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Obesity Prevention

A systematic review to determine the effectiveness of interventions designed to prevent overweight and obesity in pre-adolescent girls

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Summary

Childhood overweight/obesity is recognized as an increasing health problem. The objective of this review was to determine the effectiveness of interventions designed to prevent overweight and obesity in pre-adolescent girls. The papers included were those studying children (must include results for girls) from within the 7–11 years age range from any country and ethnic background. The included interventions lasted at least 12 weeks and modified a combination of nutrition, physical activity, knowledge, attitudes or health-related behaviours associated with the development of childhood overweight and obesity. Effect sizes were calculated where possible using Cohen's classifications of small (0.2–0.5), medium (0.5–0.8) and large (>0.8) effect sizes. Thirty studies met the inclusion criteria of which four were cluster randomized controlled trials, 14 were randomized controlled trials, 11 were controlled trials and one was a cohort pre–post trial. There were four weak, 11 moderate and 15 strong quality studies. Eleven studies were considered short term and 19 long term (≥12 months). There were 66 effect sizes less than 0.2, 56 categorized as low, 16 as medium and two as high. There is the potential for interventions aimed at pre-adolescent girls to reduce the risk factors associated with childhood overweight and obesity, although the sustainability of the effects of such interventions is less clear.

Keywords: Girls, obesity, overweight, pre-adolescent.

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Introduction

There is growing evidence for an association between childhood obesity and risk factors for adult disease (1,2). Glucose intolerance and insulin resistance, precursors for the development of Non Insulin Dependent Diabetes Mellitus, are becoming increasingly prevalent in childhood (3). Data from the National Health and Nutritional Examination Survey have shown that American children are experiencing a greater accumulation of excess body fat earlier (4). The finding that overweight and obesity can track from childhood into adulthood (5,6) suggests an urgent need to address childhood overweight and obesity levels.

The UK government's think-tank, Foresight, describe obesity as the result of complex interactions between 'individual biology, eating behaviours and physical activity, set within a social, cultural and environmental landscape' (7). This complexity means that simple recommendations for reduced energy intake and increased energy expenditure, as both a treatment and prevention strategy, are often unsuccessful (1). Prevention of obesity offers a less expensive approach than treatment (8).

Prevention efforts

While there have been several interventions attempting to prevent overweight and obesity in children, only modest improvements to the associated risk factors have been achieved (9). Factors which may mediate the effectiveness of interventions include the setting, e.g. the individuals themselves, those with whom individuals have close relationships and who influence their behaviour (e.g. families), organizations (e.g. schools), communities or the wider society. It has been suggested that focusing interventions at the individual level of behaviour change ignores the association between the environment and an individual's behaviour, including social norms which act to facilitate certain behaviours (10). Thus, interventions may be more effective if they incorporate the social relationships and organizations which mediate individual behaviour. The length of the intervention has also been identified as an important factor because large changes made over the short term will not necessarily be sustainable (1) and indeed interventions are often not designed to assess sustainability beyond their completion (10).

There have been several reviews investigating these aspects separately but fewer bringing these approaches together. The majority of interventions to prevent overweight and obesity have been based in school settings (11–13) and have produced variable and short-term results, although improvements in knowledge and attitudes have been achieved (12,14). One of the few reviews to take a broad approach was produced by the Cochrane Collaboration in a systematic review of all childhood obesity prevention interventions targeting different physical and social environments conducted between 1990 and 2005 (15). The criteria for inclusion were met by 22 studies lasting 12 weeks or more in children aged less than 18 years (15). The use of a broad age range restricts the ability to draw conclusions about specific critical periods in childhood where interventions to prevent overweight and obesity may be most effective.

At risk age and gender

Most childhood obesity prevention reviews have not addressed either critical periods in childhood associated with the development of overweight and obesity, or gender-specific intervention effects which would allow preventive measures to focus upon those most at risk (16). Recent research proposes that prevention efforts focused upon pre-adolescence are justified (17) particularly in girls (18). Evidence suggests there is a biological rationale for addressing intervention effects separately for pre-adolescent (7–11 years) girls. The Intergenerational Growth Hypothesis was proposed by Emanuel, as 'those factors, conditions, exposures and environments experienced by one generation that relate to the health, growth and development of the next' (19). Research points to childhood as a critical period for the reproductive health of future mothers (20,21). Associations between parental childhood height (particularly leg length) and offspring birth weight have been shown to be stronger in mothers than fathers and to last across generations with grand-maternal not grand-paternal associations with offspring birth weight (21). Focusing on girls rather than boys therefore has potential implications for health across several generations. Body mass index (BMI) levels in parental early life (7–16 years) can increase the risk and early development of overweight and obesity in the offspring. Strong positive associations have been shown between mothers' childhood height and offspring birth weight. Martin and colleagues suggested that childhood pre-pubertal growth rate is an important area on which to focus research because earlier growth and improved nutrition may increase the blood supply to the placenta which will contribute to better nutrition for the offspring and thus a higher birth weight (21). Maternal maturation may be a factor influencing the intergenerational transmission of offspring growth rate and body fatness (22–24). Greater pre-pubertal body fatness has been associated with earlier maturation (marked in females by age at menarche <11 years), suggesting there may be a threshold for maturation (24). Earlier maturation may also predict fatness in later life although it has been suggested that this may be mediated by earlier levels of fatness tracking into later life (22,24). Not only is early maturation a positive predictor of maternal weight status and growth tempo, but offspring childhood growth tempo and risk of overweight and obesity may also increase (22,23).

The Intergenerational Growth Hypothesis literature indicates that focusing this review on the prevention of overweight and obesity in pre-adolescent girls is appropriate. In addition, biological patterns of growth suggest that adolescence is a critical period for the timing of overweight and obesity development thus indicating that healthy behaviours instilled prior to adolescence may reduce this risk (8).

The main objective of this review is to determine the effectiveness of interventions designed to prevent overweight and obesity in pre-adolescent girls focusing upon physical activity, diet or lifestyle modification within the school, family or community setting with either a qualitative, quantitative or mixed methods approach to evaluation.

Methods

Selection of studies

The inclusion and exclusion criteria for this review are presented in Table 1.

Literature search

The literature search was conducted in six databases (Medline, SPORTDiscus, PsychINFO [accessed through

Table 1 Inclusion and exclusion criteria

Inclusion	Exclusion
Published 1990 onwards	Intervention designed specifically for the treatment of childhood obesity, eating disorders such as anorexia and bulimia nervosa or any other conditions specifically selected in the inclusion criteria (e.g. high blood pressure)
Minimum intervention length 3 months	Boys exclusively
Settings:	Participants exclusively <7 years of age or >12 years of age
• Community	Systematic reviews, meta-analysis, editorials
• Family	
• School	
• Combination of the above	
Any country; must be written in English	Cross-sectional studies
Study design:	
• Randomized controlled trial	
• Controlled pre-test and post-test	
• Non-controlled studies	
Primary prevention	
Intervention modifying:	
• Physical activity behaviours	
• Eating behaviours	
• Attitudes and knowledge towards the above	
• Body mass index or other indices of fat mass	
Participants: pre-adolescents (7–11 years)	
Present results separately for girls	

EBSCO], Web of Science, Biological Sciences and Physical Education Index [accessed through CSA illumina]) between 1990 and 17 February 2010. The full details of the search strategy used can be found in Appendix. The searches yielded 1917 journal articles once duplicates were removed. The article titles were then assessed against the inclusion criteria, which resulted in 1,604 studies being excluded. The remaining articles were firstly assessed on their abstracts (177 excluded) and secondly the whole text was evaluated (106 excluded) (Fig. 1). The search was run by two reviewers (J. K., F. P.) and article assessment against the pre-defined inclusion and exclusion criteria was conducted by one reviewer (J. K.) with consultation among two other researchers (N. C., P. G.).

Quality assessment

Included studies were quality assessed using an adapted Appraisal Tool for Quantitative Research produced by the Effective Public Health Practice Project (25). The components assessed by this tool (selection bias, study design, confounders, data collection methods, withdrawals and dropouts, intervention integrity and analyses) were categorized as either; strong, moderate or weak and were combined to produce a global rating for each study. Originally this tool included a rating of blinding procedures; however, in overweight and obesity prevention interventions it is not possible to blind children to the treatment they are receiving, thus this was replaced with a rating of the analysis, which assessed whether the statistical methods were appropriate for the study design (25).

Data analysis

Studies which present results separately for girls were analysed. Firstly, the interventions' effectiveness was assessed as a statistically significant ($P < 0.05$) effect. Secondly, effect sizes (between-group effects) were calculated where study results permitted. Odds ratios were converted into Cohen's D following the methods suggested by Chinn (26) and the effect sizes were assessed according to Cohen's D classifications of no effect size (<0.2), small (0.2–0.5), medium (0.5–0.8) and large (>0.8) (25).

Results

Included studies

The Quorom Flow Diagram (Fig. 1) demonstrates the large number of interventions in the literature attempting to prevent children from becoming overweight and obese. In total, 30 studies met the inclusion criteria (Table 2). Within these studies there were four cluster randomized controlled trials (cRCT), 14 randomized controlled trials (RCT), 11 controlled trials and one cohort pre–post trial. Out of 30 studies, four presented results from one component of a multi-component intervention the Girls health Enrichment Multi-site Studies (GEMS) which focused upon African–American girls (27–30).

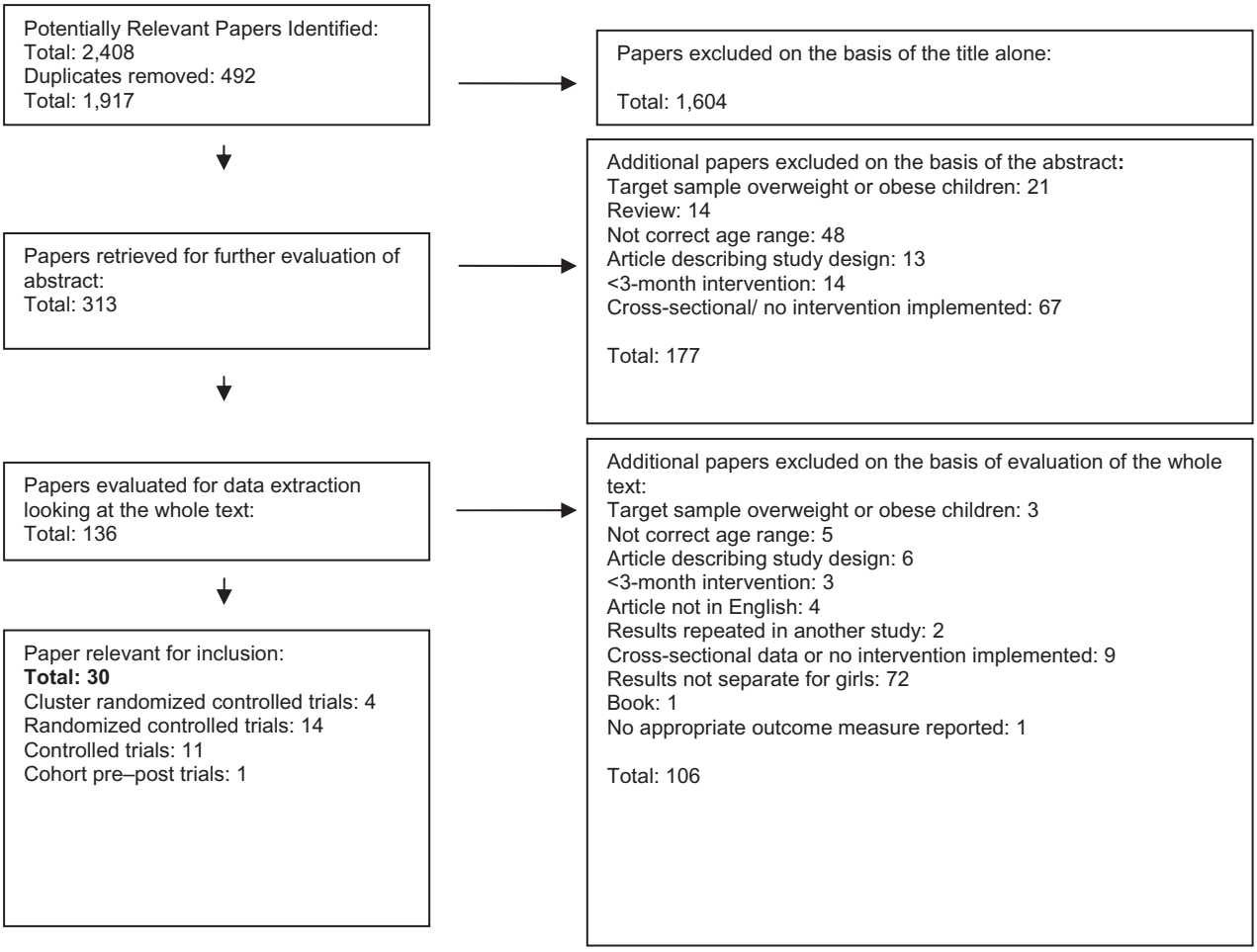

Figure 1 Quorom Flow Diagram of systematic literature search.

Study quality

Table 2 presents a summary of the quality of the included studies. There were 4 weak, 11 moderate and 15 strong quality studies. The methodological limitations included the lack of a control group (31–35) and the failure to report withdrawals (36). The strengths of the high quality studies included the blinded randomization of schools, measurements performed by blinded researchers (27,37) and regular school visits made by the researchers to ensure adherence to the proper delivery of the intervention (36,38–40). All four cRCT adopted appropriate statistical methods to account for the randomization of clusters. In the school RCT all but one randomized the schools into either intervention or control groups (29). Only half of these interventions reported taking account of the school clustering effect in the analyses (41–43).

Multifactorial interventions

The majority of the interventions ($n = 20$) included in this review were conducted in a school setting, there were three family-based, four community-based and three interventions combined a school and family-based setting. In total, seven studies focused on modifying physical activity behaviours alone, of which all were in schools. Nutrition focused interventions were performed in four studies (three in schools and one in the family). The majority ($n = 19$) of studies combined physical activity and nutrition components in the intervention, which were split between school-based studies ($n = 10$), family-based studies ($n = 2$), community-based ($n = 4$) and combined settings ($n = 3$).

Intervention effectiveness

Statistical significance

There were 218 outcome measures in girls included from the reviewed articles (Table 2) of which 84 were physical measures (BMI, weight, height, etc.), 41 were physical activity measures (24 objective and 17 self-reported), 66 were self-reported dietary measures and 27 were knowledge and attitude related. Statistically significant results were produced in 39.2% of physical measures, 50% of

Table 2 Overview of included studies, study length, quality, outcome measures and significance, effect sizes

Setting and intervention focus	Study (author, year)	Intervention	Outcome measure	Significance alpha level ($P < 0.05$)	Effect size (Cohen's D)
School Physical activity	Chavarro *et al.* 2005**[1] (44) Randomized controlled trial USA	Planet Health: aims to delay menarche through the prevention of obesity in girls. Study conducted in the USA with 508 girls who were randomized to either a modified curriculum or no curricular changes for 2 school years. Participant age: 10–13 years	BMI (increased < control group) pre- to post-intervention	+	–0.14
			Tricep skin-fold thickness (increased < control group) pre- to post-intervention	+	–0.13
			Screen time (decreased > control) (validated questionnaire) pre- to post-intervention	+	–0.096
			Physical activity (increase > control) (questionnaire for youths) pre- to post-intervention	+	–0.096
	MacKelvie *et al.* 2003**[3] (39) Randomized controlled trial Canada	Aims to assess the effects of a school-based exercise intervention during physical education lessons upon bone mineral content and bone area over 2 school years in girls. Participant age: 9–10 years	BMI change from baseline to 20 months compared to controls	–	X
			Lean mass change from baseline to 20 months compared to controls	–	
			Fat mass change from baseline to 20 months compared to controls	–	
			Long jump change from baseline to 20 months compared to controls	–	
			Vertical jump change from baseline to 20 months compared to controls	–	
			Average physical activity score change from baseline to 20 months compared to controls (Physical Activity Questionnaire for children)	–	
	Horne *et al.* 2009*[2] (59) Randomized controlled trial UK, Wales	Aims to assess the feasibility and acceptability of an intervention designed to increase physical activity levels over 14 weeks using a peer led, rewards and pedometer-based approach. Participant age: 9–11 years	Girls mean daily step counts between and within group differences comparing baseline, during intervention and follow up (pedometer step counts)	+	X

Table 2 *Continued*

Setting and intervention focus	Study (author, year)	Intervention	Outcome measure	Significance alpha level ($P < 0.05$)	Effect size (Cohen's D)
	Vizcaino *et al.* 2008**[1] (41) Randomized controlled trial Spain	Aims to assess the effects of a physical activity intervention in children upon obesity, blood lipids and blood pressure over 1 academic year. Participant age: 8–10 years	Girls % overweight or obesity change from baseline to follow up compared to controls	–	X
			Girls BMI change from baseline to follow up compared to controls	–	0.03
			Girls tricep skin-fold thickness change from baseline to follow up compared to controls	+	–0.08
			Girls % body fat change from baseline to follow up compared to controls	+	–0.13
			Girls systolic BP change from baseline to follow up compared to controls	–	–0.16
			Girls diastolic BP change from baseline to follow up compared to controls	–	–0.17
			Girls total cholesterol change from baseline to follow up compared to controls	–	0.05
			Girls apolipoprotein B change from baseline to follow up compared to controls	+	–0.24
			Girls apolipoprotein A change from baseline to follow up compared to controls	+	0.52
			Girls triglycerides change from baseline to follow up compared to controls	–	–0.07
	Manios *et al.* 2006**[1] (63) Controlled trial Greece	Aims to promote healthy lifestyles in children to reduce the risk of chronic diseases. Assessment of physical activity at the end of the intervention (6 years) and 4-year follow up. School-based intervention lasting 6 years: • Nutrition (workbooks, teaching manuals etc). • Physical education (45 min physical education classes/week) Participant age: 6–15 years.	Girls MVPA between and within group comparison across baseline, post-intervention and follow up	–	
			Girls MVPA post-intervention between groups	–	0.16
			Girls MVPA follow up between groups	–	0.09
			Girls meeting recommended physical activity levels (%) between groups across baseline, post-intervention and follow up	–	
			Girls meeting physical activity recommendations post-intervention between groups	–	0.20
			Girls meeting physical activity recommendations follow up between groups N.B. Physical activity assessed using a Standardized Activity Interview. Effect sizes calculated from difference between intervention and control adjusted for baseline value, age and cluster.	–	0.16

Table 2 *Continued*

Setting and intervention focus	Study (author, year)	Intervention	Outcome measure	Significance alpha level ($P < 0.05$)	Effect size (Cohen's D)
	Liu *et al.* 2007*[3] (48) Controlled trial Beijing	The Happy 10 programme: designed to improve physical activity, physical growth and obesity prevention in children through a classroom-based programme conducted for 10 min every day for 1 school year. Participant age: 6–12 years	BMI (pre- and post-intervention within group) BMI (between group change after intervention) Girls overweight prevalence (between groups) Girls obesity prevalence (between groups)	+ – – –	X
	Salmon *et al.* 2008**[1] (50) Cluster randomized controlled trial Australia	Switch-Play: aiming to prevent excess weight gain, reduce time spent watching TV and increase physical activity. Two intervention groups; • Behavioural modification (BM): self-monitoring, health benefits of physical activity, sedentary behaviour environments, decision making and alternatives for sedentary activities; contracts to switch off one TV programme per week for 4 weeks • Fundamental movement skills group (FMS) including running and throwing. • Combined group included BM and fundamental movements skills. • Control group. All intervention components: • 19 lessons (45–50 min) taught by the physical education teacher. Participant age: 10–11 years	Girls adjusted BMI baseline to post-intervention (BM/FMS) compared to controls Girls adjusted BMI baseline to 12 months follow up (BM/FMS) compared to controls Girls adjusted BMI baseline to post-intervention (FMS) compared to controls Girls adjusted BMI baseline to 12 months follow up (FMS) compared to controls Girls adjusted BMI baseline to post-intervention (BM) compared to controls Girls adjusted BMI baseline to 12 months follow up (BM) compared to controls Girls physical activity (accelerometers) baseline to post-intervention (BM) compared to controls Girls physical activity (accelerometers) baseline to 12 months follow up (BM) compared to controls Girls physical activity (accelerometers) Baseline to post-intervention (FMS) compared to controls Girls physical activity (accelerometers) baseline to 12 months follow up (FMS) compared to controls Girls physical activity (accelerometers) baseline to post-intervention (BM/FMS) compared to controls Girls physical activity (accelerometers) baseline to 12 months follow up (BM/FMS) compared to controls	+ + – + – – + + – – – –	0.01 –0.16 0.14 –0.10 –0.05 –0.01 0.26 0.26 0.12 0.12 0.02 0.01

Table 2 *Continued*

Setting and intervention focus	Study (author, year)	Intervention	Outcome measure	Significance alpha level ($P < 0.05$)	Effect size (Cohen's D)
School Nutrition	Sichieri *et al.* 2009*[2] (49) Cluster randomized controlled trial Brazil	Educational programme over 7 months, aiming to reduce the consumption of sugar-sweetened beverages, by encouraging the exchange of water for sugar sweetened beverages, in an attempt to reduce excessive weight gain. Participant age: 9–12 years	Girls BMI (intervention group compared to control) in those overweight at baseline	+	X
	Du *et al.* 2004**[2] (40) Randomized controlled trial Beijing	Milk supplementation intervention aiming to assess the impact upon growth and bone mineral increase in girls over 2 years. Participant age: 10 years	BMI (kg m^{-2}), milk and calcium compared to control	–	
			BMI (kg m^{-2}), milk, calcium and vitamin D compared to control	–	
			Milk intake (g d^{-1}), milk and calcium compared to control	+	
			Milk intake (g d^{-1}), milk, calcium and vitamin D compared to control	+	
			Ca intake (mg d^{-1}), milk and calcium compared to control	+	
			Ca intake (mg d^{-1}), milk, calcium and vitamin D compared to control	+	
			P intake (mg d^{-1}), milk and calcium compared to control	–	
			P intake (mg d^{-1}), milk, calcium and vitamin D compared to control	–	
			Vitamin D intake (µg d^{-1}), milk and calcium compared to control	–	
			Vitamin D intake (µg d^{-1}), milk and calcium compared to, milk, calcium and vitamin D	+	
			Vitamin D intake (µg d^{-1}), milk, calcium and vitamin D compared to control	+	
			Energy intake (KJ d^{-1}), milk and calcium compared to control	–	
			Energy intake (KJ d^{-1}), milk, calcium and vitamin D compared to control	–	
			Protein intake (g d^{-1}), milk and calcium compared to control	–	
			Protein intake (g d^{-1}), milk, calcium and vitamin D compared to control	–	

Table 2 *Continued*

Setting and intervention focus	Study (author, year)	Intervention	Outcome measure	Significance alpha level ($P < 0.05$)	Effect size (Cohen's D)
			Height (m), milk and calcium compared to control (adjusted for baseline BMC, BA, height, weight and menstruating)	+	0.33
			Height (m), milk, calcium and vitamin D compared to control (adjusted for baseline BMC, BA, height, weight and menstruating)	+	0.28
			Sitting height (m), milk and calcium compared to control (adjusted for baseline BMC, BA, height, weight and menstruating)	+	0.28
			Sitting height (m), milk, calcium and vitamin D compared to control	+	
			Weight (Kg), milk and calcium compared to control (adjusted for baseline BMC, BA, height, weight and menstruating)	+	
			Weight (Kg), milk, calcium and vitamin D compared to control (adjusted for baseline BMC, BA, height, weight and menstruating)	+	0.24
			N.B. Dietary records taken for 7-day recall at baseline and 3-day at midtrial and post-intervention. Records were checked with an interview and cross checked with a questionnaire. Comparisons represent change from baseline to post-intervention.		
	Romon *et al.* 2009**[1] (51) Controlled trial France	Fleurbaiz-Laventie Ville Sante (FLVS) study. School and community intervention comparing nutrition education, provided by teachers in one town to two control towns which received no nutritional education. Data presented for the years 2002, 2003 and 2004. Participant age: 5–12 years	Intervention girls BMI change from 2002 to post-intervention (adjusted for age and repeated observations)	+	X
			Intervention girls compared to control girls BMI compared in post-intervention (adjusted for age)	+	–0.31
			Intervention girls compared to control girls overweight prevalence	+	

Table 2 *Continued*

Setting and intervention focus	Study (author, year)	Intervention	Outcome measure	Significance alpha level ($P < 0.05$)	Effect size (Cohen's D)
School Physical activity and nutrition	Coleman *et al.* 2005**[2] (53) Controlled trial USA	El Paso Coordinated Approach to Child Health (CATCH): to test a school health curriculum over 3 years in a low-income school setting in order to reduce the risk for overweight or obesity. Schools were provided with training in: • Physical education. • Eat smart. • Classroom curriculum. • Home team components. Participant age: 9–11 years	Yards run in 9-min (girls) changes from third to fifth grade and increases in control versus intervention	+	0.01
			Risk of overweight in intervention girls compared to controls (rate of increase in intervention group risk > controls)	+	
	Stevens *et al.* 2003**[1] (42) Randomized controlled trial USA	Pathways: aims to report the psychosocial changes (e.g. attitudes, knowledge and self-efficacy) as a result of the Pathways physical activity and nutrition intervention in American–Indian children over 3 years. Participant age: 8–11 years	Girls assessed using Knowledge, Attitude and Behaviour Questionnaire:		X
			Food self-efficacy:		
			Baseline to 1 year	–	
			Baseline to 2 years	–	
			Baseline to 3 years	–	
			Food choice intentions:		
			Baseline to 1 year	+	
			Baseline to 2 years	+	
			Baseline to 3 years	+	
			Which food has more fat?		
			Baseline to 1 year	–	
			Baseline to 2 years	+	
			Baseline to 3 years	–	
			Physical activity self-efficacy:		
			Baseline to 1 year	–	
			Baseline to 2 years	+	
			Baseline to 3 years	+	
			Physical activity:		
			Baseline to 1 year	+	
			Baseline to 2 years	+	
			Baseline to 3 years	+	
			Curriculum knowledge:		
			Baseline to 1 year	+	
			Baseline to 3 years	+	
			Attempted weight loss:		
			Baseline to 1 year	+	
			Baseline to 2 years	–	
			Baseline to 3 years	–	
			Healthy body size perceptions:		
			Baseline to 3 years	–	
			N.B. Comparing intervention and control group		

Table 2 *Continued*

Setting and intervention focus	Study (author, year)	Intervention	Outcome measure	Significance alpha level ($P < 0.05$)	Effect size (Cohen's D)
	Hollar *et al.* 2010**[2] (36) Controlled trial Florida, USA	Healthier Options for Public Schoolchildren (HOPS) intervention aiming to prevent obesity and improve blood pressure, through a school-based intervention focusing upon improved nutrition and physical activity behaviours over 2 years. Participant age: 6–13 years	Girls BMI z-score intervention decreased versus control from pre- to post-intervention (2004–2006) Girls weight z-score intervention decreased versus control from pre- to post-intervention (2004–2006) Girls systolic BP intervention decreased versus control from pre- to post-intervention (2004–2006) Girls diastolic BP intervention decreased versus control from pre- to post-intervention (2004–2006) N.B. Effect sizes are for post-intervention	+ + – +	–0.22 –0.15 –0.15 –0.17
	Jiang *et al.* 2007**[1] (43) Randomized controlled trial China	The aim of this study was to evaluate the effects of a primary school intervention upon the prevalence of obesity in Beijing. Participant age: 7–9 years	BMI in girls (between group comparison at end of intervention). Intervention group < control. Odds ratio of obesity at end of intervention compared to controls Odds ratio of overweight at end of intervention compared to controls	+ + –	–0.66 –0.31 –0.22
	Danielzik *et al.* 2007**[3] (54) Controlled trial Germany	Kiel Obesity Prevention Study (KOPS): presents long-term experiences of preventing childhood overweight through a school and family-based approach. Participant age: 6–10 years	Remission of overweight and obese girls (total skin-fold and waist circumference) at 4-year follow up Girls 4-year incidence of overweight/obesity (BMI) (adjusted for age, socioeconomic status and BMI of the mother). Between groups intervention < control.	+ –	0.50 –0.07
	Kain *et al.* 2004*[2] (58) Controlled trial Chile	To investigate the impact of a 6-month nutrition and physical activity intervention upon physical fitness and body mass. Diet and nutrition intervention: • Classroom nutrition education for children. • Parental involvement-education meetings. • Meetings with Kiosk owners to improve snack provision. Physical activity intervention: • 90 min of additional physical activity per week. • Active play time. • Behavioural physical activity programme. • Used the Canadian Active Living Challenge. Participant age: 8–13 years	BMI in girls between and within group comparison 20 metre shuttle run (Leger) test (girls) between and within group comparison Girls lower back flexibility between and within group comparison N.B. effect sizes use post-intervention data	– + +	0.11 0.52 0.38

Table 2 *Continued*

Setting and intervention focus	Study (author, year)	Intervention	Outcome measure	Significance alpha level ($P < 0.05$)	Effect size (Cohen's D)
	Kain *et al.* 2009**[1] (56) Controlled trial Chile	To investigate the impact of a 2-year nutrition and physical activity intervention upon physical fitness and body mass. Intervention lasted 2 years and included: • The Canadian Active Living Challenge. • Lessons taught by teachers trained by a nutritionist. • Educational lessons for parents given by a nutritionist. Participant age: 9–13 years	Girls BMI pre- to post-intervention within and between groups Girls BMI z-score post-intervention within and between control and intervention groups Changes in girls' obesity prevalence (%) between intervention and control groups over 2 years Girls waist circumference post-intervention within and between control and intervention groups Girls total skin-fold thickness post-intervention within and between control and intervention groups N.B. Effect sizes use post-intervention data	– + + + +	–0.19 –0.15 X 0.04 –0.23
	Kipping *et al.* 2008*[1] (37) Cluster randomized controlled trial England	Evaluates the effectiveness of a US adapted intervention in the UK upon time children spent watching TV, BMI and mode of transport to and from school in a 5-month study. Intervention included: • Teacher-led lessons on healthy eating, physical activity and TV viewing Participant age: 9–10 years	Odds of being obese between intervention and control group at follow up in girls (adjusted for baseline obesity and clustering within schools)	–	0.23
	Marcus *et al.* 2009**[2] (38) Cluster randomized controlled trial Sweden	School care-based obesity prevention programme (STOPP): Aims to test the effectiveness of a 4-year school-based nutrition and physical activity intervention attempting to reduce the prevalence of overweight and obesity. Intervention schools attempted to change school environment: • Promoted low-fat dairy products and whole grain bread as snacks. • Removed sweets and sugary drinks. • Physical activity levels were increased by 30 min per day during school. • Attempts were made to reduce sedentary afterschool behaviours. • Newsletter distributed to parents. Participant age: 6–10 years	Total physical activity (accelerometry) girls Prevalence of girls overweight and obese post-intervention (between group comparison)	– –	0.09 –0.05

Table 2 *Continued*

Setting and intervention focus	Study (author, year)	Intervention	Outcome measure	Significance alpha level ($P < 0.05$)	Effect size (Cohen's D)
	Story *et al.* 2003**[1] (29) Randomized controlled trial USA	Girls Health Enrichment Multi-site Study (GEMS): Aims to present the findings from a 12-week pilot afterschool obesity prevention programme. Afterschool intervention study focused upon: • Increasing physical activity-watching less TV. • Increasing healthy eating-benefits of water, increasing fruits and vegetable consumption, eating low-fat foods, smaller portions etc. • Family component included-phone calls, family events etc. Sample size: 54 Participant age: 8–10 years	Girls BMI Girls healthy choice behavioural intentions Girls diet knowledge Girls availability of high fat food (parent interview) Girls % of calories from fat (2*24 h recall) Girls preference for physical activity N.B. Differences between intervention and control groups at follow up after adjustment for baseline levels	– + + + – +	0.19 1.20 1.45 –0.02 –0.66 X
Family Nutrition	Hakanen *et al.* 2006**[1] (55) Randomized controlled trial Finland	The aim of the study is to reduce the intake of saturated fat in children and to determine whether counselling reduced the development of overweight and obesity. Participant age: 7 months to 10 years	Overweight prevalence at 10 years in girls between groups	+	X
Family Physical and nutrition activity	Beech *et al.* 2003*[1] (28) Randomized controlled trial USA	Memphis GEMS pilot study: pilot evaluation of a family-based intervention designed to prevent excess weight gain and obesity in pre-adolescent African–American girls. This study was a three-arm trial: **1** Child targeted intervention; **2** Parent targeted intervention; **3** Comparison group focusing on self-esteem. The intervention groups involved highly interactive weekly group sessions with either girls (child-targeted programme) or parents/caregivers (parent-targeted programme). Content focused on knowledge and behaviour change skills to promote healthy eating and increased physical activity. Participant age: 8–10 years	Girls BMI (child targeted) Girls BMI (parent targeted) Girls MVPA (child targeted intervention) (accelerometer measures) Girls MVPA (parent targeted) (accelerometer measures) Girls low-fat food practice (child targeted) (questionnaire) Girls low-fat food practice (parent targeted) (questionnaire) Girls physical activity preference(child targeted) Girls physical activity preference (parent targeted) N.B. Differences between intervention groups (child and parent targeted) and control groups at follow up after baseline levels adjustment	– – – – + + – –	–0.45 –0.45 0.12 0.30 0 0.34 0.45 0.23
	Bruss *et al.* 2010**[2] (66) Controlled trial USA	Project Familia Giya Marianas (PFGM): intervention using Community Based Participatory Research principles focusing efforts upon primary care-givers to promote physical activity and healthy eating behaviours in children over 2 school years. Participant age: 8–9 years	Attending five to eight intervention lessons compared to no lessons effect upon BMI z-score in girls	+	X

Table 2 *Continued*

Setting and intervention focus	Study (author, year)	Intervention	Outcome measure	Significance alpha level ($P < 0.05$)	Effect size (Cohen's D)
Community Physical activity and Nutrition	Economos *et al.* 2007*[2] (52) Controlled trial USA	Shape Up Somerville: to investigate whether an environmental change intervention could prevent an increase in BMI z-scores in children. Community-based participatory research intervention aiming to increase physical activity and the availability of healthful foods within the before-, during-, after-school, home and community environment. Participant age: 6–8 years	Girls BMI z-score intervention compared to control group 1 Girls BMI z-score intervention compared to control group 2 N.B. Effect sizes were calculated using unadjusted change in BMI z-score from pre- to post-intervention	X	–0.079 –0.11
	Baranowski *et al.* 2003*[1] (30) Randomized controlled trial USA	GEMS: to test the effectiveness of a 12 week summer camp intervention aiming to prevent the development of obesity in healthy African–American girls. The intervention consisted of a: • 4-week summer day camp. • 8-week home Internet intervention for the girls and their parents. • Goal setting and review. The intervention summer camp activities included: • Training in dance. • Educational games targeted at increasing fruit and vegetable intake and physical activity. • Snack recipe preparation. Goal setting and review Sample size: 35 Participant age: 8 years	Girls BMI (kg m^{-2}) Girls waist circumference (cm) Girls CSA, MVPA, min (accelerometer measures) Girls metabolic equivalent adjusted gems activity questionnaire-usually (activity questionnaire) Girls total kcal (24-h dietary recall) Girls % kcal from fat (24-h dietary recall) Girls fruit juice and vegetables, servings (24-h dietary recall) Girls sweetened beverages, servings (24-h dietary recall) Girls water, servings (24-h dietary recall) Girls physical activity preference Girls sweetened beverage preference N.B. Differences between intervention and control groups at follow up after baseline levels adjustment	– – – – – – – – – – –	X
	French *et al.* 2005**[1] (46) Randomized controlled trial USA	Cal-Girls Study: aims to increase weight bearing physical activity and calcium intake in Girl Scouts to increase bone mass over 2 years. Participant age: 9–11 years	BMI between groups comparison at end of intervention Fat mass (DEXA) between groups comparison at end of intervention Lean mass (DEXA) between groups comparison at end of intervention Calcium intake (24-h recall) change in intervention group compared to controls over 2 years Weight bearing physical activity change in intervention group compared to controls over 2 years (physical activity checklist interview)	X X X + –	0.20 0.20 –0.19 0.20 0.098

Table 2 *Continued*

Setting and intervention focus	Study (author, year)	Intervention	Outcome measure	Significance alpha level ($P < 0.05$)	Effect size (Cohen's D)
	Robinson *et al.* 2003*[1] (27) Randomized controlled trial USA	Stanford GEMS: aims to pilot a 12-week intervention attempting to reduce TV viewing and increase physical activity through participation in culturally appropriate dance classes in African–American girls aged 8–10 years. Control group received health education materials. Sample size: 61 Participant age: 8–10 years	BMI (kg m^{-2}) Waist circumference (cm) MVPA (average min) (accelerometers) Self-reported previous day MVPA (min) TV, videotape and video game use (h $week^{-1}$) (self-reported) Total household TV use (0–4 scale) (self-reported) Ate breakfast with the TV on (d $week^{-1}$) (self-reported) Ate dinner with TV on (d $week^{-1}$) (self-reported) Total dietary calorie intake per day (kcal) Percentage of dietary kilocalories from fat (%) Physical activity liking (0–2 scale) Number of physical activities ever tried Over concerns with weight and body shape Body shape dissatisfaction Most recent school grades Self-esteem NB. Significance tested, using ANCOVA, as follow up of the difference between the intervention and control group adjusted for the baseline value of the dependent variable	– – – – – + – + – – – – + – – – 	0.38 0.25 0.14 0.23 0.40 0.73 0.03 0.59 0.15 0.05 0.21 0.16 0.60 0.09 0.51 0.30 Provided by authors
Combination Physical activity and nutrition	Vandongen *et al.* 1995*[3] (57) Randomized controlled trial Australia	Intervention aiming to improve cardiovascular health of children using six groups: • Physical fitness (PF). • Physical fitness + school nutrition (PF/SN). • School nutrition (SN). • School nutrition + home nutrition (SN/HN). • Home nutrition (HN). • Control group (CG). Participant age: 10–12 years	Girls sugar intake PF versus CG and pre- to post-intervention Girls sugar intake PF/SN versus CG and pre- to post-intervention Girls sugar intake SN versus CG and pre- to post-intervention Girls sugar intake SN/HN versus CG and pre- to post-intervention Girls sugar intake HN versus CG and pre- to post-intervention Girls total fat intake PF versus CG and pre- to post-intervention Girls total fat intake PF/SN versus CG and pre- to post-intervention	– – – – – – –	–0.11 –0.03 0.06 0.49 0.37 –0.10 –0.18

Table 2 *Continued*

Setting and intervention focus	Study (author, year)	Intervention	Outcome measure	Significance alpha level ($P < 0.05$)	Effect size (Cohen's D)
			Girls total fat intake SN versus CG and pre- to post-intervention	–	–0.04
			Girls total fat intake SN/HN versus CG and pre- to post-intervention	–	–0.33
			Girls total fat intake HN versus CG and pre- to post-intervention	+	–0.62
			Girls saturated fat intake PF versus CG and pre- to post-intervention	–	–0.11
			Girls saturated fat intake PF/SN versus CG and pre- to post-intervention	–	–0.40
			Girls saturated fat intake SN versus CG and pre- to post-intervention	–	–0.14
			Girls saturated fat intake SN/HN versus CG and pre- to post-intervention	+	–0.53
			Girls saturated fat intake HN versus CG and pre- to post-intervention	+	–0.56
			Girls polyunsaturated: saturated fat PF versus CG pre- to post-intervention	–	0.18
			Girls polyunsaturated: saturated fat PF/SN versus CG pre- to post-intervention	–	0.35
			Girls polyunsaturated: saturated fat SN versus CG pre- to post-intervention	–	0.34
			Girls polyunsaturated: saturated fat SN/HN versus CG pre- to post-intervention	+	0.35
			Girls polyunsaturated: saturated fat HN versus CG pre- to post-intervention	–	0.26
			Girls protein PF versus CG and pre- to post-intervention	–	0.31
			Girls protein PF/SN versus CG and pre- to post-intervention	–	0.24
			Girls protein SN versus CG and pre- to post-intervention	–	0.26
			Girls protein SN/HN versus CG and pre- to post-intervention	–	0.20

Table 2 *Continued*

Setting and intervention focus	Study (author, year)	Intervention	Outcome measure	Significance alpha level ($P < 0.05$)	Effect size (Cohen's D)
			Girls protein HN versus CG and pre- to post-intervention	–	0.13
			Girls fibre intake PF versus CG between groups and pre- to post-intervention	–	0.33
			Girls fibre intake PF/SN versus CG between groups and pre- to post-intervention	–	–0.08
			Girls fibre intake SN versus CG and pre- to post-intervention	–	0.19
			Girls fibre intake SN/HN versus CG and pre- to post-intervention	+	0.39
			Girls fibre intake HN versus CG and pre- to post-intervention	–	0.19
			Girls salt PF versus CG and pre- to post-intervention	+	0.27
			Girls salt PF/SN versus CG and pre- to post-intervention	+	0.47
			Girls salt SN versus CG and pre- to post-intervention	+	0.44
			Girls salt SN/HN versus CG and pre- to post-intervention	–	0
			Girls salt HN versus CG and pre- to post-intervention	–	0.15
			Girls endurance fitness (Leger test) PF versus CG	+	0.39
			Girls endurance fitness (Leger test) PF/SN versus CG	+	0.65
			Girls endurance fitness (Leger test) SN versus CG	–	0.09
			Girls endurance fitness (Leger test) SN/HN versus CG	+	0.43
			Girls endurance fitness (Leger test) HN versus CG	–	–0.23
			Girls BMI PF versus CG	–	0.07
			Girls BMI PF/SN versus CG	–	0.18
			Girls BMI SN versus CG	–	–0.07
			Girls BMI SN/HN versus CG	–	–0.07
			Girls BMI HN versus CG	–	0.23
			N.B. Dietary intake measured using 2-day weighed diet diaries		

Table 2 *Continued*

Setting and intervention focus	Study (author, year)	Intervention	Outcome measure	Significance alpha level ($P < 0.05$)	Effect size (Cohen's D)
	Olvera *et al.* 2010*[2] (47) Controlled trial USA	Behaviour Opportunities Uniting Nutrition, Counselling and Exercise (BOUNCE). Aiming to increase physical fitness in mother and daughter pairs over 12 weeks focusing upon: 3/week 90 min of exercise and nutrition education or counselling. Participant age: 8–11 years	Daughter 20-metre endurance shuttle run test (Leger test) Daughter average daily counts (accelerometer measures) Daughter MVPA (accelerometer measures) Self-report daughter high fat foods (School Physical Activity and Nutrition Survey) Self-report daughter sweetened beverages (School Physical Activity and Nutrition Survey) Self-report daughter fruit and vegetables (School Physical Activity and Nutrition Survey) N.B. differences between intervention and control group at 12 weeks (end of intervention)	+ – + – – –	0.78 0.39 0.75 0.40 0.36 0.34
	Chomitz *et al.* 2010**[2] (31) Cohort pre–post trial USA	Healthy Living Cambridge Kids: intervention utilizing Community-Based Participatory Research to decrease energy intake via increased fruit and vegetable consumption, decrease sedentary behaviours and increase physical fitness over 3 years. Participant age: 10–11 years	Girls BMI z-score difference from pre- to post-intervention % of girls passing the fitness test (five tests) from pre- to post-intervention % of girls passing the cardiovascular endurance test from pre- to post-intervention	+ + +	X

[1]Strong quality; [2]moderate quality; [3]weak quality.

*Short, <12 months intervention; **long, ≥12 months.

X, Effect size cannot be calculated from results.

+, Effective intervention regarding significant difference between intervention and control groups ($P < 0.05$).

–, Ineffective intervention regarding significant difference between intervention and control groups ($P < 0.05$).

BA, bone area; BMC, bone mineral content; BMI, body mass index; DEXA, dual-energy X-ray absorptiometry; MVPA, moderate to vigorous physical activity.

objective physical activity measures, 39.7% of self-reported physical activity measures, 27.3% of self-reported nutrition measures and 44.4% of knowledge and attitudes measures.

Effect sizes

The effect sizes (Table 2) ranged from 0.01 to 1.45 of which 66 were less than 0.2, 56 were categorized as low (0.2), 16 as medium (0.5) and two as high (0.8). Out of the 21 studies with effect size measures; four had effect sizes <0.20, five mainly had effect sizes less than 0.2, three were all low, three were mainly low and six studies had mixed effect sizes. Effect sizes of less than 0.2 were produced in 57.7% of physical measures, 43.7% of nutrition measures, 33.3% of objective physical activity measures, 60% of self-reported physical activity measures and 22.2% of knowledge and attitude measures. Low effect sizes were produced by 36.5% of physical measures, 42.8% of objective physical activity measures, 30% of self-report physical activity measures, 45.8% of nutrition measures and 33.3% of knowledge and attitude measures. Medium effect sizes were produced in 5.8% of physical measures, 10.4% of nutrition measures, 23.8% of objective physical activity measures, 10% of self-reported physical activity measures and 22.2% of knowledge and attitude measures. High effect sizes were only produced in 22.2% of knowledge and attitude measures.

Intervention length

Currently there is no agreed length of intervention required to produce long-term, sustainable effective changes in behavioural and physiological variables. In this review 11 studies were considered short term (3 to 12 months) and 19 long term (>12 months) (Table 2). The majority of strong quality studies were long term (11 out of 15).

Effectiveness of studies using only girls

There were nine studies conducted only with girls, four from the GEMS study (27–30), one addressing the impact of an obesity prevention intervention upon menarche, three studies with the primary aim of increasing bone mass and one using mother and daughter pairs (44).

The first GEMS trial (28) reported baseline BMI levels of 25.5 kg m^{-2} on average for the child targeted group, 23.0 kg m^{-2} for the parent targeted group and 22.6 kg m^{-2} in the control group (28). After the intervention the BMI levels were 24.3 kg m^{-2} (child targeted), 24.3 kg m^{-2} (parent targeted) and 24.7 kg m^{-2} (control) with no significant differences between the groups. The change in intervention girls BMI in the child and parent targeted group is represented by a low effect size (d = –0.45).

In the second GEMS intervention (29) the baseline BMI values on average were 21.9 kg m^{-2} for the intervention and 19.5 kg m^{-2} in the control. At the end of the 12-week intervention the BMI levels were on average 21.7 kg m^{-2} (intervention) and 21.5 kg m^{-2} (controls) resulting in no significant difference in changes in BMI and a low effect size (d = 0.19) (Table 2). However, the intervention girls significantly improved their health choice behavioural intentions and diet knowledge scores compared with the controls with a large effect size (d = 1.20).

The third GEMS intervention included culturally appropriate dance classes and either five lessons delivered in the home designed to reduce television viewing, or an active control condition (a health education programme delivered in a community centre) (27). In this intervention only three statistically significant results were achieved over the 12 weeks comparing the intervention group to the controls (adjusted for baseline values) total household TV use (d = 0.73), ate dinner with TV on (d = 0.59) and over-concerns with weight and body shape (d = 0.60). There was not a significant change in BMI levels (d = 0.38) (Table 2).

The final GEMS pilot study recruited girls and their caregivers who were randomized to receive either the intervention or the active control condition (30). Effect sizes for this study could not be calculated because the results had not been adjusted for baseline values resulting in low standard deviations in both the intervention (0.9) and controls (1.0) waist circumference measures. No statistically significant effects were produced in any of the measurements. However, there are positive aspects to the delivery of this intervention including formative research with children and parents to determine the influences on physical activity and dietary behaviours which then informed the components of the intervention.

The GEMS trials also found that participant self-efficacy decreased over the intervention, which they suggest could be due to individual's becoming more aware of what needs to be done before they make a change (45).

One study aiming to delay menarche through obesity prevention found that at follow up the intervention girls had significantly lower increases in BMI (d = –0.14), tricep skin-fold thickness (d = –0.13), a greater reduction in television viewing (d = –0.096) and an increase in moderate to vigorous physical activity (MVPA) levels (d = –0.096) when compared with girls attending the control schools, although the effects were all small (44).

The three studies initially aiming to increase bone health focused primarily upon physical activity in a school setting (39), nutrition only through milk supplementation in schools (40) and a combination of weight bearing exercise and increased calcium intake within a community setting of the Girl Scouts (46). In the RCT focused upon increasing physical activity, no significant changes were produced in any physical measures or physical activity indicators over the 2-year intervention (39). A

milk supplementation trial with two intervention arms (milk and calcium or milk, calcium and vitamin D) in Beijing achieved significant increases in height (d = 0.33 and d = 0.28 respectively) and body weight (milk, calcium and vitamin D group d = 0.24) over 2 years compared with controls and significantly improved vitamin D intake in the intervention group (40). A study within the Girl Scouts aiming to increase bone mass through weight bearing physical activity and calcium intake achieved significant changes in calcium intake (d = 0.20) over the intervention period but did not significantly change weight bearing physical activity compared with controls (d = 0.098) (46).

The Behaviour Opportunities Uniting Nutrition, Counselling and Exercise community-based intervention recruited 46 Latino mother-daughter pairs (47) and achieved significant improvements in daughter 20-metre endurance shuttle runs (d = 0.78) compared with controls and in MVPA levels (d = 0.75).

Intervention effects on body mass index and risk of overweight and obesity

Eight studies reported a statistically significant intervention effect on BMI levels in intervention girls compared with controls (31,36,43,44,48–51). Long-term significant decreases in BMI levels were reported by five studies. Salmon and colleagues found that girls in the fundamental movements skills group (i.e. throwing and running) (Table 2) and in the combined behavioural modification and fundamental movements skills group decreased their BMI levels on average by 0.07 ($P < 0.01$) (50). In the second long-term study a significant difference was found in BMI values at the end of the intervention between intervention girls (18.1 kg m^{-2}) and control girls (19.9 kg m^{-2}) (43). Table 2 shows that the change in BMI values is represented by a medium effect size (d = –0.66). The Healthier Options for Public Schoolchildren school-based intervention achieved significant reductions in girls BMI over 2 years, although this achieved a low effect size (d = –0.22) (36). In a cohort pre–post trial, one of the few studies to use a combined setting with school, family and community components, after a 3-year intervention there was a significant difference in girls BMI z-scores compared with baseline ($P < 0.01$) (31). However this intervention did not have a control group for comparison. Finally a school-based nutrition education intervention achieved statistically significant within (pre- to post-intervention) and between group differences (post-intervention) (d = –0.31) in girls BMI (51).

The remaining three studies reported short term significant changes in BMI levels (44,48,49). In an RCT aiming to reduce the consumption of sugar-sweetened beverages (49) girls defined as overweight at baseline significantly decreased their BMI ($P < 0.009$) after the intervention (Table 2). Liu and colleagues reported baseline average BMI values in girls of 18.63 kg m^{-2} (intervention) and 16.42 kg m^{-2} (controls) (48). BMI in the intervention girls decreased significantly to 18.16 kg m^{-2} compared with the control girls BMI which increased significantly to 17.08 kg m^{-2} at the end of the intervention. The change in BMI was also significantly different between the intervention and control girls. The final short-term study to effectively reduce BMI levels in girls (52) reported a mean change in BMI z-score of –0.027 in intervention girls, –0.002 in control 1, and –0.009 in control group 2. Two control groups were used in case an unplanned intervention was introduced into one of the control communities. The change in BMI for intervention girls compared with control group 1 and compared with control group 2 produced low effect sizes of d = –0.079 and –0.11, respectively (52) (Table 2).

Four long-term studies reported a significantly reduced risk of overweight and obesity in girls post-intervention (53–56). A longitudinal study found a significantly lower proportion of girls in the intervention group were overweight compared with the control girls at 10 years ($P = 0.0439$), however there was a statistically significant difference between the control and intervention group at baseline measures, which were taken at age 7 months (55). Jiang and colleagues reported a significantly lower odds ratio of being obese in girls within the intervention group, compared with controls ($P = 0.036$) (43). In the Coordinated Approach to Child Health intervention both the intervention and control group girls had a significantly increased risk of overweight from baseline to the end of the intervention however the rate of increase was lower in the intervention girls (2%) compared with the control girls (13%) (53). Danielzik and colleagues reported a statistically significant increased remission of overweight in the intervention girls as defined using tricep skin-fold measures (22.2% in controls compared with 40.9% intervention girls), $P = 0.0148$ and waist circumference measures (29.3% compared with 50%), $P = 0.0175$. The effect size produced for BMI and the adjusted odds of incidence and remission of overweight and obesity was d = –0.07 and d = 0.50, respectively (54). Finally Kain and colleagues showed a significant difference between the proportion of obese participants in the intervention group (10.3%) compared with the control group (15.2%) (56).

Intervention effects upon physical activity behaviours

Improvements in girls' physical activity behaviours have been achieved in 12 out of 17 studies which reported physical activity measures in girls. Significant improvements in girls' physical fitness compared with controls (where present) were shown in five studies using tests

such as the Leger endurance 20-metre shuttle run test (47,57,58), Cardiovascular endurance test (31), and the yards run in 9 min test (53). Both objective and self-reported measurements of habitual physical activity revealed significant changes from baseline to end of intervention compared with control girls (42,44,47,50,59). In one study the preference for physical activity was significantly different between the intervention and control group at follow up after adjustment for baseline values (29). Two studies successfully reduced the time spent engaged in screen behaviours, such as watching television (d = 0.73 and –0.096, respectively) (27,44).

Intervention effects upon nutrition behaviours

Significant changes to nutrition behaviours were achieved in seven studies out of 23 studies. Dietary records were used in only two studies (40,57). The first was a milk supplementation trial evaluating the effects upon growth and bone (40). This study asked participants to complete a 7-day diet records at baseline followed by two 3-day records during the intervention and post-intervention. The strengths of this study are the interview conducted to go through the diet records and the questionnaires used to cross-check with the diet records. This study achieved statistically significant changes in milk, calcium and vitamin D intake compared with controls (40). The second study to use diet records (57) used five intervention groups across the school and home setting and a control group. The home nutrition group achieved a statistically significant difference in total and saturated fat intake compared with controls (d = –0.62 and –0.56). The school nutrition and home nutrition group also achieved a significant difference in saturated fat intake and polyunsaturated to saturated fat ratio intake compared with controls (d = –0.53 and 0.35). Only the school physical fitness group significantly changed their fibre intake compared with controls (d = 0.33). All intervention groups achieved a significant difference in protein intake compared with controls. A 24 h recall of dietary intake was used in the Cal-Girls intervention aiming to increase calcium intake and weight bearing physical activity. This study managed to significantly increase calcium intake in the intervention group compared with control group over a 2-year intervention (d = 0.20) (46). Questionnaires assessing dietary behaviours produced significant results in two studies (27,28). Both these studies are from the GEMS trial and presented significant changes between the intervention and control groups over the intervention period for days where dinner was eaten while watching TV (d = 0.59) (27) and the practice of choosing low-fat foods (d = 0.34) (28). Attitudes and intentions to change behaviours were significantly changed compared with the control group in two studies (29,42). Story and colleagues significantly increased intervention girls' diet knowledge (d = 1.45) (29) and Stevens and colleagues significantly improved food choice intentions meaning participants were more likely to opt for the lower fat option (42).

Discussion

The purpose of this review was to determine the effectiveness of interventions designed to prevent overweight and obesity in pre-adolescent girls. The majority of the interventions failed to produce medium to large effect sizes over the long term in a broad range of behavioural and physical measures.

Effective intervention features

The effectiveness of interventions attempting to increase physical activity behaviours may be enhanced if the time spent doing sedentary activities (e.g. TV viewing) is reduced (16). The interventions, although limited in number, in this review which aimed to reduce TV viewing support this statement (37,44). In contrast, the Switch-Play project found that the intervention children significantly increased both physical activity behaviours and the time spent watching TV compared with the controls, which the authors suggest may be due to the reliability of self-reported measures (50).

An important component of the school-based interventions is the modification of school food provision, which, alongside the education components, can help facilitate healthy food choice behaviours (16). Six studies including the school setting, modified the school food provision (38,51–54,56,58). All of these studies managed to achieve significant changes to behaviour, a physical measure or both.

Cultural practices and behaviours may be associated with the development of overweight and obesity (16); therefore, it is important to develop culturally appropriate interventions. In this review, the GEMS trials acknowledged the cultural identity of African–American girls in relation to the importance of the family (27–30). The Pathways intervention (42), aimed at Native American children, included Native American games as part of the physical activity intervention component in an attempt to design a culturally relevant intervention.

Pre-adolescence

Pre-adolescence is characterized by a disassociation from parents and an increased connection with peer groups (60); therefore, there is a need to develop a formative understanding of the context within which children make decisions regarding health choices. The peer group of children aged 10 to 11 years have been reported as influencing the enjoyment, initiation and maintenance of physical activity

behaviours (61). The initiation of physical activity has been reported as encouraged by the peer group through; 'co-participation', 'modelling' and 'verbal encouragement' (61). This study may support the use of school-based interventions which utilize the peer group (61). The only intervention in this review to acknowledge the importance of peer modelling was a pedometer-based intervention which used fictional peer role models 'Fit n fun dudes' to encourage physical activity throughout the intervention (59). This study significantly changed mean daily step counts compared with control participants over the study period; however, the effects of these peer role models cannot be separated from the use of rewards for meeting step targets (59). Future studies should consider the role of the peer group in the success of interventions designed to target this age group, either as part of the intervention or in formative research (45).

Effect sizes

The majority of results failed to produce medium to large effect sizes. This is a similar finding to a meta-analysis of school-based obesity prevention (62). Those that did produce large effect sizes were over the short term (28) or produced large effects in health knowledge and attitudes (29) rather than physical measures of overweight and obesity prevention. The RCT implemented in China achieved the largest effect sizes for BMI in girls over the long term (3 years) (43). However, this study included children who were overweight and obese and resulted in weight loss which may have increased the effect of the intervention above that of interventions with exclusively normal weight children who would not have been expected to lose weight as a result of the intervention. The focus of this intervention was the school but parents were also involved, suggesting the inclusion of the family and school is beneficial. Although the majority of effect sizes were small, the clinical relevance of the interventions reviewed should not be ignored as over half of the measures produced statistically significant changes between the control and intervention group.

Intervention length

Thirty-six per cent of the interventions in this review were defined as short term. A Cochrane Collaboration review of all childhood obesity prevention interventions concluded that short-term interventions are unlikely to produce sustained behaviour change or significant weight reductions in children, because of the length of time required to alter weight status (15). Many of the effective short-term studies in this review were described as pilots, thus the sustainability of these studies needs to be investigated further. It has been acknowledged that the GEMS interventions were too short to achieve changes in BMI (45). Only two out of 30 interventions collected follow-up data. Salmon and colleagues followed up 6 months and 12 months after the intervention had finished and Manios and colleagues collected data 4 years after the intervention had ended (50,63). The lack of follow-up data limits the ability to comment on the sustainability of intervention effectiveness.

Intervention setting

The development of overweight and obesity is a complex social issue which may be best tackled holistically. The majority of the studies in this review utilized school-based settings; however, the risk factors associated with overweight and obesity are not exclusively found within schools (8). The Cochrane Collaboration review supported a multifactorial approach addressing environmental factors, community resources and individual behaviour change (15). Studies which failed to produce significant results tended to focus on changing aspects of the environment or the individual separately (15). The reason for this could be that efforts focused on one setting (such as the school) may be inhibited by the failure to address another setting (such as the family) (8). Approaches which encompass the wider social environment, including the family, community and school may be more effective. However, in this review, it is difficult to substantiate this claim with low numbers of studies combining research settings.

Six school-based interventions reported a family component (29,36,38,42,43,50,51,54,56,58) including written information specifically for parents, meetings for parents with educational material and advice, instructing parents not to bring unhealthy treats into schools for celebrations and teaching physical activity games with a family element. The involvement of parents in school-based interventions has been described as crucial (64) and in the GEMS interventions, parents were viewed as mediating daughters' participation in the intervention (45). Sichieri *et al*. propose that a lack of parental involvement may have resulted in limited intervention effects in their intervention (49).

Davison and Birch suggest that the risk factors associated with the development of overweight and obesity in children originate from the family, thus this is an important setting to investigate in research (65). However, this review found only three interventions set exclusively in the family (28,55,66). All of these studies included counselling or educational meetings involving both parents and children. Involving parents and children to facilitate family-based change may help to remove barriers to change, such as low parental knowledge.

Limitations

The conclusions drawn specifically for girls are limited to those studies which present results separately for girls.

Over 70 articles were excluded on the basis that results were not presented separately for girls (Fig. 1). As with any review of the published literature, it is possible that a more favourable view of intervention effects is presented because of publication bias (67). A further limitation to this review is the focus upon pre-adolescents aged 7–11 years. This age group may include girls who are post-menarcheal which may impact upon weight status. Only two interventions in this review presented information on menarche thus this effect cannot be measured (40,44).

Recommendations

The heterogeneity of the studies in this review makes it difficult to make simple recommendations for best practice. However, it can be suggested that the effectiveness of interventions is increased by reducing the time spent on sedentary behaviours, modifying school food provision when possible, and ensuring that interventions are culturally appropriate. Interventions should include a broader range of social settings and recognize age and gender differences in responses to intervention. Finally, to succeed in producing sustainable, effective changes it is important to invest not only in the development of long-term interventions but also to fund the follow up of interventions.

Conflict of Interest Statement

No conflicts of interest.

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Appendix

Electronic search to identify studies

Search	Results
1. (MH 'Body Weight') OR (MH 'Body Weight Changes') OR (MH 'Overweight')	151,171
2. (MH 'Obesity')	96,567
3. (MH 'Body Mass Index')	55,934
4. (MH 'Adolescent') OR (MH 'Child')	1,954,105
5. pre-adolescen* or preadolescen*	7,438
6. 4 or 5	1,959,555
7. (MH 'Child Nutrition Sciences')	775
8. (MH 'Nutrition Assessment')	6,124
9. (MH 'Feeding Behavior')	31,389
10. (MH 'Eating')	36,215
11. (MH 'Food Habits')	16,154
12. (MH 'Diet')	90,285
13. 7 or 8 or 9 or 10 or 11 or 12	166,987
14. 1 or 2 or 3	263,582
15. (1 or 2 or 3) and (6 and 13 and 14)	5,331
16. intervention* or control* or prevention*	4,187,671
17. school* or famil* or communit*	3,835,302
18. 15 and 16 and 17	1,359
19. (MH 'Exercise')	52,975
20. 'physical activity'	81,169
21. (MH 'Physical Fitness')	18,218
22. 19 or 20 or 21	133,533
23. (19 or 20 or 21) and (18 and 22)	577
24. female* or girl*	6,025,680
25. 23 and 24	453
26. 'body weight' or 'body size' or weight or overweight or obes* or 'body mass' or bmi	678,689
27. control* or prevention* or intervention*	3,196,322
28. child* or juvenile* or paediatric* or pediatric* or adolescen* or pre-adolescen* or preadolescen*	2,035,475
29. female* or girl*	3,886,110
30. nutrition* or eat* or diet* or feed* or food*	934,930
31. 'physical activit*' or exercis* or 'physical training' or 'physical fitness' or 'activity pattern*'	387,915
32. famil* or school* or communit*	3,081,751
33. 26 and 27 and 28 and 30 and 31 and 32	2,967
34. 29 and 33	1,769
35. 25 or 34	**1,777**
36. Keyword search run in CSA illumina (Biological Sciences and Physical Education Index)	**267**
37. Keyword search run in Web of Science	**468**
38. Duplicates removed from combination of 35, 36 and 37	**1,917**