maddison *et al.* 2011, DeBar *et al.* 2012).

The components of the complex interventions are categorized in this review as follows: supervised exercise and promotion of physical activity. Promotion of physical activity included the following components: (1) behavioural management skills, (2) material and informational support, (3) motivational interviewing (4) and social support

(Table 2). Dietary regimen or restriction was also included in some studies (Elloumi *et al.* 2010, Lee *et al.* 2012). Two studies described using motivational interviewing as part of the intervention (Black *et al.* 2010, Davis *et al.* 2011). Aspects of behavioural management skills were included in the interventions of all except the following studies: (Hagströmer *et al.* 2009, Elloumi *et al.* 2010, Ounis *et al.* 2010, Lee *et al.* 2012). Techniques used to enhance behavioural management skills included goal setting, problem-solving, behaviour monitoring, preplanning, self-rewarding, coping strategies and motivation.

Social support was used in eight studies (Saelens *et al.* 2002, White *et al.* 2004, Daley *et al.* 2006, Doyle *et al.* 2008, Tsiros *et al.* 2008, Black *et al.* 2010, Reinehr *et al.* 2010, DeBar *et al.* 2012). This aspect of the intervention consisted of support from mentors (Black *et al.* 2010), professionals (Saelens *et al.* 2002, DeBar *et al.* 2012), parents (Saelens *et al.* 2002, White *et al.* 2004, Doyle *et al.* 2008, Reinehr *et al.* 2010, DeBar *et al.* 2012) and also individualized feedback from interventionists by newsletter (Doyle *et al.* 2008). Adolescents were encouraged to seek support (Davis *et al.* 2011), while moderated meetings and discussions were held with adolescents alone, (Doyle *et al.* 2008, Davis *et al.* 2011, DeBar *et al.* 2012), parents alone, (Saelens *et al.* 2002, Reinehr *et al.* 2010, DeBar *et al.* 2012), and with adolescents and parents together (Saelens *et al.* 2002, White *et al.* 2004, Tsiros *et al.* 2008, Reinehr *et al.* 2010).

Material and informational support was used in six of the interventions. Support was mainly informative and included: a newsletter (Doyle *et al.* 2008), menu suggestions (Tsiros *et al.* 2008) and information sheets for parents (Saelens *et al.* 2002) or online educational material (White *et al.* 2004). Two of the studies used videogames as material support to enhance physical activity (Maddison *et al.* 2011, DeBar *et al.* 2012) and one study used pedometers to promote adolescents' physical activity (Tsiros *et al.* 2008).

Eight of the interventions recorded in these studies were comprised of supervised exercise. Hagströmer *et al.* (2009) and Ounis *et al.* (2010) included exercise as only one component of their intervention. In the Ounis and colleagues study (2010), exercise was conducted at an intensity at which adolescents' fat oxidation was maximal. Lee *et al.* (2012) and Elloumi *et al.* (2010) also included exercise as a main component of their intervention; the effects of aerobic exercise and strength training were compared with the control condition (Lee *et al.* 2012), or exercise training, dietary restriction, or both were compared with the control condition (Elloumi *et al.* 2010). Daley *et al.* (2006), DeBar *et al.* (2012) and Reinehr *et al.* (2010) combined exercise training with other components, such as social support. Motivational interviewing was combined with a circuit-training programme and compared with circuit training only and to the control condition in the study of Davis *et al.* (2011).

Dietary regimen and dietary restriction were features of interventions in two studies. In the study by Elloumi *et al.* (2010), this intervention was compared with interventions involving only exercise. Lee *et al.* (2012) asked adolescents to maintain a healthy diet and record energy intake. Many other studies included dietary counselling as a part of behavioural management skills, but did not use dietary restriction or regimen in the interventions they introduced.

Outcome measures

For this review we used BMI, BMI z-scores, physical activity and psychological outcomes as inclusion criteria. All studies used BMI or BMI z-scores to estimate the effects of the intervention. Physical activity was assessed in nine studies. Five of these studies measured physical activity objectively using an accelerometer (Tsiros *et al.* 2008, Hagströmer *et al.* 2009, Black *et al.* 2010, Davis *et al.* 2011, Maddison *et al.* 2011). Physical activity questionnaires were used in the remaining four (Saelens *et al.* 2002, Daley *et al.* 2006, Reinehr *et al.* 2010, DeBar *et al.* 2012). Maddison *et al.* (2011) also estimated the physical activity playing active and non-active videogames. Psychological symptoms were evaluated in adolescents using a different kind of questionnaire in five studies, where problematic eating habits and eating disorders (Saelens *et al.* 2002, Doyle *et al.* 2008), physical self-perception (Daley *et al.* 2006), body satisfaction, (DeBar *et al.* 2012), depression (Daley *et al.* 2006), satisfaction with life or quality of life (White *et al.* 2004, DeBar *et al.* 2012) were assessed. Postintervention outcomes are presented in Table 3.

Effects on BMI or BMI z-scores

Ten of the 14 studies reported significant improvement in the BMI or BMI z-scores of adolescents in the intervention groups. Elloumi *et al.* (2010) saw improvement in the BMI of participants in all their intervention groups, but the most significant improvement was observed in the energy restriction and exercise group. Lee *et al.* (2012) found a small but significant change in BMI in those from the resistance exercise group, but not from those who did aerobic exercise, compared with the control group. Compared with the control participants, the participants in five studies saw significant decreases in BMI postintervention (White *et al.* 2004, Tsiros *et al.* 2008, Elloumi *et al.* 2010, Ounis *et al.*

2010, Lee *et al.* 2012) and in another five studies, participants saw significant decreases in BMI z-scores postintervention (Saelens *et al.* 2002, Doyle *et al.* 2008, Reinehr *et al.* 2010, Maddison *et al.* 2011, DeBar *et al.* 2012, see Table 3). The BMI of adolescents in the control groups increased after the intervention in three studies (Black *et al.* 2010, Ounis *et al.* 2010, Elloumi *et al.* 2010). In the subgroup analysis of the interventions including only exercise or supervised exercise, the summary effects size was −0·36 (−0·64, −0·08, 95% CI) with $P = 0·539$ and I^2 value 0·0%. Interventions that included both supervised exercise and a component promoting physical activity showed effect sizes of −0·18 (−0·40, 0·03, 95% CI), $P = 0·44$ and I^2 value 0·0%. For interventions that included physical activity promotion components, the effect size was −0·10 (−0·24, 0·04, 95% CI) $P = 0·088$ and I^2 value 47·7% (Figure 2).

Effects on physical activity

No significant differences were seen in objectively assessed physical activity postintervention except for the study of Black *et al.* (2010), although the effects no longer existed at the 6-month follow-up. Daley *et al.* (2006) reported a marginally significant improvement in self-reported physical activity, with significant improvement at the postintervention follow-up (Table 3). For interventions that included only exercise or supervised exercise, the summary effect size was −0·01 (−0·42, 0·45 95% CI) $P = 0·039$ and I^2 value 70·8%. For interventions that included both exercise and a component promoting physical activity among adolescents, the effect size was 0·08 (−0·14, 0·30 95% CI) $P = 0·026$ and I^2 value 72·7%. For interventions that included a component promoting physical activity alone, the effect size was 0·09 (−0·06, 0·25 95% CI) $P = 0·000$ and I^2 value 84·6%. (Figure 3).

Effects on psychological symptoms

Interventions had positive effects with respect to physical self-perception (Daley *et al.* 2006), body satisfaction (DeBar *et al.* 2012) and eating disorder symptoms (Saelens *et al.* 2002, Doyle *et al.* 2008), but not with respect to depression symptoms (Daley *et al.* 2006). In the Daley and colleagues study, they assessed physical and general self-perception separately and discovered positive effects on general self-perception at the 14-week and 28-week follow-up, but not immediately after the intervention. White *et al.* (2004) suggested that depression symptoms and satisfaction with family life are associated with body composition in adolescents, although the effects of interventions on these outcomes were not significant. Saelens *et al.* (2002) did not find any significant treatment effects with respect to weight-related beliefs or concerns.

Discussion

The studies included in this review investigated physical activity and exercise interventions. We used these studies to examine the effects of interventions on BMI, subsequent physical activity and psychological symptoms for overweight and obese adolescents. None of these interventions were targeted to the environment and none were policy-based. Instead, they were aimed at achieving a change in BMI, subsequent physical activity or psychological symptoms in the lives of individuals. Khan *et al.* (2002) systematically reviewed the promotion of physical activity interventions and, as a result, strongly recommended community-wide health education campaigns, school-based physical education and social support in community settings. They also highlighted complex interventions and recommended similar approaches to the ones we identified and reviewed; that is, promoting a change towards healthy behaviour in the individual.

The interventions included in this review were complex and it is challenging to summarize the intervention effects and analyse what component is the key factor behind positive changes. We carried out the subgroup analysis to separate the exercise interventions alone from physical activity intervention components, as the treatment methods between studies varied (JBI 2014). The effects on BMI were greater with interventions that used supervised exercise. Yet the effect was still small (0·36). The BMI of adolescents in control groups increased in three studies (Black *et al.* 2010, Ounis *et al.* 2010, Elloumi *et al.* 2010), which suggests that if nothing is done to help such adolescents to manage their weight, they may continue to gain weight.

The effect on physical activity was also small and interventions that included a component promoting physical activity with or without supervised exercise seem to be more effective than supervised exercise interventions alone. In an earlier review and meta-analysis by Metcalf *et al.* (2012), they reported that physical activity interventions on average bring about a small increase in children's total physical activity volume. In this review the intervention effects on physical activity were heterogeneous ($I^2 > 75\%$) (Higgins *et al.* 2003). The effect on physical activity varied between the reviewed studies, as did the physical activity measurements. In this meta-analysis we included studies that measured physical activity with self-reports or objective measurements, such as accelerometers. Five studies used accelerometers (Tsiros *et al.* 2008, Hagströmer *et al.*

2009, Black *et al.* 2010, Davis *et al.* 2011, Maddison *et al.* 2011) and four studies used self-reports (Saelens *et al.* 2002, Daley *et al.* 2006, Reinehr *et al.* 2010, DeBar *et al.* 2012). A strict recommendation for methods promoting physical activity cannot be made, as measurement methods varied and statistical heterogeneity exists between the studies (JBI 2014).

Behavioural and social approaches to promoting physical activity are widely used for physical activity interventions (Khan *et al.* 2002). In fact, behavioural management skills and social support were used in most of the studies examined for this review. Physical activity interventions commonly include group or individual discussions that focus on encouraging increased physical activity by teaching behavioural management skills (Khan *et al.* 2002). In objectively measured physical activity, significant improvement was found in one study (Black *et al.* 2010) out of four and the effect was small (SMD 0·41). In that study, they used social support, behavioural management skills and motivational interviewing as a part of their Challenge!-program. The control group participants, however, exhibited decreased physical activity, so the effectiveness of promoting physical activity in overweight adolescents remains unclear (Black *et al.* 2010). In two studies, the adolescents were already rather active at baseline, exercising with moderate-to-vigorous intensity for more than 80 minutes per day (Black *et al.* 2010, Maddison *et al.* 2011). Adolescents who did not participate in these interventions may have been sedentary, while finding and motivating them to take part in physical activity programs would have been problematic. Obesity is a sensitive issue and obese adolescents may fear being stigmatized (tenHave *et al.* 2013) and may therefore choose not to participate in interventions targeted at overweight or obese adolescents. Adolescence is also a sensitive time, so it may be that promoting their health is more complex than for example that of younger children. The review of Waters *et al.* (2011) found strong evidence that obesity prevention programs affected BMI at ages 6-12 years.

Exercise therapy affected adolescents' self-perception (Daley *et al.* 2006). It is generally recommended that adolescents should be physically active at moderate-to-vigorous intensity every day for at least 1 hour (WHO 2010); so if exercise therapy is offered only once a week, adolescents should be encouraged to become physically active outside of the organized sessions. Otherwise they might reduce their everyday physical activity (Hagströmer *et al.* 2009). The health-related quality of life of obese children is similar to that of patients diagnosed with cancer (Schwimmer *et al.* 2003). Even if an intervention does not improve adolescents' body composition or fitness activity, it may improve their mental health, or reduce their depression (Biddle & Asare 2011). As Daley *et al.* (2006) highlighted with their study, exercise therapy may improve adolescents' physical self-perception even if the effect on subsequent physical activity is marginal.

Strengths and limitations

The systematic study selection process, which involved three phases, was undertaken by two reviewers independently to minimize subjective selection bias. We followed the CRD (2008) and JBI (2014) guidance in conducting the systematic review and PICO questions were used to clarify the study search. Age was limited to 12-18 years old adolescent, but when searching for studies in many relevant studies the age range was e.g. 10-14 years, so we decided to select the study if the mean age was 12 to 18 ($\pm$ 1) year, so as not to limit coverage of the full period of adolescence. The search was conducted together with an information specialist. The databases used in this systematic review were Medline, PsycInfo and Cinahl and the total amount of studies identified were 7384. The Cochrane database for trials could have been used as well, although that database would have produced enormous amount of duplicate studies with the selected database. This issue was discussed with the information specialist. Studies that addressed adolescents with long-term disease, mental health problems, intellectual disabilities or eating disorders were excluded. In the study by Doyle and colleagues (2006), participants had an eating disorder or problematic eating as an outcome, although participants in that study did not have these, as this was an exclusion criterion in that study. A language restriction was applied at the third phase of the study selection and 14 studies in languages other than English, Swedish or Finnish were excluded; this may have led to publication or language bias (CRD 2008). It could be possible to rate the quality of evidence with Grading of Recommendations Assessment, Development and Evaluation (GRADE) (Guyatt *et al.* 2008), for these included studies as well, but this review used assessment criteria for methodological quality of studies according to JBI and Cochrane collaboration risk-of-bias assessment and analysed the effectiveness with the methods of meta-analysis. The quality assessment, using the JBI SUMARI criteria, was carefully evaluated to ensure the validity of the review (Higgins & Green 2011). For this review studies of low quality were excluded. Although this may increase the selection bias, the aim was to review high quality interventions. A sensitivity analysis could have been done, but we followed the JBI guidance for conducting systematic

reviews. The excluded studies and their quality assessment are available in a supplementary information file. To ensure the suitability of the methodology, we assessed risk-of-bias and made judgments accordingly (Higgins & Green 2011). There is a chance that the review could be biased if the methodology of the studies examined were inadequate, but this was addressed by evaluating bias in all the selected studies (Jüni *et al*. 2001, Higgins & Green 2011). The strength of this study is that it synthesizes evidence from complex interventions by combining a narrative synthesis with the methods of a fixed-effect meta-analysis. Although there was high statistical heterogeneity between studies that assessed physical activity.

Conclusion

Interventions that included supervised exercise were most effective at improving the BMI of overweight or obese adolescents, but the effect on physical activity was contradictory. The effect on physical activity was small, but it seems that complex interventions that included a component that promotes physical activity (i.e. behavioural management skills and social, material and informational support) with or without supervised exercise can affect the implementation of subsequent physical activity in overweight or obese adolescents.

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Conflict of interest

No conflict of interest has been declared by the authors.

Author contributions

HR conceived and designed the study. HR and MK collected the data. HR & HK performed data analysis. HR and MK drafted the manuscript. TT and HK made critical revisions to the paper for important intellectual content. HK gave final approval of the version to be submitted.

All authors have agreed on the final version and meet at least one of the following criteria [recommended by the ICMJE (http://www.icmje.org/recommendations/)]:

- substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data;
- drafting the article or revising it critically for important intellectual content.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site.

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