Systematic review of school-based interventions that focus on changing dietary intake and physical activity levels to prevent childhood obesity: an update to the obesity guidance produced by the National Institute for Health and Clinical Excellence

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Summary

To determine the effectiveness of school-based interventions that focus on changing dietary intake and physical activity levels to prevent childhood obesity. MEDLINE and EMBASE were searched (January 2006 to September 2007) for controlled trials of school-based lifestyle interventions, minimum duration of 12 weeks, reporting weight outcome. Thirty-eight studies were included; 15 new studies and 23 studies included within the National Institute for Health and Clinical Excellence obesity guidance. One of three diet studies, five of 15 physical activity studies and nine of 20 combined diet and physical activity studies demonstrated significant and positive differences between intervention and control for body mass index. There is insufficient evidence to assess the effectiveness of dietary interventions or diet vs. physical activity interventions. School-based physical activity interventions may help children maintain a healthy weight but the results are inconsistent and short-term. Physical activity interventions may be more successful in younger children and in girls. Studies were heterogeneous, making it difficult to generalize about what interventions are effective. The findings are inconsistent, but overall suggest that combined diet and physical activity school-based interventions may help prevent children becoming overweight in the long term. Physical activity interventions, particularly in girls in primary schools, may help to prevent these children from becoming overweight in the short term.

Keywords: Children, obesity, prevention, systematic review.

Introduction

In developed countries, the prevalence of obesity among children is increasing (1). In addition, obesity in childhood is known to be an independent risk factor for adult obesity (2). Therefore, there is a need to develop interventions to reduce the prevalence of obesity in children. Because there is good evidence that obesity is related to the energy content of the diet and an increasingly sedentary lifestyle, these interventions should focus on changing these behaviours. Schools have been a popular setting for implementation of interventions, as they offer continuous, intensive contact with children. School infrastructure and physical environment, policies, curricula and staff have potential to positively influence child health. However, despite the apparent advantages of addressing childhood obesity in a school setting, a relative lack of effectiveness of a number of major interventions to reduce childhood obesity has brought into question the wisdom of allocating scarce resources to school-based interventions.

In 2004, the National Institute for Health and Clinical Excellence (NICE) commissioned the Institute for Health Sciences and Social Care at the University of Teesside to carry out a series of rapid reviews on the prevention of overweight and obesity. These reviews formed part of the supporting evidence for the NICE obesity guidance (3). This systematic review aimed to examine new research evidence and update the review of interventions for the prevention of overweight and obesity in school children, contained within the NICE obesity guidance (3).

The main objective of this review was to determine the effectiveness of interventions that focus on improving diet and physical activity (PA) behaviours in school children. A secondary aim was to identify study characteristics that may affect outcome such as gender, age, socioeconomic status, setting, process indicators and contextual factors.

Methods

Study inclusion criteria were identical to the criteria used within the NICE obesity guidance (3), with one exception: this review only includes studies that reported a weight outcome. Weight could be presented as change or absolute values (at baseline and follow-up) and could include any measure of weight, including but not restricted to, body mass index (BMI), BMI *z*-score, percentage of body fat, skin-fold thickness and percentage of overweight. A study was included if the design was a randomized controlled trial or controlled clinical trial, of a lifestyle intervention, set in schools and at least 12 weeks of duration. School-aged children, 5–18 years old, were included. Study designs that compared lifestyle interventions with usual care or with other active interventions were included.

A lifestyle intervention was defined as including healthy eating, increase in PA, reduction in sedentary behaviours, behaviour therapy, social support and education for diet and activity behaviours. Studies were only included if the study did not recruit children on the basis of weight (or any other measure of weight). Studies were not included or excluded based on the aim of the study. Studies were not excluded on the basis of language. Studies in children with critical illness or eating disorders were excluded.

The interventions, lumped within each comparison (diet, PA, diet plus PA), could vary by mode of delivery and content. This would facilitate comparison of whether less expensive and more easily feasible interventions were as effective as more expensive interventions that involved great expense and effort.

The search strategy was identical to that used for the NICE obesity guidance (3). The electronic databases, MEDLINE and EMBASE, were searched on 25 September 2007 – from January 2006 to September 2006, week 2 (MEDLINE) and week 38 (EMBASE). Copies of the full search strategies are available on request. All references identified in the searches were electronically imported into the reference managing software. All titles and abstracts were initially screened for inclusion by one researcher (TJB). The full text of references identified as potentially relevant or references that could not be rejected with certainty were obtained and assessed independently by two reviewers (TJB, CS) using the predefined inclusion criteria. Differences between reviewers regarding assessment of full texts were resolved by discussion. The reference lists of these studies were checked for other relevant studies.

Data extraction was performed by one reviewer (TJB). Details were extracted regarding study design, setting, participants, aim, intervention, duration, sample size, dropout, change in BMI (or other weight outcome however reported), potential confounders and process indicators.

Data from the studies identified in the update search were integrated with data from the trials that fit the inclusion criteria and were included in the review of interventions for the prevention of overweight and obesity in school children, contained within the NICE obesity guidance (3).

When absolute values for weight or BMI were reported, the change was calculated by subtracting values at baseline from values at follow-up.

Results

Literature search

Seven hundred and thirteen references were identified in MEDLINE and 840 in EMBASE. Initial screening of the references produced 70 potentially relevant references which were obtained as full papers. Fifteen new studies (4–20) were included and two additional papers (21,22) provided longer term follow-up data for two studies (23–26) included within the NICE obesity guidance (3). Twenty-three studies (23–50) were included from the NICE obesity guidance (3) (Fig. 1).

Five studies that fit the inclusion criteria for this review but do not currently have a weight outcome published were identified. These are the 'Intervention centered on adolescents' PA and sedentary behaviour' study (51), the Kinder-Sportstudie (52), the '5-2-1 Go!' study (53), the 'JUMP-in' study (54) and the Trial of Activity for Adolescent Girls (55).

Three studies (4,5,21,23) were dietary interventions (Tables 1 and 2), 15 studies were PA interventions (9–11,16–18,35–46) (Tables 1 and 3) and 20 studies (6–8,12–15,19,20,22,24–34,47–50) were combined diet and PA interventions (Tables 1 and 4), of which five aimed to improve cardiovascular health or reduce the risk of diabetes.

Seventeen of the 38 studies were conducted in American schools, three were based in UK primary schools, and two were set in Australian schools and two in schools in
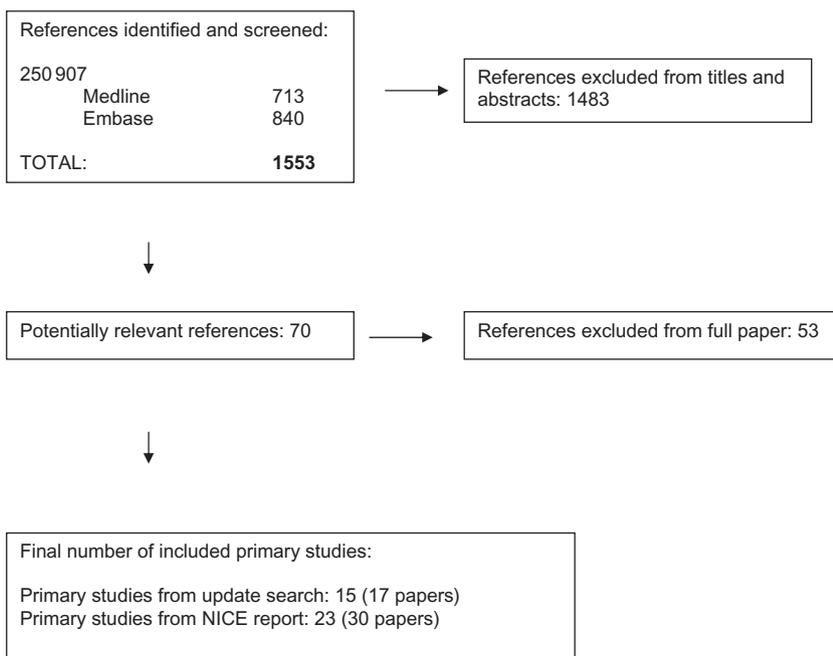
Figure 1 Flow diagram for locating primary studies of controlled trials for systematic review. NICE, the National Institute for Health and Clinical Excellence.

Germany. The remaining 14 studies were based in schools in 14 other European and non-European countries.

Twenty-three studies were set in primary schools and 12 studies were based in secondary schools. Two studies were set in a kindergarten or pre-school and one study included adolescents aged 16–18 years in a 'high school' in Croatia.

Age of the children ranged from 4 to 18 years. Mean baseline BMI ranged from 15.5 to 27.6 kg m^{-2} (23 studies). Duration (including active intervention and any follow-up) of the 38 studies ranged from 12 weeks to 22 years. Twenty-two studies had follow-up of less than 1 year, nine studies had follow-up between 1 and 2 years, four studies had follow-up between 3 and 5 years and two studies had longer follow-up (10 and 20 years). The Trois-Riveries Growth and Development study took place in the 1970s with a follow-up at 22 years and so differs substantially compared with the other included studies.

Study results (Table 5)

Dietary intervention vs. control

Three studies (4,5,21,23) aimed to improve diet in school children. The Christchurch obesity prevention programme in schools study aimed to help 644 7–11-year-old children in one UK primary school to reduce their consumption of carbonated drinks in a low-intensity intervention that lasted 1 year (23). At 12 months, the percentage of overweight and obese children had increased in the control group by 7.5% compared with a decrease in the intervention group of 0.2% (mean difference 7.7%, 95% confidence interval [CI] 2.2%, 13.1%). No difference was observed in mean BMI. However, at 3-year follow-up, the prevalence of overweight had increased in both the intervention and control group and the significant difference between the groups at 12 months was no longer evident (21).

A pilot study of 291 12-year-old Caucasian children in three middle schools in Italy aimed to test the efficacy of a board game 'Kaledo' in providing nutrition knowledge and promoting healthy dietary behaviour. Mean BMI score was significantly higher in the intervention group at baseline. At 24 weeks, the change in BMI z-score was not significantly different between intervention and control (controlling for baseline values) 0.35 (95% CI 0.30, 0.39) vs. 0.41 (0.35 to 0.47) (4).

A pilot study of 54 15-year-old adolescents in one secondary school in Norway aimed to evaluate if dietary habits and school performance improved by eating breakfast. BMI increased significantly in both male and female in the control group ($P < 0.01$ for male and $P < 0.05$ for female), but not in the intervention group at 4 months (5).

Physical activity interventions vs. control

Fifteen studies aimed to increase PA levels and were compared with a usual care control group (9–11,16–18,35–46). These studies involved various types, intensities and duration of PA. Ten of the 15 studies were 6-months duration or less. Five of the 15 studies showed statistically significant improvements in mean BMI (10,35–37,46). Of these five studies, two reported significant differences for girls but not for boys (35,46). Participants in four of the five studies had a mean age less than 9 years.

Table 1 Overview of included studies

Study	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
DIET ONLY STUDIES						
Amaro *et al.* 2006 (4)	The control group did not have play sessions with Kaledo.	Board game Kaledo, one play session per week lasting 15–30 min with two players on each team. Players match difference between the total energy intake given by the nutrition cards and the total energy expenditure given by the activity cards. At the end of the game the player with the least difference between energy intake and expenditure is the winner.				
Ask *et al.* 2006 (5)	The other school class was not served breakfast, but got the same information about the importance of a healthy diet; in addition, all parents were encouraged to provide a packed lunch for their children every day.	The intervention consisted of served breakfast at the beginning of each school day. The students were also offered a food supplement consisting of vitamins, minerals and omega-3 fatty acids. The breakfast consisted of low-fat milk, orange juice, whole-grain bread, different spreads with fish, meat and cheese and a fruit.				
James *et al.* 2004 (23) (CHOPPS)	Control – no further details	1-h session each class each term (four sessions) encouraging children not to drink carbonated drinks but to switch to water or fruit juice diluted 1:3 with water.				
PA ONLY STUDIES						
Flores 1995 (35)	Usual PA (playground activities)	Culturally sensitive health education curriculum twice a week plus dance-orientated aerobic PE class three times a week (50 min each) for 12 weeks.				
Harrison *et al.* 2006 (9) (Switch Off – Get Active)	Usual health education curriculum	10 lessons, teacher-led, emphasized self-monitoring, budgeting of time and selective viewing. Points system for activity and viewing time. Intervention philosophy based on social cognitive theory for behaviour change. Designed to complement existing social, personal and health education curriculum. Two key messages were to minimize time spent watching TV and playing computer games and the need to increase PA. Teacher resources, pupil workbooks and diaries provided, teachers supported by visits every 2 weeks and parents encouraged in writing to support children.				
Jamner *et al.* 2004 (40)	Control – no further details	Special PE class. The class met 5 d week⁻¹ for 60 min each day (approximately 40 min of activity time). Types of activity included aerobic dance, basketball, swimming and Tae Bo. 1 d week⁻¹ of class time was devoted to a lecture or discussion focusing on the health benefits of PA and strategies for becoming more physically active.				
Lazaar 2007 (10)	All children were given 2 × 1 h sessions of PE per week incorporated within the school timetable.	1-h sessions twice a week of PA after class, supervised by sports science students training to become PE teachers. All children were given 2 × 1 h sessions of PE per week incorporated within the school timetable.				
Mo-suwan *et al.* 1998 (46)	Both schools had 1-h PE per week	15-min walk before morning class, 20-min aerobic dance session after afternoon nap, three times per week for 29.6 weeks. Both schools had 1-h PE per week.				

Table 1 *Continued*

Study	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Pangrazi *et al.* 2003 (43)	No treatment control	PLAY Promotes 30–60 min moderate to vigorous PA daily, 15-min activity break each day to teach variety of PA, promotes attitudes and behaviours to sustain active habits for life; includes self-monitoring and self-awareness. PLAY is not intended to replace comprehensive PE programme but act as important supplement. The intervention comprised three stages: Step 1: promote play behaviour (first week) teachers and students participated, more walking, less standing, sitting, children were informed about the importance of PA and identified appropriate adult role models. Step 2: teacher-directed activities (3 weeks) games and activities that were enjoyable and could be played outside school. Step 3: encourage self-directed activity (8 weeks) with students aiming to achieve 30 min of activity per day independently of teacher outside school. Treatment and PE schools; children received log sheets similar to the PLAY ones but were asked to record their after school activities (active and sedentary).	PE Promotes 30–60 min moderate to vigorous PA daily, 15-min activity break each day to teach variety of PA, promotes attitudes and behaviours to sustain active habits for life; includes self-monitoring and self-awareness. PLAY is not intended to replace comprehensive PE programme but act as important supplement. The intervention comprised three stages: Step 1: promote play behaviour (first week) teachers and students participated, more walking, less standing, sitting, children were informed about the importance of PA and identified appropriate adult role models. Step 2: teacher-directed activities (3 weeks) games and activities that were enjoyable and could be played outside school. Step 3: encourage self-directed activity (8 weeks) with students aiming to achieve 30 min of activity per day independently of teacher outside school. Treatment and PE schools, children received log sheets similar to the PLAY ones but were asked to record their after school activities (active and sedentary).	PLAY + PE Promotes 30–60 min moderate to vigorous PA daily, 15-min activity break each day to teach variety of PA, promotes attitudes and behaviours to sustain active habits for life; includes self-monitoring and self-awareness. PLAY is not intended to replace comprehensive PE programme but act as important supplement. The intervention comprised three stages: Step 1: promote play behaviour (first week) teachers and students participated, more walking, less standing, sitting, children were informed about the importance of PA and identified appropriate adult role models. Step 2: teacher-directed activities (3 weeks) games and activities that were enjoyable and could be played outside school. Step 3: encourage self-directed activity (8 weeks) with students aiming to achieve 30 min of activity per day independently of teacher outside school. Treatment and PE schools, children received log sheets similar to the PLAY ones but were asked to record their after school activities (active and sedentary).		

Table 1 *Continued*

Study	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Pate *et al.* 2005 (38)	Control – no further details	LEAP, based on social ecological model drawn mainly from social cognitive theory; LEAP project staff supported the LEAP teams within the schools which included a LEAP champion; girl-friendly PA of moderate to vigorous PA for 50% or more of PE class time (aerobics, dance, walking, self-defence, martial arts, weight training plus competitive sport and traditional PE). Environmental change included role modelling by school staff, family and community-based activities.				
Robbins *et al.* 2006 (11) (Girls on the move)	After completing computerized questionnaires, each girl in the control group received a handout listing the PA recommendations.	To encourage PA, each girl in the intervention group received computerized, individually tailored feedback messages based on her responses to the questionnaires, individual counselling from the school's PNP and telephone calls and mailings from a trained research assistant. Each wellness centre staffed by PNP, social worker and medical assistant.				
Robinson 1999 (36)	Control – no further details	Based on Bandura's social cognitive theory; 18 × lessons of 30–50 min, included self-monitoring of TV, videotape and video game use, then 10-d turn-off, then 7-h budget, children taught to become selective viewers and advocators of reducing media use. Parental involvement.				
Sallis *et al.* 1993, 1997 (41,42)	Control – no further details	Two intervention groups receiving the same programme – provided by teachers trained for total 38 h in-house over 2 years. 3 × 30-min classes per week including warm-up, fitness activities such as walk/run/jog/aerobic dance and sports skills such as soccer/basketball/softball; plus weekly 30-min self-management training, also incentives and parental involvement through newsletters and signature on weekly goal sheets.	Two intervention groups receiving the same programme – provided by certified PE specialist. 3 × 30-min classes per week including warm-up, fitness activities such as walk/run/jog/aerobic dance and sports skills such as soccer /basketball/softball; plus weekly 30-min self-management training, also incentives and parental involvement through newsletters and signature on weekly goal sheets.			

Table 1 *Continued*

Study	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Schofield *et al.* 2005 (39)	Control – no further details	Minutes intervention: Increase by 10–15 min daily each week until reached daily average of 30–60 min d⁻¹. Group meetings once a week for 6 weeks for 30 min each in groups of eight either before or after school or during lunch break. Intervention groups received log book to record minute in PA or amount of step counts; actual activity intervention was 12 weeks with weeks 7–12 maintenance phase (no group meetings).	Pedometer intervention: 1000–2000 steps increase daily each week until reached 10 000 steps per day. Group meetings once a week for 6 weeks for 30 min each in groups of eight either before or after school or during lunch break. Intervention groups received log book to record minute in PA or amount of step counts; actual activity intervention was 12 weeks with weeks 7–12 maintenance phase (no group meetings).			
Stephens & Wentz 1998 (37)	Control children received usual PE (45 min once per week).	Supplementary programme of PA on weight in addition to usual PE (45 min once per week).				
Trudeau 2000 (44), Trudeau *et al.* 2001 (45)	Control – no further details	6-year intervention involving 1 h d⁻¹ (5 h week⁻¹) of PE to increase aerobic and muscular capacity, in comparison with a control group that received single 40-min PE per week.				
Valdimarsson *et al.* 2006 (16) Linden *et al.* 2006 (17) (The Malmo Pediatric Osteoporosis Prevention [POP] Study)	In the control schools, the same type of PA was used as in the intervention school but at a level within the compulsory Swedish school curriculum of PE, consisting of one or two sessions per week (total 60 min week⁻¹).	The ordinary indoor and outdoor PA used within the Swedish school curriculum, now increased to 40 min d⁻¹ (200 min week⁻¹), supervised by the ordinary teacher. The intervention did not consist of any programmes specifically designed as being osteogenic. Activities included ball games, running and jumping, virtually no specific sports training was conducted. The teachers also conducted a variety of different PA so as not to bore the children with repeated standardized activities.				
Viskic-Stalec *et al.* 2007 (18)	Control group attended standard PE (66 sessions)	Intervention group attended 66 sessions including aerobics, step aerobics, folk, social and jazz dance, rhythmic gymnastics.				

Table 1 *Continued*

Study	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
COMBINED DIET AND PA STUDIES						
Caballero *et al.* 2003 (33) (Pathways)	Control – no further details	Four components: (1) Change in dietary intake (Pathways guidelines for food-service personnel and regular visit by Pathways nutritionist to support and monitor school lunches). (2) Increase in PA (3 × 30-min moderate to vigorous PA based on SPARK programme [see Sallis 1993 [41]] per week during term-time, exercise break during classroom time and guided play during recess). (3) A classroom curriculum focused on healthy eating and lifestyle (12 weeks year⁻¹, 8 weeks in fifth grade, twice weekly 45-min classroom lessons integrating social learning theory with American–Indian traditions and indigenous learning modes such as story telling). (4) A family-involvement programme (family fun nights, workshops, events at school and fun packs linked to classroom curriculum).				
Danielzik *et al.* 2007 (6) (KOPS)	Control – no further details	6-h course of nutrition education followed by 20 min of 'active break' (eat fruit and vegetables every day, reduce intake of high-fat foods, keep active for at least 1 h d⁻¹, decrease TV consumption to 1 h d⁻¹). Message also given to parents. Three schools received intervention per year.				
Donnelly *et al.* 1996 (34)	Control – no further details	Components included a nutrition intervention (changes to school lunches using Lunchpower! which is a reduced energy, fat and sodium lunch and nutrition education in curriculum) and PA intervention of 30–40 min d⁻¹ 3 d week⁻¹ of aerobic activities.				
Eliakim *et al.* 2007 (7)	Control – no further details	Nutritional education integrated into curriculum, 45 min d⁻¹ 6 d week⁻¹ of exercise training mainly circuit training, also encouraged to reduce sedentary behaviour.				
Gortmaker *et al.* 1999 (28) (Planet Health)	Control – no further details	Promotion of PA, modification of dietary intake (decreasing consumption of high-fat foods, increasing fruit and vegetable consumption) and reduction of sedentary behaviours (with a strong emphasis on reducing TV viewing). Underpinned by behavioural change and social cognitive theory. 32 classroom lessons of 45 min each over two school years.				
Graf *et al.* 2005 (29)	Control – no further details	The STEP TWO programme, which is designed for overweight and obese children, consisted of health education and PA delivered by a team of nutritionists, gymnasts, psychologists and medical doctors.				

Table 1 *Continued*

Study	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Haerens *et al.* 2006 (8)	Control – no further details	The PA environmental intervention focused on increasing levels of moderate to vigorous PA to at least 60 min d⁻¹. Schools were encouraged to create more opportunities to be physically active during breaks, at noon or after school hours. This resulted in a weekly organization of an average 4.7 h of extra PA. Schools encouraged varying content of PA, non-competitive activities encouraged and extra sports materials provided. Over two school years a total of four class hours spent on promoting PA at the personal level – computer tailored PA including feedback based on personal physical fitness and based on stages of change theory. Food intervention focused on increasing fruit consumption to at least two pieces per day, reducing soft drink and increasing water consumption and reduce fat intake (free or low-price water and fruit made available). Over two school years a total of two class hours spent in promoting healthy eating at personal level – computer tailored intervention. Parental involvement included adult computer tailored intervention for fat intake and PA.				
Kain *et al.* 2004 (30)	Control – no further details	Intervention children received 8–11 h dietary education in sixth grade and 5–6 h for seventh and eighth grade over 6 months; 90 min week⁻¹ of PA (sport) by school PE/classroom teacher or research PE for 6 months; active recess once a day for the last 3 months; healthy kiosks; parental involvement (two meetings) and special activities including prize for eating the most healthy snacks.				
Luepker *et al.* 1996 (47) (CATCH)	Control schools received usual care	Modifications to school food service (30% fat), enhanced PE (moderate to vigorous activity for 40% class time) and classroom health curricula. Intensity but not duration of PE lessons changed in intervention group compared with control.	Modifications to school food service (30% fat), enhanced PE (moderate to vigorous activity for 40% class time) and classroom health curricula, and 28 of the 56 intervention schools also had family education (activity packs and family fun nights). Intensity but not duration of PE lessons changed in intervention group compared with control.			
Manios *et al.* 1998, 1999, 2002 (24–26) Kafatos *et al.* 2007 (22) (Cretan Health and Nutrition Education Program)	Control – no further details	Nutrition component comprised 13–17 h classroom materials conducted by class teacher each year; 4–6 h classroom material on theory of PE and 2 × 45 min PE per week by PE teachers. Theoretical framework based on social cognitive theory, targeting children and parents, social and physical environment. Adapted 'Know Your Body' school health promotion programme.				

Table 1 *Continued*

Study	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Rosenbaum *et al.* 2007 (12)	Control – no further details	45-min classroom session once per week integrated into regular science programme and taught by the study investigators.				
		Nutrition education and dietary modification to lower dietary fat, sweetened drinks and fast or super sized food consumption. Exercise sessions consisted of dance/no-contact kickboxing three times per week or attend regular gym classes – exercise sessions supervised by one study investigator.				
Sahota *et al.* 2001 (32) (APPLES)	Control – no further details	Included teacher training, modification of school meals, the development of school action plans targeting the curriculum, PE, tuck shops and playground activities.				
		Sahota used a population approach underpinned by the Health-Promoting Schools philosophy and the intervention involved the whole school community including parents, teachers and catering staff.				
Sallis *et al.* 2003 (27)	Control – no further details	The primary aims of the intervention were: (1) Increase the total energy expenditure from PA by the student population at school. (2) Decrease the grams of total saturated dietary fat purchased or brought to school by students.				
		One intervention component was designed to increase PA in PE classes through changing lesson context, lesson structure and teacher behaviour. Another intervention component was intended to increase PA on campus during leisure periods throughout the school day.				
		Interventions with school food service staff and managers were undertaken to provide more low-fat choices at these sources.				
Singh *et al.* 2007 (14) (Dutch Obesity Intervention in Teenagers [DOiT study])	Control schools maintained regular curriculum	Intervention developed using mapping protocol, which is based on theory and empirical evidence. 11 lessons in Biology and PE that aimed to increase awareness and behavioural changes concerning energy intake and output. Reduce high-sugar, high-fat snacks, sugar-sweetened beverages, reduce sedentary and increase active behaviours, individually tailored advice via internet or CD-ROM, additional PE classes encouraged, changes to school canteen.				
Spiegel *et al.* 2006 (15)	Control – no further details	Intervention based on the Theory of Reasoned Action. Programmed integrated into various parts of the core curriculum, include wellness, nutrition, PA and fitness. Intervention classes followed a 10-min aerobic exercise routine each day during class time. Web site provided resources for teachers, students and parents.				

Table 1 *Continued*

Study	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Taylor *et al.* 2007 (20) (A Pilot for Lifestyle and Exercise – APPLE project)	Schools received payment of $500–$1000 depending on school size for the purchase of school equipment as a reimbursement for the time required to measure children	Nutrition education targeting reductions in sweetened drinks and increased fruit and vegetable intake, also interactive card game (mainly in second year of intervention) and activity coordinators (0.5 full-time equivalent per school) who managed an activity programme that focused on non-curricular lifestyle-based activities such as community walks (in breaks, lunchtime and after-school).				
Trevino *et al.* 2004 (48), Trevino 2005 (49)	Control – no further details	The intervention was the Bienestar Health Program based on Social Cognitive Theory in which personal factors, social factors and behaviour are inter-related and have dynamic influences on each other. The Bienestar Program was designed to influence each determinant to decrease dietary fat and increase dietary fibre consumption and to promote participation in moderate to vigorous PA. Programme activities were bilingual and included a parent education and involvement programme, a classroom health and PE curriculum, a student after school health club and a school cafeteria programme.				
Vandongen *et al.* 1995 (50)	Control group	Fitness group. Fitness: 6 × 30 min classroom sessions and 15 min every school day of activity to increase heart rate to 150–170 beats min⁻¹.	School nutrition group. Nutrition programme: Increase consumption of fruit, vegetables, whole-grain bread and cereals relative to other foods and decrease consumption of fatty, sugary and salty foods, 33% energy intake as fat, 12% as sugar, 25 g fibre d⁻¹. School-based: 10 × 1-h lessons.	Home nutrition group. Nutrition programme: Increase consumption of fruit, vegetables, whole-grain bread and cereals relative to other foods and decrease consumption of fatty, sugary and salty foods, 33% energy intake as fat, 12% as sugar, 25 g fibre d⁻¹. Home-based: Homework exercise sheets.	Fitness and school nutrition group. Fitness: 6 × 30 min classroom sessions and 15 min every school day of activity to increase heart rate to 150–170 beats min⁻¹. Nutrition programme: Increase consumption of fruit, vegetables, whole-grain bread and cereals relative to other foods and decrease consumption of fatty, sugary and salty foods, 33% energy intake as fat, 12% as sugar, 25 g fibre d⁻¹. School-based: 10 × 1-h lessons.	Fitness and home nutrition group. Fitness: 6 × 30 min classroom sessions and 15 min every school day of activity to increase heart rate to 150–170 beats min⁻¹. Nutrition programme: Increase consumption of fruit, vegetables, whole-grain bread and cereals relative to other foods and decrease consumption of fatty, sugary and salty foods, 33% energy intake as fat, 12% as sugar, 25 g fibre d⁻¹. Home-based: Homework exercise sheets.

Table 1 *Continued*

Study	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Warren *et al.* 2003 (31)	Control	Nutrition group Underpinned by Social Cognitive Theory and took place in lunchtime clubs where an interactive and age-appropriate nutrition and/or PA curriculum was delivered by the research team, with both involving parents. The intervention ran for 20 weeks over four school terms (approximately 14 months).	PA group Underpinned by Social Cognitive Theory and took place in lunchtime clubs where an interactive and age-appropriate nutrition and/or PA curriculum was delivered by the research team, with both involving parents. The intervention ran for 20 weeks over four school terms (approximately 14 months).	Nutrition and PA group Underpinned by Social Cognitive Theory and took place in lunchtime clubs where an interactive and age-appropriate nutrition and/or PA curriculum was delivered by the research team, with both involving parents. The intervention ran for 20 weeks over four school terms (approximately 14 months).		
Williamson *et al.* 2007 (19) (Wise Mind Project)	Active control programme was to modify children's beliefs on the use and abuse of tobacco, alcohol and illicit drugs	Wise Mind is based on notion that with the knowledge and environmental changes students can make wise decisions about nutrition, PA and substance use/abuse. Intervention required large-scale environmental modifications within the schools (vending machines in all schools eliminated before study). To improve healthy eating, increase PA, decrease sedentary behaviour and encourage the same behavioural changes outside school. Dietary goals were five fruit and vegetables per day, less than 30% total energy from fat, less than 10% total energy from saturated fat, 20–30 g fibre d^{-1}. Wise Mind staff worked closely with teachers and cafeteria personnel to encourage appropriate portion sizes, calories and nutrient content of lunches. Various media used. Indoor and outdoor ply supplies provided. Monthly newsletter emailed to parents plus weight gain prevention web site available to families.				

CHOPPS, the Christchurch obesity prevention programme in schools; PA, physical activity; PE, physical education; PNP, paediatric nurse practitioner; SPARK, Sports, Play and Active Recreation for Kids.

Table 2 Diet interventions to prevent obesity in school children

Study	Design/power	Population	Number/baseline mean BMI (SD) kg m^{-2}	Aim	Follow-up/not assessed %
Amaro et al. 2006 (4)	RCT Cluster by class Pilot study. Detectable difference in BMI z-score change with type one error rate of 0.05 and 80% power was 0.366.	Setting: 16 classes in three middle schools in Naples, Italy Participants: 291 children, Age 12 (11–14) Caucasian	I: 188 C: 103 BMI z-score: I: 0.47 (0.93) n = 153 C: 0.15 (0.88) n = 88	To test efficacy of a board game Kaledo in providing nutrition knowledge and promoting healthy dietary behaviour.	24 weeks I: 19% C: 15%
Ask et al. (5)	RCT Cluster by class Small pilot study, power not reported	Setting: Two tenth grade classes in one lower secondary school in rural district of Southern Norway Participants: 54 adolescents Age 15	I: 26 C: 28 Median BMI (range): I: male; 22.6 (17.8–33.6); female 21.8 (16.9–27.3) C: male; 21.7 (17.0–29.4); female 21.6 (16.7–28.4)	To evaluate if dietary habits and school performance improved in a lower secondary school class as a result of introducing breakfast.	4 months I: 0% C: 0%
James et al. 2004 (23) (CHOPPS)	RCT Cluster by class 90% power to detect differences of 0.14 between control and intervention groups.	Setting: 19 classes in six Primary schools in Dorset, UK Participants: Male/female: 324/320 Age: 8.7 (7–10.9)	I: 325 C: 319 I: 17.4 (0.6) C: 17.6 (0.7)	To reduce consumption of carbonated drinks.	12-month intervention with follow-up at 3 years 12 months: I: 9% C: 13% 3 years: I: 33% C: 33%

CHOPPS, the Christchurch obesity prevention programme in schools; BMI, body mass index; SD, standard deviation; RCT, randomized controlled trial; I, intervention; C, control.

Table 3 PA interventions to prevent obesity in school children

Study	Design/power	Population	Number/baseline mean BMI (SD) kg m^{-2}	Aim	Follow-up/not assessed %
Flores 1995 (35)	RCT Cluster by class Power not stated	Setting: Four PE classes at 1 school in Palo Alto, CA, USA Participants: Male/female: 46%/54% Age 12.6 (10–13) 44% African–American 43% Hispanic	I: 43 C: 38 I (girls): 22.9 (6.1) C (girls): 22.9 (4.4)	To evaluate an aerobic dance programme to help maintain or decrease weight.	12 weeks I: unclear C: unclear
Harrison et al. 2006 (9) (Switch Off – Get Active)	CCT Unit of assignment was school 'Sample size was not large enough to ascertain efficacy of the intervention in boys and girls or in normal and overweight children separately'	Setting: Nine primary schools in towns and rural areas of South-East Ireland, in areas of greatest social disadvantage Participants: 42–44% girls Age 10	I: 182 C: 130 I: 19.0 (0.2) C: 19.2 (0.4)	To determine the efficacy of a health education intervention on BMI targeted sedentary behaviours and PA in Irish primary school children.	16 weeks I + C: 9%
Jamner et al. 2004 (40)	CCT Unit of assignment was school Power not stated – small study	Setting: Two public high schools in Orange County, CA, USA Participants: Male/female: 0/58 Age 14.94 (0.79) 53% non-Hispanic white, 29% Hispanic, 8% Asian and 3% 'other'	I + C: 58 BMI percentile: I: 67.28 n = 25 C: 60.47 n = 22	To evaluate the effect of a school-based intervention designed to increase PA among sedentary girls.	4 months I + C: 19%
Lazaar 2007 (10)	CCT Unit of assignment was school Power not stated	Setting: 19 local state elementary schools, France Participants: 425 healthy children Age 7.4 (6–10) Participating in scheduled school PE lessons and in less than 3 h extra school sports activity per week	I (non-obese):138 I (obese): 59 C (non-obese):187 C (obese): 41 I (non-obese girls): 15.9 (1.2); I (obese girls): 20.1 (2.8); I (non-obese boys): 15.5 (1.2); I (obese boys): 21.0 (2.4); C (non-obese girls): 15.6 (1.1); C (obese girls): 20.4 (2.2); C (non-obese boys): 15.4 (1.1); C (obese boys): 20.0 (1.3) kg m^{-2}	To evaluate the effect of school-based PA on body composition according to BMI categories and gender.	6 months I + C: 1.1%
Mo-suwan et al. 1998 (46)	RCT Cluster by class Power not stated	Setting: Two kindergartens in privately owned schools Southern Thailand Participants: Second year kindergarten pupils, boys and girls Age 4.5 (0.4)	I: 158 C: 152 I: 16.25 (2.35) C: 16.36 (2.22)	To evaluate the effect of a school-based aerobic exercise programme on obesity indexes of preschool children.	30 weeks I: 7% C: 5%

Table 3 *Continued*

Study	Design/power	Population	Number/baseline mean BMI (SD) kg m^{-2}	Aim	Follow-up/not assessed %
Pangrazi *et al.* 2003 (43)	CCT Control schools were not randomly selected Power not stated	Setting: 35 schools in Arizona, USA Participants: boys and girls Age 9.8 (0.6)	PLAY + PE: 183 PE only: 175 PLAY only: 150 No treatment control: 91 BMI not reported	To evaluate the effects of the PLAY intervention.	12 weeks I: unclear C: unclear
Pate *et al.* 2005 (38)	RCT Cluster by school Power not stated	Setting: 24 high schools in 14 South Carolina counties, USA Participants: Male/female: 0/2744 Age 13.6 48.7% African–American, 46.7% white	I: 1523 C: 1221 I: 22.9 (5.4), 863 C: 23.0 (5.5), 741	To evaluate school-based PA intervention among high school girls.	6 months I + C: 42%
Robbins *et al.* 2006 (11) (Girls on the move)	RCT Cluster by grade (6,7,8) 'The small sample size may have precluded the ability to detect significant difference between the groups'	Setting: Wellness centres in two two middle schools in Michigan, USA (low-socioeconomic geographic areas in the Midwest) Participants: Male/female: 0/77 Age: 11–14 racially diverse sedentary girls, self-identified as being in the 'contemplation' and 'preparation' stages of change	I: 45 C: 32 I: School 1, seventh grade: *n* = 19; 24.55 (9.89) School 2: sixth grade *n* = 22; 23.29 (5.37) School 2: eighth grade *n* = 4; 22.26 (4.11) C: School 1: sixth grade: *n* = 8; 24.15 (8.22) School 2: seventh grade *n* = 15; 21.88 (5.12) School 1: eighth grade *n* = 9; 24.59 (5.30)	To determine the feasibility of an individually tailored PA programme plus nurse counselling intervention in increasing PA.	12 weeks I: 0% C: 0%
Robinson *et al.* 1999 (36)	RCT Cluster by school Designed to have 80% power to detect an effect size of 0.20 or greater.	Setting: Two public elementary schools in San Jose, CA, USA Participants: Boys and girls Age 8.9	I: 95 C: 103 I: 18.38 (3.67) C: 18.10 (3.77)	To evaluate a school-based intervention to reduce TV, videotape and video game use on adiposity.	6 months I: 3% C: 3%
Sallis *et al.* 1993, 1997 (41,42) (SPARK)	RCT Cluster by school Power not stated	Setting: Seven suburban elementary schools in Southern California, USA Participants: Boys and girls Age 9.25 85% non-Hispanic white	I + C: 745 BMI not reported	To evaluate a school-based intervention involving PE and self-management (delivered either by specialists or teachers) on weight and adiposity.	2 years I + C: 26%

Table 3 *Continued*

Study	Design/power	Population	Number/baseline mean BMI (SD) kg m^{-2}	Aim	Follow-up/not assessed %
Schofield et al. 2005 (39)	CCT Unit of assignment was school Power not stated	Setting: Three high schools in central Queensland, Australia Participants: Male/female: 0/85 Age 15.8 Low active girls	I (Pedometer):27 I (Minutes): 28 C: 30 I (Pedometer): 22.3 (4.1); I (Minutes): 23.7 (6.6); C: 24.5 (5.5)	To pilot efficacy of using pedometer as basis of time efficient yet effective non-curriculum school-based programme.	12 weeks I (Pedometer):15% I (Minutes): 25% C: 20%
Stephens & Wentz 1998 (37)	CCT Unit of assignment was school Power not stated	Setting: Two urban elementary public schools in Cleveland, OH, USA Participants: I: male/female: 44%/56% Age 8.4 98% African–American; C: male/female: 57%/43% Age 8.4 78% African–American; 'Predominantly from low-income families'	I: unclear (45 at follow-up) C: unclear (44 at follow-up) Weight (kg) I: 25.4 C: 26.1	To evaluate a school-based supplementary programme of PA on weight in addition to usual PE.	15 weeks I + C: unclear
Trudeau 2000 (44), Trudeau et al. 2001 (45) (The Trois-Riveries Growth and Development study)	CCT Power not stated – subgroup analysis unlikely to be powered	Setting: Primary schools in Trois-Rivieres, Quebec, Canada Participants: boys and girls Age 6 French descent	I: 272 C: 275 BMI not reported	To evaluate whether a programme of PA and fitness in school children over 6 years would result in enhanced cardiovascular fitness in adulthood.	6 year intervention and 22 year follow-up. I: 75% C: 76% Random selected sample assessed at 22-year follow-up
Valdimarsson et al. 2006 (16) Linden et al. 2006 (17) (The Malmo Pediatric Osteoporosis Prevention [POP] Study)	CCT Unit of assignment was school The small sample size may have precluded the ability to detect significant difference between the groups	Setting: Four schools in middle class area of Malmo, Sweden Participants: Male/female: 0/53 Age: I: 7.6; C: 7.9; Healthy, Caucasian, Tanner stage 1	I: 55 C: 64 I: 16.9 (2.9) n = 49 C: 16.3 (1.9) n = 49	To determine whether a general, moderately intense exercise intervention programme could increase the accrual of bone mineral content and areal bone mineral density and increase bone width.	2 years I: 11% C: 22%
Viskic-Stalec et al. 2007 (18)	CCT Power not stated	Setting: High school, Zagreb, Croatia Participants: Male/female: 0/220 Age 16–18 Clinically healthy	I: 115 C: 105 I: 21.05 (2.12) n = 115 C: 20.1 (1.83) n = 102 Greater body weight in Intervention group compared with control	To analyse the impact of special programmed PE including dance, aerobics and rhythmic gymnastics on the development of motor and functional abilities and morphological characteristics of female fourth-grade high schoolers in Zagreb.	One academic year I: 0% C: 3%

PA, physical activity; PE, physical education; SPARK, Sports, Play and Active Recreation for Kids; BMI, body mass index; SD, standard deviation; RCT, randomized controlled trial; CCT, controlled clinical trial; I, intervention; C, control.

Table 4 Combined diet and PA interventions to prevent obesity in school children

Study	Design/power	Population	Number/baseline mean BMI (SD) kg m^{-2}	Aim	Follow-up/not assessed %
Caballero et al. 2003 (33) (Pathways)	RCT Cluster by school Power not stated	Setting: 41 elementary schools in 7 American–Indian communities in Arizona, New Mexico, South Dakota, USA Participants: American–Indian school children. Age 7.6 (0.6)	I: 879 C: 825 I:19.0 C:19.1	To evaluate a school-based multi-component intervention to reduce % body fat in American–Indian children.	3 years I: 17% C: 17%
Danielzik et al. 2007 (6) (Kiel Obesity Prevention Study)	CCT Longitudinal data Power not stated	Setting: 32 primary schools in Kiel, Germany Participants: 49–50% boys Age 6	I: 780 C: 1420 Median BMI (inter-quartile range) I: 15.6 (14.8–15.7) n = 344 C: 15.4 (14.6–16.4) n = 1420	To evaluate feasibility and 4-year outcome of school-based health promotion on overweight	3.8 (0.4) years I: 56% C: 0%
Donnelly et al. 1996 (34)	CCT Unit of assignment was school Power not stated	Setting: Elementary schools in rural Nebraska, USA Participants: Boys and girls Age 9.2 94% White, 42–44% received free and reduced school lunches.	I: 102 C: 236 I: 18.3 (3.9) C: 18.5 (3.4)	To evaluate a school-based PA and nutrition programme to attenuate obesity and promote fitness.	2 years I: 57% C: 73%
Eliakim et al. 2007 (7)	RCT Cluster by class Power not stated	Setting: Four pre-school classes in upper-middle class SES community, Oranit, Israel Participants: Male/female: 58/43 Age 5–6	I: 54 C: 47 I: 15.7 (0.2) C: 15.9 (0.2)	To study effects of a brief school-based health promotion intervention	14 weeks I: 0% C: 0%
Gortmaker et al. 1999 (28) (Planet Health)	RCT Cluster by school Only 33 incident cases of obesity 'limited the statistical power of the study to detect differences'	Setting: 10 secondary schools in Boston, USA Participants: Male/female: 52%/48% Age 11.7 (0.7) Higher % African–American girls in control schools (17 vs. 10%) and Hispanic boys in control schools (18 vs. 12%).	I + C: 1560 I: 20.6 (4.5) n = 641 C: 20.7 (4.0) n = 654	To evaluate impact of school-based health behaviour intervention known as Planet Health on obesity among boys and girls in grades 6 to 8.	Two school years I + C: 17%
Graf et al. 2005 (29) STEP TWO	CCT Unit of assignment was school Power not stated	Setting: Seven primary schools in Cologne, Germany Participants: Male/female: 830/848 girls Age 8.2 (1.3)	I + C: 1678 I + C: 17.1 (2.9)	To present the baseline and final data from the STEP TWO programme.	8–9 months I + C: 89% Only subsample invited to take part in study

Table 4 *Continued*

Study	Design/power	Population	Number/baseline mean BMI (SD) kg m^{-2}	Aim	Follow-up/not assessed %
Haerens *et al.* 2006 (8)	RCT Cluster by school The analyses showed that an *n* = 300 in each group was sufficient to power the study at 0.8 and to detect a difference of 0.3 in BMI, given the 0.05 level of significance.	Setting: 15 middle schools with technical and vocational training in West-Flanders, Belgium Participants: Intervention with parental support: Male/female: 60%/40% Age 13 68% lower SES; Intervention without parental support: Male/female: 84%/16% Age 13 years 79% lower SES C: male/female: 41%/59% Age 13 52% lower SES	I (parent support): 1226 I (without parent support): 1006 C: 759 I (parent support): 19.68 (3.83); I (without parent support): 19.52 (3.50); C: 18.96 (3.28)	To evaluate the effects of a 2-year middle school PA and healthy food intervention, including an environmental and computer-tailored component on BMI and BMI z-score in boys and girls.	21 months (two school years) I (parent support): 21% I (without parent support): 28% C: 22%
Kain *et al.* 2004 (30)	CCT Unit of assignment was school *Post hoc* power 0.8, alpha 0.05	Setting: Five primary schools in Santiago, Curico, Casablanca, Chile Participants: Male/female: I: 53.5%/46.5%; C: 52%/48% Age 10.6 (2.6) (Approximately 35% received school lunch programme).	I: 2375 C: 1202 I: 19.6 (3.8) *n* = 2141 C: 19.2 (3.6) *n* = 945	To evaluate a school-based nutrition education and PA intervention on adiposity and physical fitness.	6 months I: 10% C: 21%
Luepker *et al.* 1996 (47) (CATCH)	RCT Cluster by school Sample size determined – adequately powered	Setting: 96 public state schools in 12 school districts in California, Louisiana, Minnesota and Texas Participants: Male/female: 2645/2461 Age 8.76 Ethnically diverse (white, African–American and Hispanic).	I + C: 5106 I: 17.68 (3.23), 1627 C: 17.58 (2.90), 2332	To evaluate a school-based intervention including a home programme for the primary prevention of cardiovascular disease.	3 years I + C: 20%
Manios *et al.* 1998, 1999, 2002 (24–26) Kafatos *et al.* 2007 (22) (Cretan Health and Nutrition Education Program)	CCT Unit of assignment was school Power not stated	Setting: Primary schools in Iraklio and Rethimno (intervention) and Chania (control) Crete, Greece Participants: Male/female: 509/453 Age 5.5–6.5	I: 602 C: 444 I: 16.2 (2.2), 231 C: 16.3 (2.3), 162	To evaluate a school-based intervention involving a health and nutrition element and a physical fitness and activity element, on chronic disease risk factors	I: unclear C: unclear separate random samples analysed at 3 years, 6 years and 10 years

Table 4 *Continued*

Study	Design/power	Population	Number/baseline mean BMI (SD) kg m^{-2}	Aim	Follow-up/not assessed %
Rosenbaum *et al.* 2007 (12)	RCT Cluster by class Power not stated	Setting: New York City public school Participants: Male/female: 31/42 Age 14 years First or second generation in the US majority with origins in the Dominican Republic (Hispanic). 53% with known affected first or second degree relative with type II diabetes	I + C: 79 I: 24.7 (1.4) *n* = 49 C: 24.3 (1.8) *n* = 24	To evaluate the effect of school-based intervention consisting of health, nutrition and exercise classes plus an aerobic exercise programme on diabetes risk.	12 weeks I + C: 8%
Sahota *et al.* 2001 (32) APPLES	RCT Cluster by school 80% power to detect difference in means of a normally distributed outcome measure of at least 1.8 SD at 5% significance level	Setting: 10 primary schools in Leeds, UK Participants: Boys and girls Age 8 (7–11)	I: 314 C: 322 BMI SD score: I: 0.12 (1.01) C: 0.04 (1.17)	Assessed the impact of a primary school-based intervention, which included teacher training, modification of school meals, the development of school action plans targeting the curriculum, PE, tuck shops and playground activities.	1 year I: 7% C: 6%
Sallis *et al.* 2003 (27)	RCT Cluster, schools randomized by district Power not stated	Setting: 24 public middle schools in San Diego County, California, USA Participants: 49% female, 44.5% non-white, 39.5% received free or reduced school meals, 36.4% were bussed to school. Mean age not reported.	Mean enrolment across 24 schools was 1109 (SD 356) students per school BMI not reported	To evaluate the effects of environmental, policy and social marketing interventions on PA and fat intake of middle school students.	Two school years Number assessed in each group at follow-up not reported
Singh *et al.* 2007 (14) (Dutch Obesity Intervention in Teenagers [DOiT study])	RCT Cluster, by school or location and stratified by urban vs. rural Sample size of 500–600 from 16 schools was required – study adequately powered	Setting: 18 prevocational secondary schools (of the lowest educational level), the Netherlands Participants: Male/female: 492/561 Age 12.7	I: 600 C: 453 I girls: 19.0 (3.0) C girls: 19.48 (3.38) I boys: 18.16 (2.64) C boys: 19.05 (2.86)	To evaluate whether a school-based multi-component health promotion for Dutch adolescents would be successful in positively influencing body compositions and aerobic fitness.	8 months I + C: 7%

Table 4 *Continued*

Study	Design/power	Population	Number/baseline mean BMI (SD) kg m^{-2}	Aim	Follow-up/not assessed %
Spiegel *et al.* 2006 (15) (Wellness Academics and You [WAY study])	RCT Power: sample size not mentioned but relatively large sample	Setting: 69 classes, 16 elementary schools across four states, USA Participants: Students in fourth and fifth grade	I: unclear (534 completed) C: unclear (479 completed) Mean baseline BMI: not stated. 39.4% control and 36.4% intervention were overweight or at risk for overweight.	To evaluate the effectiveness of a multidisciplinary elementary school-based intervention.	6 months I: 13.7% C: 16.2%
Taylor *et al.* 2007 (20) (A Pilot for Lifestyle and Exercise – APPLE project)	CCT Pilot study Study had potential to detect an effect size of 0.3 in any of the measures with 80% power with the use of 5% level of significance	Setting: seven primary schools in 2 communities, Otago, New Zealand Participants: Male/female: 246/223 Age 7.7 (5–12) 82.6% white Intervention children were leaner (*P* = 0.004) with smaller waist circumference (*P* = 0.001)	I: 279 C: 234 I: 17.4 (2.4) *n* = 250 C: 18.2 (3.3) *n* = 219	To determine effectiveness of a 2-year controlled community-based intervention to prevent excessive weight gain in 5–12-year-old children by enhancing opportunities for healthy eating and non-curricular PA.	2 years I: unclear C: unclear Children enrolled at different time points
Trevino *et al.* 2004 (48), Trevino 2005 (49)	RCT Cluster Power not stated	Setting: Nine Elementary schools located in low-income inner city neighbourhoods of the San Antonio Independent School District, TX, USA Participants: Male/female: 47%/53% Age I: 9.8; C: 9.7 97% of students were Mexican–American, more than 95% were in the US Department of Agriculture food assistance programs, average of 3.5 people occupied each household, mean household incomes US$10 337 in the intervention group and US$11 691 in the control schools.	I: 200 C: 189 I boys: 19.23 (4.78) I girls: 18.92 (4.87) C boys: 19.18 (4.14) C girls: 19.90 (5.42)	To evaluate the effect of the Bienestar Health Program (programme designed to reduce risk factors associated with the onset of type 2 diabetes) on physical fitness in low-income Mexican–American children.	8 months I: 0% C: 1%

Table 4 *Continued*

Study	Design/power	Population	Number/baseline mean BMI (SD) kg m⁻²	Aim	Follow-up/not assessed %
Vandongen *et al.* 1995 (50)	RCT Cluster by school Power calculations based on alpha level 0.05 and beta level of 0.8 to detect difference of five laps of Leger run with a SD of 14	Setting: 30 schools in Western Australia Participants: Age 10–12	Fitness group: $n = 81$ boys and 77 girls Fitness and school nutrition group: $n = 81$ boys and 81 girls School nutrition group: $n = 91$ boys and 108 girls School and home nutrition group: $n = 58$ boys and 68 girls Home nutrition group: $n = 97$ boys and 84 girls Control group: $n = 78$ boys and 67 girls. BMI (kg m⁻²) at baseline: Fitness group: 18.2 (17.7–18.7) boys, 18.2 (17.7–18.7) girls. Fitness and school nutrition group: 18.1 (17.5–18.8) boys, 17.9 (17.4–18.5) girls School nutrition group: 18.0 (17.5–18.5) boys, 17.5 (17.0–17.9) girls School and home nutrition group: 18.2 (17.4–19.0) boys, 17.5 (16.8–18.2) girls Home nutrition group: 17.7 (17.2–18.1) boys, 18.2 (16.9.18.9) girls Control group: 18.1 (17.5–18.6) boys, 17.6 (16.9–18.3) girls	To evaluate programme of fitness and nutrition alone and combined and school and home-based nutrition programmes to improve cardiovascular health.	9 months All groups: 15%
Warren *et al.* 2003 (31) (Be Smart)	RCT Individuals randomized Not powered	Setting: Three primary schools in Oxford, UK Participants: Children Age 5–7	Nutrition intervention: 56; PA intervention: 54; Combined nutrition and PA intervention: 54; C: 54 Nutrition intervention: 16.1 (2.7) PA intervention: 16.0 (2.0) Combined nutrition and PA intervention: 15.8 (2.0) C: 15.5 (1.6)	Be Smart was a school and family-based intervention to prevent obesity in children aged 5–7 years.	20-week intervention over 14 months. Nutrition intervention: 25% PA intervention: 22% Combined nutrition and PA intervention: 22% C: 15%
Williamson *et al.* 2007 (19) (Wise Mind Project)	RCT Cluster by school Pilot study, not powered to detect significant differences	Setting: Four private Catholic schools, USA Participants: Male/female: 333/328 Age 9.2 94.9% white	I: 313 C (active control): 348 Mean baseline BMI: not stated. BMI percentile of all children at baseline: 59.8 (30.34) Weight for all children at baseline: 35.7 kg (12.21)	To test whether an environmental approach for weight gain prevention delivered in schools was more effective for weight gain prevention in comparison with an active control programme that used an environmental approach to prevent substance abuse.	18 months (2 academic years) I: 10% Active C: 13%

PA, physical activity; PE, physical education; SPARK, Sports, Play and Active Recreation for Kids; BMI, body mass index; SD, standard deviation; RCT, randomized controlled trial; CCT, controlled clinical trial; I, intervention; C, control; SES, socioeconomic status.

Table 5 Results of included studies

Study	Results	Comments
DIET ONLY STUDIES		
Amaro *et al.* 2006 (4)	Change in BMI *z*-score at 24 weeks was not significantly different between intervention and control (controlling for baseline values) 0.345 (95% CI 0.299 to 0.390) vs. 0.405 (0.345 to 0.465).	Significant baseline difference between groups on BMI *z*-score.
Ask *et al.* 2006 (5)	BMI increased – statistically significant in both male and female in the control group ($P < 0.01$ for male and $P < 0.05$ for female), but not in the intervention group.	
James *et al.* 2004 (23) (CHOPPS)	Change in BMI over 12 months not significantly different between intervention and control 0.7 (0.2) vs. 0.8 (0.3) kg m^{-2}.	
	Percentage of overweight and obese children increased in the control group by 7.5% at 12-months compared with a decrease in the intervention group of 0.2% (mean difference 7.7%, 95% CI 2.2, 13.1).	
	Assessed at 3 years: age and sex-specific BMI *z*-scores (SD scores) had increased in the control group by 0.10 (SD 0.53) but decreased in the intervention group by –0.01 (SD 0.58), with a mean difference of 0.10 (95% CI –0.00 to 0.21, $P = 0.06$).	
	The prevalence of overweight increased in both the intervention and control group at 3 years and the significant difference between the groups seen at 12 months was no longer evident.	
	Mean change in BMI: Intervention: 1.88 (SD 1.71) Control: 2.14 (SD 1.64) Mean difference of 0.26 (–0.07 to 0.58, $P = 0.12$)	
	The waist circumference increased in both groups after 3 years with a mean difference of 0.09 (–0.06 to 0.26, $P = 0.25$).	
PA ONLY STUDIES		
Flores 1995 (35)	Statistically significant reductions in BMI between intervention and control girls at 12 weeks: Intervention girls: 22.1 (SD 6.0); Control girls 22.5 (SD 4.4)	
	This represents a change of –0.8 kg m^{-2} in the intervention group and +0.3 kg m^{-2} in the control grou*p* ($P < 0.05$).	
	No statistically significant change between intervention and control boys for BMI (BMI –0.2 kg m^{-2} intervention boys vs. –0.6 kg m^{-2} control boys).	
Harrison *et al.* 2006 (9) (Switch Off – Get Active)	No statistically significant change between intervention and control for BMI, –0.08 (95% CI –0.38 to 0.22, $P = 0.63$)	
Jamner *et al.* 2004 (40)	The intervention had no significant effect on BMI percentile, 67.28 at baseline and 66.74 at 4 months; % body fat 32.64 at baseline and 31.85 at 4 months.	
Lazaar 2007 (10)	Average BMI remained unchanged overtime; however, there was significant difference between groups for BMI (for both genders and obese and non-obese).	
	The pattern of response to PA intervention was similar in girls and boys although the magnitude of change in anthropometric variables was greater in girls. There was a greater response in obese children than non-obese children.	
Mo-suwan *et al.* 1998 (46)	Both intervention and control groups experienced reduction in BMI and not significantly different between groups at 30 weeks: Intervention: 15.76 (2.46) Control: 15.94 (2.26)	One school had swim class for 1 h per week (adjustments made for these children).
	Not significant.	
	No significant difference between groups in skin-fold thickness at 30 weeks.	
	Intervention girls had significantly lower mean BMI at 30 weeks than intervention boys ($P < 0.01$).	
	Intervention girls had lower likelihood of having an increased BMI slope than the control girls (OR 0.32; 95% CI 0.18, 0.56).	
Pangrazi *et al.* 2003 (43)	No significant differences between groups were found for BMI.	

Table 5 *Continued*

Study	Results	Comments
Pate *et al.* 2005 (38)	% Girls classified as overweight or at risk for overweight (at least 85th percentile BMI 34% both groups) or overweight (at least 95th percentile BMI 17% both groups) did not differ between intervention and control.	Slightly higher % African–American girls lost to follow-up.
Robbins *et al.* 2006 (11) 'Girls on the Move'	No significant differences between intervention vs. control and pre vs. post BMI.	
Robinson 1999 (36)	Compared with controls, children in the intervention group had statistically significant relative decreases in BMI –0.45 kg m^{-2} with 95% CI –0.73, –0.17, $P = 0.002$; TSF –1.47 mm with 95% CI –2.41, –0.54, $P = 0.002$; and waist-to-hip ratio –0.02 with 95% CI –0.03, –0.01, $P < 0.001$.	Assessors blinded
Sallis *et al.* 1993, 1997 (41,42)	Specialist PA promotion programme did not produce significant reductions in children's BMI or adiposity. No differences observed between teacher-led and specialist-led programme.	Interim results only (2-year data from 3-year study).
	All boys in all three groups increased their BMI over 2 years.	
	Control girls had significantly lower BMI than girls in either teacher-led or specialist-led intervention group ($P < 0.01$).	Actual data for BMI and skin-fold thickness is only presented in graphical form.
	Changes in skin-fold thickness not significant between groups in girls or boys.	
Schofield *et al.* 2005 (39)	No significant difference between groups for BMI or from baseline to follow-up.	
Stephens & Wentz 1998 (37)	Control group gained significantly more weight ($P < 0.001$). Weight (kg) intervention vs. control at 15 weeks = 25.8 vs. 27.0.	Significantly more black children in intervention compared with control group ($P < 0.01$).
	Significant decrease in skin-fold thickness intervention vs. control, $P < 0.01$.	
	Baseline: 25 vs. 26 mm	
	15 weeks: 23.5 vs. 28.5 mm	
Trudeau 2000 (44), Trudeau *et al.* 2001 (45) (The Trois-Riveries Growth and Development study)	No significant difference between intervention and control with respect to BMI, body fat, skin-fold thickness, waist-to-hip ratio (Trudeau 2000). Baseline values not reported.	Random selected sample (22% of original group) contacted by telephone for follow-up.
	Comparisons of tracking suggested intervention and control developed similar gains in BMI and skin-fold thickness over 22-year interval (Trudeau *et al.* 2001).	
	Change in BMI (kg m^{-2}) over 22-year intervention vs. control: 5.7 (0.4) female ($n = 57$), 8.6 (0.4) male ($n = 56$) vs. 5.8 (0.3) female ($n = 38$), 8.0 (0.2) male ($n = 40$).	
	BMI was not significantly different between intervention and control groups at age 10, 11, 12 and 34 years.	
	Skin-fold thickness change also available (not significant between groups).	
Valdimarsson *et al.* 2006 (16), Linden *et al.* 2006 (17) (POP Study)	Mean annual change in weight: Intervention: 3.9 kg (1.6) $n = 49$ Control: 3.2 kg (1.3) $n = 50$	Control group exercised more during leisure time at baseline compared with intervention groups.
Viskic-Stalec *et al.* 2007 (18)	Initially greater baseline body weight in intervention group decreased and body weight in control group remained almost unchanged. Dance activities had the most favourable effect on body weight.	Initially greater baseline body weight in intervention group
	Change in BMI: I: –0.74 $n = 115$; C: +0.47 n 102	
COMBINED DIET AND PA STUDIES		
Caballero *et al.* 2003 (33) (Pathways)	No significant difference in weight, BMI, % body fat or skin-fold thickness between intervention and control groups. BMI in the intervention group at baseline was 19.0, at follow-up 22.0. In the control group BMI was 19.1 kg m^{-2} at baseline and 22.2 kg m^{-2} at follow-up. Mean difference in BMI = –0.2 (95% CI –0.50, 0.15) kg m^{-2}.	
	% body fat increased by approximately 7% in both groups at 3 years.	

Table 5 *Continued*

Study	Results	Comments
Danielzik *et al.* 2007 (6) (KOPS)	Median change in BMI (inter-quartile range): I: 1.7 (0.7, 3.1); C: 1.8 (0.9, 3.3) Non-significant difference between groups re BMI. Intervention increased remission of overweight with no significant effect on incidence – effect more pronounced in girls.	Significant difference in median BMI at baseline between groups – lower in control.
Donnelly *et al.* 1996 (34)	Significant increase in BMI in both groups from baseline to follow-up but no significant difference between groups.	
Eliakim *et al.* 2007 (7)	Significant between group difference in BMI (intervention BMI remained same as baseline and control BMI increased).	
Gortmaker *et al.* 1999 (28); (Planet Health)	At 2 years: prevalence of obesity among girls in the intervention schools was reduced compared with controls, controlling for baseline obesity (OR 0.47; 95% CI 0.24, 0.93; $P = 0.03$). Among boys obesity declined among both control and intervention students; however, after controlling for covariates, there was no significant difference in outcome (OR 0.85; 95% CI 0.52, 1.39; $P = 0.48$). There was greater remission of obesity among intervention girls vs. control girls (OR 2.16; 95% CI 1.07, 4.35; $P = 0.04$).	Outcome assessors blinded.
Graf *et al.* 2005 (29)	The increase in BMI tended to be lower in those undergoing intervention mean difference in BMI for the intervention and control groups were 0.27 kg m^{-2} and 0.66 kg m^{-2} respectively ($P = 0.069$). After intervention, the increase in waist circumference with time was lower than the controls (3.11 cm and 4.56 cm respectively).	Intervention group had higher BMI, waist circumference and blood pressure at baseline than control. Body weight showed high correlations with the result of bioelectric analyses ($r = 0.770$, $P \leq 0.001$) and waist circumference ($r = 0.857$, $P \leq 0.001$), and low correlation with the waist-to-hip ratio ($r = 0.180$, $P = 0.001$) adjusted for gender and age.
Haerens *et al.* 2006 (8)	A significant gender by condition interaction was found. Therefore, results are presented separately for boys and girls. In girls, BMI and BMI *z*-score increased significantly less in the intervention with parental support group compared with the control group ($P < 0.05$) or the intervention – alone group ($P = 0.05$). In boys, no significant positive intervention effects were found.	
Kain *et al.* 2004 (30)	BMI significantly higher in control boys only at 6 months compared with intervention boys (intervention boys BMI maintained while control boys BMI increased).	Significantly more obese in intervention schools.
Luepker *et al.* 1996 (47) (CATCH)	BMI did not differ significantly between groups at 3 years.	
Manios *et al.* 1998, 1999, 2002 (24–26) Kafatos *et al.* 2007 (22) (Cretan Health and Nutrition Education Program)	At 3 years: Change in BMI (kg m^{-2}) +0.7 (1.5) vs. +1.7 (1.4) intervention vs. control, $P < 0.0005$. At 6 years: BMI change intervention vs. control: +3.68 (SE 0.16) $n = 356$ vs. +4.28 (SE 0.16) $n = 285$, $P < 0.05$ At 6 years: Bicep skin-fold thickness (mm) change intervention vs. control: +2.97 (SE 0.24) $n = 356$ vs. +4.47 (SE 0.24) $n = 285$, $P < 0.001$. At 6 years: Tricep skin-fold thickness (mm) change intervention vs. control: +6.46 (SE 0.38) $n = 356$ vs. +7.90 (SE 0.39) $n = 285$, $P < 0.0$ At 10 years: BMI *z*-score Intervention: −0.09 (0.09) $n = 85$; Control: 0.17 (0.09), $n = 91$, $P = 0.042$	
Rosenbaum *et al.* 2007 (12)	BMI (and % body fat) significantly lower in intervention group compared with control and compared with baseline.	Classroom element was mandatory whereas exercise element was voluntary.

Table 5 *Continued*

Study	Results	Comments
Sahota *et al.* 2001 (32) (APPLES)	At 1 year, there was no difference in change in BMI between the children in the two groups (BMI SD score, weighted mean difference 0 (95% CI –0.1, 0.1).	
Sallis *et al.* 2003 (27)	There was a significant reduction in BMI among intervention boys, compared with control boys, but there was no effect for girls.	
	Boys BMI (kg m^{-2}) at baseline for the intervention and control groups, 20.12 (0.98) and 19.68 (0.63) respectively. BMI for the controls and the boys in the intervention group after 2 years 20.04 (0.85) and 19.84 (0.61).	
	Girls BMI (kg m^{-2}) at baseline for the intervention and control groups, 19.76 (0.77) and 19.52 (0.89) respectively. BMI for the girls in the intervention group and the controls after 2 years 19.88 (1.16) and 19.73 (1.16) respectively.	
	Gender-specific analyses revealed the time by condition interaction was significant for boys ($F = 12.16$, $P = 0.00$) with a large effect size of $d = 1.10$. The intervention was not significant for girls ($F = 0.73$, $P = 0.396$), and the effect size was small.	
Singh *et al.* 2007 (14) (Dutch Obesity Intervention in Teenagers [DOiT study])	BMI	
	Intervention vs. control girls: –0.05 (95% CI –0.18 to 0.08)	
	Intervention vs. control boys: –0.02 (95% CI –0.11 to 0.16)	
	No significant intervention effects were found for BMI (or BMI class) although tended to favour intervention group.	
Spiegel *et al.* 2006 (15)	Change in BMI: Intervention: 0.1606; Control: 0.5210, $P = 0.01$	
	Significant shifts in BMI were noted in the intervention group, with a 2% reduction in overweight (BMI > 85% for age and sex) youth in the intervention group There was no significant shift in the comparison group, but there was a notable reduction in the intervention group in overweight and at risk for overweight classification, which was most significant at the at risk for overweight (BMI-for-age between 85% to 95%) level.	
Taylor *et al.* 2007 (20) (A Pilot for Lifestyle and Exercise – APPLE project)	Mean BMI *z*-score was significantly lower in intervention children than in control children by 0.09 (95% CI: 0.01, 0.18) after 1 year and 0.26 (95% CI: 0.21, 0.32) at 2 years. Changes in BMI did not result from variation in height *z*-scores but rather from differences in relative weight between intervention and control children over time. Waist circumference was also significantly lower at 2 years in intervention children (–1.0 cm). The prevalence of overweight did not differ between the intervention and control groups.	Participants recruited in 2003 were followed up at 2004 and 2005; participants recruited at 2004 were followed up at 2005.
	An interaction existed between intervention group and overweight status ($P = 0.029$), such that mean BMI *z*-score was reduced in normal-weight (–0.29; 95% CI: –0.38, –0.21) but not overweight (–0.02; 95% CI: –0.16, 0.12) intervention children relative to controls.	
Trevino *et al.* 2004 (48), Trevino 2005 (49)	% body fat: did not differ between groups; adjusted difference intervention ($n = 619$) vs. control ($n = 602$) +0.18 (95% CI, –1.75–2.11), $P = 0.56$	
Vandongen *et al.* 1995 (50)	No significant difference between groups for sub scapular skin-fold thickness (mm), % body fat or BMI (kg m^{-2}) respectively at 1 year:	
	Triceps skin-fold thickness decreased significantly in fitness + school nutrition group compared with controls.	
Warren *et al.* 2003 (31)	No significant changes in the rates of overweight and obesity were seen as a result of the three different approaches	Subject numbers too small for statistical analyses; This study may have been subject to ceiling effects as the study population was relatively well educated as 39% of parents had obtained either a degree or a post-graduate qualification.
Williamson *et al.* 2007 (19) (Wise Mind Project)	Both programmes associated with significant weight gain prevention in children with higher BMI *z*-scores at baseline.	All students within the schools were exposed to the environmental intervention.

CHOPPS, the Christchurch obesity prevention programme in schools; PA, physical activity; CI, confidence interval; BMI, body mass index; SD, standard deviation; OR, odds ratio; SE, standard error; TSF, tricep skinfold; I, intervention; C, control.

Two hours extra physical education (PE) per week significantly improved BMI compared with control at 6 months but did not significantly change BMI overtime (10). There was a greater magnitude of change in girls compared with boys and in obese compared with non-obese children. The study was set in 19 primary schools in France among 425 7-year-old children.

A 6 month intervention to encourage reduction in TV, videotape and video game usage (18 lessons of 30–50 min, self-monitoring and a 7 h TV use budget per week) in 9-year-olds resulted in significant reduction in BMI, skin-fold thickness, waist circumference and waist-to-hip ratio in intervention children compared with controls (36). The mean difference in BMI (adjusted for baseline age and sex) was -0.45 kg m^{-2} (95% CI -0.73, -0.17; $P = 0.002$).

A 15-week PA intervention in low-income, minority school children (mean age 8 years) demonstrated significantly more weight gain among controls and significant decreases in skin-fold thickness among intervention children (37).

A 12-week aerobic dance intervention (150 min of dance per week over three sessions) in African–American and Hispanic children (mean age 13 years) significantly reduced BMI but only among intervention girls compared with control girls (-0.8 kg m^{-2} and 0.3 kg m^{-2} respectively) (35).

A 30-week aerobic exercise programme – encouraging a pre-class walk and three 20-min aerobic sessions per week – in kindergarten children (aged 4–5 years) in Thailand produced results that varied by gender (46). A reduction in BMI occurred in both intervention and control groups and was not significantly different between groups. However, the intervention girls had significantly lower mean BMI at 30 weeks than intervention boys ($P < 0.01$) and lower likelihood of having an increased BMI slope than the control girls (odds ratio: 0.32; 95% CI: 0.18, 0.56).

Ten of the studies did not report significant improvements in mean BMI or percentage of overweight. Five of these studies were among female adolescents in secondary schools. These included a 6-month intervention promoting a supportive school environment and programme champion (38), a 12-week intervention targeting moderate activity (walking) in low-active girls (39), a 4-month intervention promoting additional PE classes (40), a 12-week intervention including individual counselling from a school nurse (11) and an aerobic, dance and gymnastic programme (66 sessions) over one academic year in 16–18-year-olds in Croatia (18).

Five studies among children (aged 8–10 years) found no difference in mean BMI or weight between control and intervention groups. These included a 12-week PA programme supplementary to usual PE (43), a 2-year specialist PA programme (41,42), a 16-week intervention to reduce TV and computer game usage in 312 children from nine primary schools in Ireland (9), a 2-year intervention to improve bone mineral content in 53 girls from four primary schools in Sweden (16,17) and a 22-year follow-up in a 22% subsample of a 6-year PA intervention in primary school children in Quebec (44,45).

Three of the five studies among children included head-to-head comparisons. The 2-year specialist PA programme (41,42), Sports, Play and Active Recreation for Kids, was compared with trained teacher-led PA and a usual PE control group. Both the specialist and teacher-led interventions provided three 30-min sessions of PA per week. Results for boys showed that the control group had significantly lower BMI at 6 and 12-months ($P = 0.05$), but not at 18-months. All boys in all three groups increased their BMI over 2 years. Girls' results showed the control group to have lower BMI at each time point and this reached significance at 18-months ($P < 0.01$).

The 12-week PA programme supplementary to usual PE (43) had four conditions: PLAY and PE, PLAY only, PE only and control (no PE or PLAY). No significant differences were found at 12 weeks between the intervention or control groups for BMI.

The 12-week intervention among low-active high school girls in Australia (39) compared the use of a pedometer to encourage increase in steps walked and a group encouraged to increase time in activity compared with control. No significant differences were found between the three groups for BMI at 12 weeks or from baseline to follow-up for any group.

Diet and physical activity interventions

Twenty studies (6–8,12–15,19,20,22,24–34,47–50) aimed to increase PA and improve diet among school children. Three of these studies aimed to prevent cardiovascular disease and two aimed to reduce the risk of developing diabetes.

Diet and physical activity studies demonstrating significant and positive effect between intervention and control groups

Nine (7,8,12,15,20,22,24–28,30) of the 20 studies showed significant improvements in mean BMI in the intervention compared with the control groups; one study (Kiel Obesity Prevention study [KOPS]) (6) showed both significant and non-significant results and one study nearly reached significance (29). There were two studies in boys only (27,30) (non-significant in girls), two studies in girls only (8,28) (non-significant in boys) and five studies in both girls and boys.

A 6-month dietary education and sport intervention (including active recess, healthy kiosks, special activities and parental involvement) in over 3500 11-year-old children in five primary schools in Chile maintained baseline BMI in intervention boys while BMI in control boys increased (30). This resulted in a significant difference

between groups at 6 months for boys only (non-significant difference in BMI at 6 months for girls).

An environmental, policy and social marketing intervention in over 1100 11–13-year-old children in 24 middle schools in the USA showed significant reduction in BMI in the intervention boys (but not girls) compared with control over two school years (27).

'Planet Health' (28) promoted PA, modification of dietary intake and reduction of sedentary behaviours (with a strong emphasis on reducing TV viewing) in over 1500 children aged 12 years in 10 secondary schools in the USA. The intervention significantly reduced the prevalence of obesity (odds ratio 0.47, 95% CI 0.24, 0.93, $P = 0.03$) and increased remission of obesity in intervention girls compared with control girls over two school years. There was no significant difference in prevalence of obesity between intervention boys and control boys.

One intervention combined environmental changes with personal computer-tailored feedback on BMI, with and without parental support, compared with control in nearly 3000 13-year-olds in 15 middle schools in Belgium. The intervention included 4.7 h extra PE per week. In girls, BMI and BMI z-score increased significantly less in the intervention with parental support group compared with the control group ($P < 0.05$) or the intervention-alone group ($P = 0.05$). In boys, no significant positive intervention effects were found after two school years (8).

A diet and activity intervention that aimed to prevent cardiovascular disease in school children in Crete by adapting the 'Know Your Body' programme showed significant improvements compared with control at 3 and 6 years for BMI and skin-folds. At 3 years the change in BMI was 0.7 kg m^{-2} (standard deviation [SD] 1.5) in the intervention group compared with 1.7 kg m^{-2} (SD 1.4) in the control group ($P < 0.0005$) (24,25). At 6 years, the change in BMI (mean and standard error [SE]) was 3.68 kg m^{-2} (SE 0.16, $n = 356$) in the intervention group compared with 4.28 kg m^{-2} (SE 0.16, $n = 285$) in the control group ($P < 0.05$) (26). At 10 years, the mean change in BMI z-score was −0.09 (SD 0.09, $n = 85$) in the intervention group and 0.17 (SD 0.09, $n = 91$) in the control group ($P = 0.042$) (22).

A 12-week diet and activity intervention to reduce risk of diabetes showed a significant improvement in percentage of body fat and BMI compared with control in 73 14-year-old adolescents in one New York public school. These adolescents were first or second generation migrants to the USA, mainly from the Dominican Republic, and 53% had a first or second degree relative with type II diabetes (12).

The APPLE study of 460 8-year-old children from seven primary schools in the USA significantly reduced the rate of excessive weight gain in children at 2 years, although this may be limited to those not initially overweight. BMI z-score was significantly lower in intervention than in control children by a mean of 0.09 (95% CI: 0.01, 0.18) at 1 year and 0.26 (95% CI: 0.21, 0.32) at 2 years, but the prevalence of overweight did not differ. An interaction existed between intervention group and overweight status ($P = 0.029$), such that mean BMI z-score was reduced in normal weight (−0.29; 95% CI: −0.38, −0.21) but not overweight (−0.02; 95% CI: −0.16, 0.12) intervention children relative to controls (20).

The WAY programme was a PA and wellness programme that was incorporated into the curriculum. It included some family involvement in approximately 1000 9–11-year-olds (US grade 4–5) in 16 primary schools in the USA. At 6-months, there was a significant reduction in risk of developing overweight and a 2% reduction in overweight (BMI > 85% for age and sex) in the intervention group but not the control group. BMI in the intervention vs. control children was 0.16 kg m^{-2} vs. 0.52 kg m^{-2} ($P = 0.01$) at 6 months (15).

A 14-week nutrition education and circuit training plus encouragement to reduce sedentary behaviours resulted in a significant difference in BMI in approximately 100 5–6-year-old children in four pre-schools in Israel. The BMI remained stable in the intervention children and increased by 0.3 kg m^{-2} in the control children (7).

A 3.8-year follow-up of the KOPS longitudinal data in 2200 6-year-olds in 32 primary schools in Germany increased remission of overweight with no significant effect on incidence; this effect was more pronounced in girls. However, there was significant difference in median BMI at baseline between the groups (lower BMI in control group) (6).

The STEP TWO programme in over 1600 8-year-old children in seven primary schools in Germany demonstrated that the increase in BMI and waist circumference tended to be lower in those undergoing intervention compared with controls (BMI 0.27 kg m^{-2} vs. 0.66 kg m^{-2}, $P = 0.069$ respectively) (29).

Diet and physical activity studies demonstrating non-significant effect between intervention and control groups

Two studies that found no significant difference in mean BMI between intervention and control children were UK-based. One study (Be Smart) (31) of approximately 100 5–7-year-old children was insufficiently powered to detect differences in BMI at 14 months' follow-up. Another UK-based study (Active Programme Promoting Lifestyle in Schools [APPLES]) (32) that was sufficiently powered included teacher training, modification of school meals, school action plans targeting the curriculum, PE, tuck shops and playground activities. The intervention was underpinned by the Health-Promoting Schools philosophy and the intervention involved the whole school community

including parents, teachers and catering staff. At 1 year, there was no significant difference in change in BMI between the children in the two groups.

An additional seven studies reported that intervention had no effect on BMI. Six of these studies were in primary school children. These included a 3-year PA and dietary intervention included modifying school lunches in over 1700 8-year-old American–Indian children (33), a 2-year US-based intervention included modifying school lunches (34) in over 300 9-year-old children, a large 3-year cardiovascular risk reduction programme (47), a 1-year programme to improve cardiovascular health (50), a study (48,49) that aimed to prevent diabetes in over 1200 low-income Mexican–American 9-year-olds and a pilot study (The Wise Mind Project) (19) in 661 9-year-old children from four private Catholic schools in the USA comparing an environmental approach for weight gain prevention with an environmental approach to prevent substance abuse. Both active interventions were associated with significant weight gain prevention in children with higher BMI *z*-scores at baseline.

One study that did not show a significant difference in BMI between intervention and control groups was in adolescents. The 8-month Dutch Obesity Intervention in Teenagers study (13,14) included environmental changes to the school canteen in nearly 1000 13-year-olds in 18 secondary schools in the Netherlands.

Process evaluations

Information on process and process evaluations were either not reported as part of the studies included in this review or included but with little detail (except [32]). The majority of the interventions were at least in part provided by existing staff that were trained by research staff. There was a tendency for the combined diet and PA interventions to involve more school personnel and for the intervention to be integrated into the curriculum. There did not appear to be a pattern that these interventions (that were more likely to be sustainable) were more likely to be successful.

There was no consistent pattern to the results in terms of family involvement.

Process evaluations indicate that these lifestyle interventions may be better implemented if built into the curriculum. Overall, authors reported that parents responded positively to diet and PA changes but this did not necessarily lead to behaviour change or change in BMI. However, it is of course the level of engagement with the intervention that has an impact on involvement, and this was not reported in any meaningful way in any of the papers included in this review.

Male adolescents who ate breakfast at school for 4 months reported a significant increase in school content-ment ($P < 0.05$) (5). The students missed the free breakfast provision when it was stopped; however, teachers were not satisfied with the serving of breakfasts in classrooms.

The 12-week PA intervention by Robbins *et al.* (11) reported that the school nurses experienced difficulty counselling some girls who lacked places, resources and social support for engaging in PA. Some girls expressed that their parents discouraged PA at home because of the noise and the low importance placed on being physically active as compared with doing homework or chores.

Planet Health (28) reported that schools experienced with interdisciplinary curricula found it easier to implement Planet Health material. Another study reported that PE was implemented because it was incorporated into the curriculum (30).

The UK-based APPLES (32) intervention was successful in changing the ethos of the schools and the attitudes of the children, but had little effect on children's behaviour other than a modest increase in the consumption of vegetables. Eighty-nine per cent of the actions points were implemented in the 10 schools and changes were made to food provision. Both parents and teachers were supportive of the dietary education and promotion of PA. Parental questionnaires (64% returned) suggested improvements such as promotion of healthier break-time snacks with enforcement by school, material on healthy eating for children and fun PA ideas. Of the 20 teachers invited, 19 attended and were satisfied with the training, resources and materials offered. Children had higher scores for knowledge and attitudes, and were positive about the intervention in focus groups.

One UK-based feasibility study (31) considered the sustainability of their intervention and concluded that it would be too expensive and unsustainable as it was delivered by non-school personnel. Children enjoyed the practical tasks, quizzes and tasting. Eighty-three per cent of parents thought their child had benefited from the programme and all teachers thought that components should be integrated into the personal, social and health education curriculum.

Pathways (33) was a culturally sensitive diet and PA intervention. The classroom curriculum was delivered successfully (94%) and the food service guidelines were implemented (78%), with most schools achieving the minimum PE sessions per week. Parents who attended the family events responded positively. The intervention was designed to be delivered by existing staff and was integrated into the school curriculum. Despite all these elements, this relatively large 3-year study did not significantly improve children's weight or BMI.

Discussion

This review expands and updates the evidence base of lifestyle interventions to prevent obesity in school children.

The rate of publications of interventions to prevent obesity in school children is increasing dramatically. Twenty-three studies were identified between 1990 and 2005. An additional 15 studies were identified between 2006 and September 2007. The percentage of studies set in secondary schools is increasing. Seven of the 15 studies identified in the update search are based in secondary schools, whereas only six of the original 23 studies were based in secondary schools.

One of three (33%) diet studies, five of 15 (33%) PA studies and nine of 20 (45%) combined diet and PA studies demonstrated significant differences between intervention and control for BMI.

There is insufficient evidence to assess the effectiveness of dietary interventions to prevent obesity in school children or the relative effectiveness of diet vs. PA interventions.

School-based interventions to increase PA and reduce sedentary behaviour may help children to maintain a healthy weight but the results are inconsistent and short-term. PA interventions may be more successful in younger children and in girls.

Two PA interventions that aimed to reduce sedentary behaviour by reducing TV viewing and video/computer games in 9–10-year-olds produced conflicting results.

Six PA interventions included dance (two studies were in girls only and four studies in boys and girls). Of these six studies, two were successful in reducing BMI in intervention girls but not boys (35,46) and four studies were unsuccessful (18,38,40) with one study (41,42) demonstrating a significantly lower BMI in control girls compared with intervention girls (regardless of whether the PA intervention was led by a specialist or a teacher).

The effectiveness of combined diet and PA school-based interventions to prevent obesity is equivocal.

The majority of the longer-term studies (at least 1 year) were combined diet and PA interventions. The diet and PA interventions also tended to be larger studies compared with the diet studies and the PA studies. However, overall there did not appear to be a consistent pattern between significant effect and the size and duration of the study. It was not the case that all large long-term studies, underpinned by theory, involving existing school staff, the whole school community and significant environmental modifications, were successful. It is not clear whether it is more effective to target single or multiple behaviour change outcomes (energy restriction and increased PA). There is some evidence of effectiveness for both simultaneous and sequential behaviour change interventions (56). The development of health behaviour theory of multiple behaviour change has the potential to create better understanding of why some 'simple' interventions appear more effective than more complex interventions and vice versa (57). This will enable more effective behaviour change interventions to prevent obesity in children.

Some interventions showed different and inconsistent effects for girls and boys (aged 10–14 years) and the reasons for this are unclear. Two of the combined diet and PA interventions significantly improved BMI in boys but not girls and two combined diet and PA interventions significantly improved BMI in girls but not boys. All four studies were in children aged between 10 and 14 years and it may be that in this age group genders respond differently to different elements of the interventions.

It is interesting that some interventions appear to vary in effectiveness according to gender, age or weight status of the children. Although some studies only recruited children from ethnic minorities, none of the other studies assessed weight according to ethnic minority status. None of the included studies assessed weight by socioeconomic status. A paper on KOPS (published after the search for this review) showed that the intervention was associated with a reduced cumulative 4-year incidence of overweight only in children from families with high socioeconomic status (SES) (58).

Some studies were not adequately powered to detect differences between the intervention and control groups. Some studies were pilot studies to test the feasibility of the intervention. It is unclear whether some of the interventions were of sufficient length or intensity to produce a change weight or BMI.

Assessment of effectiveness can be exacerbated by weaknesses in assessment measures. For example, there is high intraindividual variance in movement measured by pedometers or accelerometers reaching >20% (59). Although age-specific BMI is the most commonly used definition of overweight and reported outcome for these studies, other proxy measures for assessing body fatness are useful and would provide a more comprehensive picture of childhood overweight both at specific time points and across time. Indeed skin-fold thickness of adolescents has been shown to be a better predictor of high body fatness in adults compared with BMI (60).

The majority of the studies did not provide adequate data for meta-analysis and in some cases it was necessary to rely on authors' reporting of significant or non-significant effects of the interventions. The studies were heterogeneous in terms of design, participants, intervention and outcomes, making it difficult to generalize about what interventions are effective in preventing obesity. Existing studies and initiatives need to be better evaluated using quantitative and qualitative outcomes and focusing on study and study population characteristics that may impact on effectiveness. There is a need for research to view behaviour change within the context of an obesogenic environment (61) and the co-dependency of the success of prevention interventions upon a 'paradigm shift in thinking' (62).

In conclusion, the findings are inconsistent, but overall suggest that combined diet and PA interventions may help

to prevent children becoming overweight in the long term. Dietary interventions such as providing breakfast for adolescents and PA interventions particularly in girls in primary schools may help to prevent these children from becoming overweight in the short term.

Conflict of Interest Statement

No conflict of interest was declared.

Acknowledgements

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