The prevention of overweight and obesity in children and adolescents: a review of interventions and programmes

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Summary

Overweight and obesity are serious, large-scale, global, public health concerns requiring population-based childhood overweight and obesity prevention. The overall objective of this review is to identify aspects of successful childhood overweight prevention programmes. This objective will be met by assessing existing interventions quantitatively as well as qualitatively, identifying efficacy, effectiveness and implementation, and evaluating potential adverse effects of previous studies. This review was limited to school-based studies with a quantitative evaluation using anthropometric outcomes and that intervene on diet or activity-related behaviours. Quantitative and qualitative approaches are used to identify factors related to successful interventions as well as adverse consequences. Sixty-eight per cent of the interventions, or 17 of the 25, were 'effective' based on a statistically significant reduction in body mass index (BMI) or skin-folds for the intervention group. Four interventions were effective by BMI as well as skin-fold measures. Of these, two targeted reductions in television viewing. The remaining two studies targeted direct physical activity intervention through the physical education programme combined with nutrition education. Of the interventions reported here, one was effective in reducing childhood overweight but was also associated with an increase in underweight prevalence. Few other studies reported outcomes for underweight. The majority of overweight/obesity prevention programmes included in this review were effective. Physical education in schools and reducing television viewing are two examples of interventions that have been successful. Because few studies report on underweight prevalence, this review recommends giving more attention to preventing adverse outcomes by reporting the intervention impact on the frequency distribution for both BMI and adiposity measures.

Keywords: childhood, obesity, prevention, overweight.

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Introduction

During the past two decades the prevalence of overweight and obesity in children has increased rapidly worldwide (1–5). These trends have been associated with various changes in the social, economic and physical environment related to the nutrition transition (6). The nutrition transition is generally associated with an increase in the consumption of energy dense foods that are low in fibre, sugar, and sweetened drinks, a decrease in physical activity and a more sedentary lifestyle. Thus, overweight and obesity have become serious, large-scale, global, public health concerns (7, 8). The obesity epidemic has been associated with a dramatic increase in related healthcare costs, for example in the USA a more than a threefold increase between 1979 and 1981 and 1997–1999 was observed (9).

Childhood obesity, itself, is associated with a wide range of serious medical complications. Early medical consequences of obesity include orthopaedic complications, metabolic disturbances, type 2 diabetes, disrupted sleep patterns, poor immune function, skin problems, impaired mobility, and increased blood pressure and hypertension (10). Childhood obesity has an immediate impact on a child's physical appearance and can result in additional psycho-social consequences, such as a low self-esteem, social alienation, and lack of self-confidence (10, 11), discrimination (12) and, for girls, depression (13). Additional long-term health risks are partly related to the tracking of childhood obesity into adulthood. Long-term follow-up studies show that obese children tend to become obese adults (14–16). Related to the continuity of obesity into adulthood are long-term consequences of childhood obesity such as increased risk of cardiovascular disease, insulin resistance, type 2 diabetes, hyperlipidaemia, gall bladder disease, osteoarthritis and certain cancers (11). Moreover, adults who were obese children have an increased risk on morbidity and mortality independent of their adult weight (11). Obese children are more vulnerable to orthopaedic abnormalities related to damage to an unfused growth plate, slipped capital epiphyses, bowing of the legs and tibial tortion, sleep disorders, and insulin resistance has been noted even in children below 10 years (11).

The need for effective prevention of overweight and obesity is generally considered to be urgent. The disagreement is not whether to prevent overweight and obesity in children but rather when to introduce interventions on a wide scale and what preventive measures should be used. Calls for action have come from a number of sources including academics (17, 18) and politicians (19). As these calls for action gain attention, the debate between those who advocate immediate action vs. waiting for more evidence for effectiveness of preventive interventions has been increasingly polarized. On the one side, the need for immediate action is clear. We cannot continue to wait for more studies and more research while the epidemic continues to unfold unabated. Yet, the argument for additional research is also well founded. There is a dearth of data into specific causes of childhood obesity. Furthermore, there is a clear need for the continuation of research, using better and larger studies, with a long follow-up and improved research methodologies. Through this review we aim to identify the most promising elements of existing programmes and successful interventions that could be implemented and evaluated on a large scale.

Prevention and treatment of obesity and overweight may be somewhat easier in children than in adults because children are still growing in height. Related to the increased energy needs during growth, a child can achieve reductions in adiposity without reducing energy intake. One example of a treatment programme for obese children involves holding energy intake constant during growth in order to reduce a child's body mass index (BMI) percentile and adiposity measures. Using such a treatment approach at a young age, reversing overweight and obesity can be achieved without drastic behaviour changes. Although paediatric studies show that the effects of all types of treatment approaches diminish over time, there is still evidence showing long-term benefits related to obesity treatment (20). However, prevention has been shown to be potentially more efficient than treatment alone in addressing the obesity epidemic (21). Furthermore, effective prevention of childhood overweight is the first step towards preventing obesity. Effectively preventing obesity in childhood onwards may also prevent the onset of adult obesity and reduce chronic disease.

Preventing overweight and obesity requires understanding and addressing the 'obesogenic environment' in which children live. Environmental factors take precedence in prevention efforts because they provide the most potential for the greatest impact. Furthermore, other factors have played a lesser role in bringing about the current trends. Although gene–environment interactions may contribute to childhood obesity, genetics alone cannot explain the epidemic (22). It is the environment rather than genetics that has changed. Thus, we focus on population-based prevention childhood overweight and obesity prevention programmes, particularly interventions that address environmental determinants and can be applied on a large scale and are sustainable (preferably multi-sectorial).

The inclusion criteria for this review are broader than previous studies, with the goal of including more studies in order to provide insights into the state-of-the-art in childhood obesity prevention programmes. Earlier reviews often had a specific, narrower focus. For instance, reviews focused only on interventions targeting obese children, only including interventions focusing on overweight or obesity, or restricting inclusion criteria to interventions with a randomized trial design. For example, Story (23) only included school-based obesity prevention programmes. Resnicow (24) restricted their review of school-based programmes to the 'Know Your Body' Programmes, with the aim of reducing cardiovascular risk. Reviews by Glenny (25) and Campbell *et al.* (26–28) are restricted to interventions with preventing obesity as a primary aim. Hardeman *et al.* (29) included only interventions with the aim of preventing weight gain. We further contribute to the literature by including a wider range of studies and by incorporating a qualitative perspective into our methodology.

Aims of the review

The overall objective of this review is to identify aspects of prevention programmes that are most likely to succeed if implemented on a large scale. We fulfil this objective

through three specific aims. Our first aim is to compare the key elements and methodological approaches of existing interventions with anthropometric measures as outcomes quantitatively. Our second aim is to study the articles to glean qualitative information related to efficacy, effectiveness, and implementation of the prevention programmes. Our third and final aim is to consider possible adverse effects related to the intervention, quantitatively as well as qualitatively. Through these three aims we will identify those intervention programmes and strategies that are most efficacious, effective and with the greatest potential to be implemented on a large scale without causing harm.

Materials and methods

Inclusion and exclusion criteria

The initial list of articles were collected based on Medline searches in June 2003 and an additional update in August 2005, personal contacts with researchers, Internet web searches, references from published reviews, and additional Medline searches of authors with ongoing intervention studies. We include studies which evaluated public health programmes that seek to prevent obesity, that aim to prevent obesity-related dietary patterns, that encourage behaviours related to increasing physical activity, or that focus on preventing weight gain, reducing obesity prevalence or reducing obesity-related risk factors. This review includes studies in which obesity prevention may not be the primary aim but is, at least, a potential outcome. We have created a limited set of broad inclusion and exclusion criteria. In order to be included a study must meet the four following inclusion criteria:

1 The study must focus on school-aged children (6–19 years of age).

2 The study must have taken anthropometric measurement of body weight or adiposity (such as BMI or skinfolds) at baseline and follow-up.

3 The study must include an intervention on a diet or physical activity-related behaviour or both.

4 The study must be monitored and evaluated in manner that has been documented (i.e. as a published paper or with publicly accessible documentation).

In order to avoid the inclusion of studies that are very focused and not public health based, that are clinical treatments of obese children, or that are pilot studies not designed to show statistically significant results, we add the following exclusion criteria. Exclude if:

1 The aim of the study has a relevant diet or physical activity component but the aim of the study is so narrowly defined that the intervention is unlikely to impact obesity. (For example if a study intervention on diet or physical activity is focused only on preventing osteoporosis or dental caries).

2 Exclude programmes in a clinical setting that focus only on treatment of obese children. Targeting of obese children are included if these children are drawn from a broad-based, school population.

3 The study is described as a pilot study as such studies are exploratory and are not designed to show statistically significant outcomes.

This review considers these inclusion and exclusion criteria to be minimal requirements that will allow us to compare a variety of programmes that can potentially reduce childhood obesity and overweight. In our review we include all interventions that seek to alter diet and physical activity-related behaviours that have a broad public health base. We include interventions that seek to reduce television viewing because prevention of sedentary behaviour can potentially reduce energy intake as well as increase physical activity. Because our inclusion criteria are broader than previous reviews, we will be able to compare a greater number of interventions using a variety of approaches and from multiple sociocultural contexts.

Comparing the results

This review includes interventions that report different types of anthropometric outcomes in different ways. Although the broad inclusion criteria used here allow for more interventions to be included, differences in the way the programmes assessed the outcome prevented pooling of results. Thus, meta-analysis was impossible because the effect estimates differ as do the meaning of the outcomes, such as BMI, throughout the age range covered. Given the variability in outcome measures used it was also not possible to define a programme as 'effective' based on a set change, as the articles use different measures and report them in different ways. Instead, we define a programme as 'effective' if the intervention group shows a statistically significant improvement in comparison to a control group. Studies that report both weight for height measures as well as skin-fold measures will be compared and evaluated. Afterwards, results for all studies showing any effective result, regardless of the measure used, will be pooled. Interventions that have statistically significant results based on anthropometric or skin-fold outcomes will be compared with interventions that do not show any effect or that show a change that is not statistically significant. Thus, even if there is increase in BMI or skin-folds the intervention would be deemed effective if the increase in the reference group is greater. An additional analysis will consider the direction of effect for the studies with no statistically significant result.

Aim one: quantitative

We use as the basis for the review multiple points of consideration. We consider how comprehensive the intervention is in terms of the exposures addressed, target population, duration of intervention and methodology. The six criteria of action and the 10 action principles by Kumanyika *et al.* (30) are used to assess interventions. Our model, shown in Table 1, is the integration of two complementary models incorporating the specific risk factors related to childhood obesity (31) with 'environmental risk factors' that affect the whole community as defined by Kumanyika *et al.* (30). We applied Kumanyika's causal pathways to the condition of obesity risk in children. The reviewers then met to discuss the criteria for assessing an intervention and to further elaborate on the Kumanyika *et al.* (30) guidelines to fit the conditions of childhood obesity interventions, as shown in Table 1. The action recommendations and action principles formed the basis of the 12 questions that were used in our review (see Table 2).

In the first question we assess whether the intervention addresses three prevention targets related to childhood obesity: diet, physical activity and television viewing. Intervening on the television viewing has the potential to alter sedentary behaviour as well as dietary habits and is therefore addressed separately. Second, we consider whether interventions address both in-school and outside-school (after school) activities. In addition to the specific lifestyle factors addressed we consider the environment in which they occur in Question 3. We used Swinburn's (32) definitions to categorize elements of the intervention as addressing physical, sociocultural, and/or economic environment. Micro-level factors related to the family environment are addressed separately in Question 6.

Question 4 concerns sustainability. For an intervention to be adopted on a large scale and to have the greatest impact over the longest period of time it must be sustainable. The two dimensions we use to answer this question are structural and financial. In the first instance, does the intervention put a structure in place that can be continued? Is it costly to continue the programme? For example, a change in school canteens that can be continued is a sustainable intervention if accepted by the school and those responsible for catering. Sustainability of the intervention is evaluated only at the institutional level. The second concern, financial sustainability is related to whether the programme can be continued by the institution with minimal additional costs and efforts. We do not assess sustainability of behaviour change at the individual level, as this requires long-term follow-up.

Question 5 considers the level of participation by the children, their parents, teachers and the broader community. Parental support by giving informed consent or staff that are only involved by allowing the intervention to proceed are not considered active participation. Question 6 (action principle five) addresses the extent to which the programme is tailored to the needs of the local community, schools and families. This variable will be coded to identify programmes that are adapted and thus are different according to the specific conditions within a participating community, school or family. Small points of flexibility within an intervention programme will not be considered 'tailoring', e.g. allowing the teachers and principals to determine which classes receive the intervention in accordance with the teaching plans is not considered tailoring. Furthermore, separation of high-risk individuals, for the purpose of providing more intensive treatment, is a secondary prevention programme. As such these interventions will not be considered tailored. A programme is 'tailored' only when it is specifically adapted to the needs of the target population, defined locally. Tailoring may indicate a sustainable intervention in one particular school but may limit implementation in other schools.

Question 7 covers the different points of interventions (level of factors addressed), the involvement of multiple sectors and level of participation. In Question 8 national, regional and community level factors are addressed separately. Question 9 assesses whether an intervention builds links between sectors, such as the food service sector and parent–teacher organizations. In Question 10 we consider whether the intervention reaches the intended target population. School-based programmes have the intention to treat all children within the community. Thus, we use participation rates to quantify whether the intervention reaches the target population.

In order to ascertain the specific elements that contribute to a successful intervention we will use the questions described in Table 2. In addition, we compare interventions in terms of study design, sample size, target age group and duration of the study. Studies using different height and weight vs. skin-fold measures will be compared in terms of effectiveness. Furthermore, interventions associated with statistically significant changes in diet and physical activity will also be compared, along with the measure used (i.e. self-report vs. direct measure). Effective programmes will be compared against non-effective programmes, quantitatively.

Aim two: qualitative

The last two Questions, 11 and 12, have to do with the programme design and implementation and will be assessed qualitatively. Question 11 addresses whether the intervention has the potential to be or are integrated into existing initiatives. Further, we consider the theoretical framework upon which an intervention is based. Author comments related to the success or failure of interventions will be included as supplemental, qualitative information.

Table 1 Causes of childhood overweight and obesity

International factors	National factors	Community/locality	School	Home	Individual
1. Globalization of markets: more convenience foods, sedentary entertainment 2. Marketing of foods to children, child-oriented foods 3. Food and nutrition 4. Development: children's spending power	1. Transport 2. Urbanization 3. Manufactured/ imported goods 4. Sanitation 5. Health 6. National education 7. Child labour protections 8. Vending machines 9. Media and culture 10. Economy	1. School buses 2. Safety of children 3. Community awareness/attitudes 4. Adult obesity prevalence 5. Community sports clubs 6. Local school board and Parent Teacher Organizations 7. Paediatric care 8. Agriculture/gardens 9. Local markets 10. Playgrounds/parks 11. Education level of community 12. Median income of community	1. Active play at school: time and space, physical education, school playground 2. Walking/cycling to school 3. Teacher knowledge/ attitudes 4. School nurse knowledge/attitudes 5. School lunch programme 6. School snack shop 7. Education regarding diet and activity	1. Family diet 2. Number of televisions 3. Family activity patterns 4. Family SES 5. Child care 6. Parent knowledge/ attitudes 7. Family paediatrician knowledge/attitudes	1. Child's diet and activity patterns at school 2. TV in child's room 3. Child's diet and activity outside school

SES, socioeconomic status.

Table 2 Criteria for evaluating interventions drawing on criteria by Kumanyika *et al.* (30)

1. Does the intervention address dietary habit, physical activity patterns and television viewing of children?
2. For interventions that include physical activity intervention, does the intervention include activities inside and outside school?
3. Does the intervention seek to change behaviours by changing the physical, economic, or sociocultural environment?
4. Is the programme sustainable over time at the structural and institutional level with minimal additional inputs?
5. What is the level of involvement from the participants, parents, teachers and/or the broader community?
6. Is the intervention a primary prevention programme tailored to the needs of the local community, schools and/or families that are included in the target population?
7. To what extent does the intervention address family and individual level factors?
8. Does the intervention have multiple focal points and levels of intervention, including national, regional, and community levels?
9. Does the intervention build links between sectors by involving multiple organizations/groups that may be otherwise viewed as independent?
10. Does the intervention reach all children within the community?
11. Is there potential for integrating the programme into existing initiatives? Did the programme tap into existing initiatives or pre-existing programmes?
12. Did the programme build on existing theory and evidence?

Question 12 compares study designs of effective and non-effective interventions in a descriptive, qualitative fashion.

Aim three

Quantitative measures of unexpected outcomes will be considered in terms of the anthropometric measures with respect to the following: Is there evidence that the intervention has increased underweight prevalence or contributes to weight loss in normal weight children? Is there evidence that some interventions that are associated with an increase in percentile measures of either anthropometric or skin-fold measures? We will consider such results as possible evidence of an adverse outcome but will evaluate the intervention results in terms of the authors' explanation of the results. Finally, we consider evidence for the intervention as an effective means of preventing overweight and obesity. Is there evidence that the intervention contributes to maintaining children's relative percentile scores for anthropometric measures over time?

Results

There were 102 articles considered for initial inclusion in this study (see Appendix for full details). Of these, 41 were clearly treatment programmes or had a target population outside the selected age group. All four authors read the remaining abstracts to determine whether the articles fit the inclusion/exclusion criteria. The decision to exclude a study was based on consensus of the four authors. Of the original 102 articles, 63 articles did not meet the inclusion criteria or were excluded as having a narrowly defined objective or as a treatment programme (see Appendix). Thirty-nine articles either fit the predetermined inclusion criteria or the abstract did not include sufficient information for exclusion. Upon close reading, 20 more articles either were not intervention programmes or did not fit the inclusion criteria (see details in the Appendix).

After the above exclusions, there were 19 articles from the initial search. Two newly published articles were then added to update the review in 2003, thus, a total of 21 articles. Three more articles were again added after the second review update in August 2005. The broad inclusion criteria allowed for 25 articles in our review as compared with seven studies in Campbell *et al.* (27) and five studies in Hardeman *et al.* (29). The interventions included here differ from the 22 studies in the most recent update of the Cochrane review (28). The updated Cochrane review included a broader age range (including pre-schoolers) and included pilot studies but excluded interventions with goals other than obesity prevention and excluded interventions before 1990 (28). The details of the 25 studies included in our review are described in Tables 3 and 4, with articles deemed effective by either skin-folds or BMI measures listed first. Details of the study design and intervention are given in Tables 3 and 4.

Effectiveness

Effectiveness of the intervention is based either on an intervention producing statistical differences between the intervention and comparison groups according to height/weight measures (e.g. BMI), skin-folds or both. That is to say, the results are not based only on a percentile changes for the intervention group only, but rather are based on a comparison with the control group. In Table 4, the first 17 articles are effective according to height/weight measures, skin-folds or both. Because there are limitations to both measures it is useful to compare the results for studies with measures of both types of outcomes. Table 5 shows the results comparing height/weight and skin-fold measures. Fifteen studies had outcome measures based on height and weight as well as skin-folds data. Of these, nine had the same results according to both measures. Of the six remaining studies, five were effective by skin-fold measures but not according to BMI. Gender differences in the interven-

Table 3 Details of study design and intervention

Author(s)	Study design	Intervention
Effective interventions		
Alexandrov *et al.* (33)	CT. Controlled trial with a non-random intervention assignment.	Primary prevention: all intervention children received counselling and lectures on prevention by trained instructors. Secondary prevention: children with risk factors were invited, with their parents, to a single individual counselling session.
Dwyer *et al.* (34)	Phase I: RCT. Randomized Control Trial. Phase II: HCT. Historical control trial. Results for students in 1980 (after two years of intervention) were compared against cross-sectional measures of the 1978 Grade 5 baseline.	Phase I: control group, skill group (increased frequency and duration of exercise) fitness group (goal being to raise the heart rate). Phase II: daily physical activity as part of the regular curriculum for all children in the schools.
Flores (35)	SSCT. Small scale control efficiency trial with randomization. Randomized by classrooms, using a class-by-class pattern to achieve two groups.	Control: usual physical activity consisted mostly of playground activities. Intervention: aerobic dance and health education.
Gortmaker *et al.* (36)	RCT. Randomized Controlled Trial. Planet Health. Field trial with 5 intervention and 5 control schools. Outcomes were assessed using pre-intervention (fall 1995) and follow-up measures (spring 1997).	Planet Health is an interdisciplinary programme, education-based programme that is designed to fit within the regular curriculum existing sixth, seventh and eighth grade classes.
Harrell *et al.* (37)	RCT. Randomized Controlled Trial.	The education component included instruction to all third and fourth graders twice a week for 8 weeks. Intervention children also received physical activity interventions three times a week for 8 weeks.
James *et al.* (38)	RCT. Cluster randomized controlled trial. Clusters were randomized according to a random number table, with blinding to schools or classes.	Education-based intervention discouraging the consumption of carbonated beverages (sweetened and unsweetened), encouraging fruit intake, and promoting the consumption of water.
Kain *et al.* (39)	Controlled trial Non-random assignment to intervention or control school determined by the county education authorities and related to impressions of overweight prevalence and willingness to participate.	Educational programmes on diet and physical activity, encouraging school kiosks to sell healthy foods, meetings with parents, organized sports activities and physical education (PE) programme based on interest and input from the PE teacher.
Killen *et al.* (40)	SSCT. Small scale randomized matched Controlled Trial, matched.	Educational programmes provided students with information on health effects related to behaviours, cognitive and behavioural skills enabling change. Intervention as part of regular PE programme.
Manios *et al.* (41)	CT. Controlled trial, non-random intervention assignment involving three counties in Crete.	The intervention involved two components: the health and nutrition components and a physical fitness and activity component.
McMurray *et al.* (42)	RCT. Randomized controlled trial	The study involved a control and three treatment groups: exercise only, education only, and combined exercise and education.
Muller *et al.* (43)	RCT-MC. Randomized matched controlled trial with a crossover design. CT. Non-randomized controlled trial for the secondary prevention component. Families with an overweight/obese child or with normal weight children and obese parents were given an additional structured sports programme.	Five- to seven-year-old children recruited from 1996 to 2002 from different parts of Kiel, Germany. School intervention aimed at nutrition education and health promotion for all children, their parents, and teachers was carried out in three intervention schools. Every alternating year schools changed and 'control' schools became 'intervention' schools and vice versa.
Robinson (44)	SSCT. Small scale controlled trial with randomization.	One school was randomly assigned to the programme for reducing television, videotape and video game use. The other was assigned to an assessments only control. Households received a television time manager.
Rodgers *et al.* (45)	CT. Controlled trial with non-random intervention assignment (school principles and teachers determine the intervention groups). Quasi-experimental with pre-test and post-test control design.	One hour of instruction once a week for 10 weeks. Assignments: 30 min exercise each day and Workbook activities entitled 'Just for kids' (based on SHAPEDOWN children's workbook).

Table 3 *Continued*

Author(s)	Study design	Intervention
Sallis *et al.* (46)	RCT. Randomized controlled trial for grades 6–8 in San Diego.	Increase physical activity during leisure periods throughout the school day. Nutrition change to provide market low-fat foods at all school food sources.
Simoetti D'Arca *et al.* (47)	SSCT. Small scale semi-randomized controlled trial. Health education programme in Rome, Italy, designed to prevent obesity in children 4–9 years of age.	Testing two means of transmitting health information, written action (only printed material) and Multimedia Action School (adding audiovisuals and discussion meetings with families and teachers).
Tamir *et al.* (48)	CT-M. Control study, matched. Non-randomized intervention groups.	Educational programme of 10 units based on Israeli version of the 'Know Your Body' Programme. Two components related to overweight/obesity. The programme was translated and adapted into Arabic for the Arab schools.
Vandongen *et al.* (49)	RCT. Randomized control trial.	Nutrition and fitness programmes: Five different combinations of three intervention (FIT) (FIT+SN) (SN) (SN+HN) and (HN) were compared with controls. FIT (fitness group): Daily fitness programmes and PE classes.SN (school nutrition): lessons given by teachers to improve knowledge, attitudes and eating habits. HN: Nutrition messages transmitted to parents through homework.
Non-effective programmes		
Alexandrov *et al.* (33)	Study design, and primary and secondary interventions were the same as for the effective study, based on measurements at 52 weeks. Study not shown to be effective after 156 weeks.	
Bush *et al.* (50)	RCT-M. Randomized controlled trial, matched.	Full intervention: The 'Know Your Body' curriculum with students given results to place on a 'Health Passport'. Intervention began in grades 4–6 and continued into grades 7–9.
Caballero *et al.* (51)	RCT-M. Randomized controlled trial, matched. Forty-one schools in seven American Indian communities were enrolled.	Intervention consisted of four components: classroom curriculum, food service, PE and family involvement.
Donnelly *et al.* (52)	CT-M. Matched controlled trial with non-random selection of students to assess outcome measures. Two school districts in rural Nebraska, from grades 3 to 5.	Intervention school received enhanced physical activity, nutrition education and a modified school lunch programme.
Luepker (53–57)	RCT. Controlled trial with randomized treatment assignment. The study involved third grade students from 96 public schools from 12 school districts who agreed to provide a blood sample at baseline.	Intervention to improve the school lunch programme and physical education intervention goal to increase moderate to vigorous physical activity to 40% of PE classes. Classroom education focusing on eating behaviours and physical activity. Home curriculum involved activity packets complementary to the classroom curricula.
Sahota *et al.* (58)	RCT-M. Randomized matched control trial. 10 primary schools in Leeds, UK were recruited to the study. Cluster randomization design.	The specific interventions were based on perceived needs of individual schools. Programme consisted of teacher training, modification of school meals, and the development and implementation of school action plans designed to promote healthy eating and physical activity over one academic year.
Sallis *et al.* (59)	RCT. Randomized Controlled trial. Intervention was designed to evaluate a school-based physical activity promotion programme. The intervention involved fourth grade children from seven suburban elementary schools to be followed up for 3 years beginning in the fall 1990.	Programme included teacher-led and specialist-led interventions. Changes to the PE curriculum in the schools. Self-management curriculum: teaching children behaviour change skills related to physical activity outside schools.
Walter (60, 61)	RCT. Randomized control trial. Intervention involved demographically dissimilar study populations in and near New York City.	Beginning in grade four and continuing to grade nine students were taught the 'Know Your Body' curriculum. The curriculum targeted change in risk-related behaviour related to diet, physical activity and cigarette smoking The regular school teacher taught the curriculum in classrooms for approximately 2 h each week.

Table 4 Interventions included in the review

Author(s)	Type of programme	Location	Study length (weeks)	Target age group (years)	Gender differences	Schools (*n*)	Students with outcome measures (*n*)	Height/weight	Skin-folds
Effective programmes									
Alexandrov *et al.* (33)*	Diet + Activity	Moscow, Russia	52	11–12	Study only includes boys	23	766	Effective by mean BMI	
Dwyer *et al.* (34)	Activity	Adelaide, Australia	104	10		5	216	Not Effective by mean BMI	Effective by sum of four skin-folds
Flores (35)*	Diet + Activity	California, USA	12	10–13	Effective only for girls	1	110	Effective by mean BMI	
Gortmaker *et al.* (36)*	Diet + Activity + TV	Massachusetts, USA	91	11–12	Effective only for girls	10	1.295	Effective by % obesity BMI cut-offs	Effective by % obesity triceps skin-folds
Harrell *et al.* (37)	Diet + Activity	North Carolina, USA	8	8–9		12	1.274	Not effective by mean BMI	Effective by skin-folds (not specified)
James *et al.* (38)	Diet (Beverage)	South-west England	156	7–11		6	644	Effective by % overweight and obesityNot Effective by mean BMI	
Kain *et al.* (39)*	Diet + Activity	Santiago, Curico and Casablanca Chile	26	Grades 1–8	Effective only for boys	5	3.086	Effective by mean BMI Z-score, crude BMI and waist circumference	Not effective by skin-folds (mm)
Killen *et al.* (40)*	Diet + Activity	California, USA	8	14–16	Effective only for girls	4	1.130	Effective by mean BMI	Effective by triceps and subscapular skin-folds, mean (mm)
Manios *et al.* (41)	Diet + Activity	Crete, Greece	156	6		40	962	Effective, by mean BMI	Effective by mean suprailiac skin-folds (mm) but not by three other skin-fold measures
McMurray *et al.* (42)	Activity	North Carolina, USA	8	11–13		5	1.140	Not effective, by mean BMI	Effective, by subscapular skin-folds (mm)
Müller *et al.* (43)	Diet + Activity + TV	Kiel, Germany	52	5–7		–	1.640		Effective by triceps skin-folds and percentage fat mass
Robinson (44)	TV	California, USA	30	8–9		2	192	Effective by mean BMI, mean waist circumference, mean waist-hip ratio	Effective by triceps skin-folds (mm)

Table 4 *Continued*

Author(s)	Type of programme	Location	Study length (weeks)	Target age group (years)	Gender differences	Schools (*n*)	Students with outcome measures (*n*)	Height/weight	Skin-folds
Rodgers *et al.* (45)	Diet + Activity	California, USA	10	9		1	109	Not Effective by mean BMI	Effective, triceps skin-folds (mm)
Sallis *et al.* (46)*	Diet + Activity	California, USA	104	11–13	Effective only for boys	24	26.616	Effective by mean BMI	
Simonetti D'Arca *et al.* (47)	Diet	Rome, Italy	52	4–9		3	1.321	Effective by % overweight and obese based on BMI reference	
Tamir *et al.* (48)	Diet + Activity	Jerusalem, Israel	104	Grade 1 (6)		16	829	Effective by mean BMI	
Vandongen *et al.* (49)	Diet + Activity	West Australia	36	10–12		30	971	Not effective by mean BMI	Effective triceps skin-folds (mm) in FIT+SN group. Not effective by subscapular skin-folds
Non-effective programmes									
Alexandrov *et al.* (33)	Diet + Activity	Moscow, Russia	156	12–15	Study only includes boys	23	766	Not effective by mean BMI	
Bush *et al.* (50)	Diet + Activity	Washington DC, USA	104	9–13		9	431	Not effective by change in ponderosity index	Not effective, mean triceps skin-folds
Caballero *et al.* (51)	Diet + Activity	Multi-centre, USA	156	8–10		41	1.704	Not effective, mean BMI change and % body fat based on bio-electrical impedance	Not effective, changes in triceps skin-folds and subscapular skin-folds (mm)
Donnelly *et al.* (52)	Diet + Activity	Nebraska, USA	104	8–12		2 school districts	338	Not effective	Not effective
Leupker (53–57)	Diet + Activity	Multi-centre, USA	130	8–10		96	3.959	Not effective based on mean BMI	Not effective based on triceps skin-folds and subscapular skin-folds (mm)
Sahota *et al.* (58)	Diet + Activity	Leeds, UK	52	7–11		10	595	Not effective by BMI weighted mean difference	
Sallis *et al.* (59)	Activity	California, USA	104	9–10		7	550	Not effective by mean BMI	Not effective, sum of triceps skin-folds and calf skin-folds
Walter (60, 61)	Diet + Activity	New York, USA	260	9–13		37	2.474	Not effective by change in ponderosity index	

BMI, body mass index; FIT + SN, fitness + school nutrition. *Studies showing an effect only fo boys and girls.

Table 5 Comparisons of skin-fold and height/weight outcomes

	Skin-folds		Total number of studies
	Not effective	Effective	
Height/weight			
Not effective	5	5	10
Effective	1	4	5
Total number of studies	6	9	15

tion effect for Gortmaker *et al.* (36, 62) and Killen *et al.* (63) held true according to both height/weight as well as skin-fold measures.

Because 'effectiveness' is defined based only on statistically significant results, the eight studies that were deemed 'ineffective' were further assessed for direction of effect. Of these, three of eight studies reported a small relative reduction in either height/weight measures or triceps skin-folds compared with controls (51, 59, 60). However, results showing an effect in the Sallis *et al.* study (59) are based on skin-folds only. There was a concomitant increase in BMI compared with the controls. However, in three other studies the intervention group had a relative increase in skin-folds with either no relative difference in BMI (52) or an increase in one or more subgroups (50, 57). The Sahota *et al.* study (64) showed no change in the intervention group.

The Alexandrov study (33) was effective after 1 year but not after 3 years of intervention. After 3 years the intervention results showed only a negligible difference between the intervention and control group with the intervention group having a slightly greater BMI increase compared with the controls. The mean change was 2.2 BMI points in the intervention group vs. 2.0 for the controls. Because duration of the intervention is an important aspect of the comparisons, this intervention appears twice in Table 4 and is entered twice in the analysis, once with the earlier time point as an effective intervention and again as a non-effective intervention with the later time point. The intervention was conducted in an all-boys school and the fact that these results apply only to boys is noted in Table 4.

Only two studies were effective according to both BMI as well as skin-fold measures and were also equally effective for both boys and girls. One of these studies was a school-based intervention in California targeting reductions in television viewing (44). The second is the Manios *et al.* intervention (41) increasing physical education as well as nutritional education in schools in Crete. Two other studies categorized were effective according to both BMI and skin-fold measures (36, 40, 62), but these two studies were effective only for girls, not for boys. An additional study, Dance for Health, was also effective for girls and not for boys (35).

Differences between effective/non-effective interventions

Comparisons of effective and non-effective interventions based on the first 10 questions used in our analysis are shown in Table 6. Seventeen interventions were categorized as effective. Thus, over half of the interventions (68%) showed a statistically significant result for at least one time point or subgroup. Each question was scored as a dichotomous answer whether or not an intervention addressed the concern (1 = yes) or not (0 = no). If the answer was not clear from the text of the article the study is excluded from the sample. In the event that the information was missing or unclear in one or more articles, the sample size is given. Table 4 does not show any clear patterns based on the first 10 questions.

There was a general pattern in which the non-effective interventions included more of the components considered here. In fact, slightly more of the non-effective interventions intervene on diet and activity, more include activity outside school as part of the intervention, and more target the physical environment. More of the non-effective interventions were scored as sustainable based on reviewers' assessment of cost of continuing the intervention. Non-effective interventions also scored better by more frequently requiring active participation of children and also actively involving parents and the broader community. Interventions that were not effective also more frequently address family level factors. However, most of these differences are small and none of these comparisons are statistically significant.

Comparisons of means for participation rate and sample sizes are shown at the bottom of Table 6. The non-effective studies have a higher mean participation rate (83%) as compared with the effective interventions (71%) although this difference was not statistically significant. Additional comparisons of mean number of students, number of schools, and duration of the study are also informative. The effective interventions had a larger mean sample size (2488 vs. 1353) but a lower mean number of participating schools (11 vs. 32) and a shorter mean duration (61 vs. 133 weeks). Finally, age group comparisons are difficult as a number of the studies include children of a broad age range. However, comparisons of effective and non-effective interventions show that 65% of non-effective interventions include children between age 8 and 10 years. In comparison, only 35% of the effective interventions include 8–10-year-old children. Comparisons for other age groups were less informative, a similar proportion of non-effective (62%) and effective (58%) interventions include children above age 10 years. Only one of the non-effective interventions

Table 6 Comparisons of primary prevention programmes based on Kumanyika *et al.* (30)*

Intervention includes	Effective interventions ($n = 17$)	Non-effective interventions ($n = 8$)
1. Diet, activity and TV viewing		
Intervenes on diet	82%	88%
Intervenes on activity	88%, $n = 16$	100%
TV viewing	20%, $n = 15$	0
2. Activity		
Activity inside school	67%, $n = 15$	63%
Activity outside school	67%, $n = 15$	88%
3. Environment		
Intervention targets physical environment	24%	25%
Intervention targets sociocultural environment	100%	100%
Intervention includes change to economic environment	0%	0%
4. Sustainability		
Does the intervention involve putting a structure into place that could be continued	94%, $n = 16$	88%
Could the intervention be continued with minimal financial inputs	69%, $n = 16$	71%
5. Participation		
Participants/children	82%	100%
Parents	47%	57%
Teachers	100%, $n = 16$	100%
Broader community	6%	14%
6. Is the primary prevention component of the programme tailored to the needs of:		
Families	0%	0
Communities	0%	0
Schools	18%	14%, $n = 7$
7. To what extent does the intervention address individual and family level factors?		
Individual level	100%	100%
Family level	41%	57%, $n = 7$
8. To what extent does the intervention address community, regional and national level factors?		
School level	100%	100%
Regional level	0%	0%
National level	0%	0%
9. Does the intervention link sectors that would otherwise be separate	25%	25%
10. Does the intervention reach all children within the community?		
Mean participation rate	71%, $n = 13$	85%, $n = 6$
Additional information		
Mean number of students	2.488	13531.353
Mean number of schools	12, $n = 16$	32, $n = 7$
Mean number of weeks	61	133
Age comparisons†		
Target group between 6 and 8 years	35%	65%

*See Table 2, Questions 1–10.

†Subgroups add up to greater than 100% owing to rounding.

include young school aged children below the age of 8 (13%), compared with six studies in the effective interventions (35%).

Potential for unhealthy outcomes

Underweight

Only three studies commented on the intervention impact on underweight in the study population. The first was Pathways, showing no change in underweight but also no reduction in overweight or obesity (51). The second study was Simonetti D'Arca *et al.* (47) showing a significant increase in underweight prevalence together with a significant reduction in overweight and obesity prevalence. The third study, by Kain *et al.* (39), separately explores the impact of the intervention on underweight, normal weight and overweight children, combining results from boys and girls.

Overweight

Three studies showed that the intervention was not related to a reduction, but rather a statistically significant increase in weight for height measures in part of the target population (57) or in the whole intervention group (59, 63).

In order to better understand the lack of significant outcomes or negative outcomes we present explanations based on these and other interventions.

Caballero *et al*. (51) give the frequency distribution of the control and intervention groups. This distribution shows that children in the Pathways Study have a BMI distribution that is shifted towards higher values as compared with the Center for Disease Control and Prevention's 2000 reference population. The distribution curve is not different for the intervention vs. the control group. The authors remark that this may be related to the study design, being a primary vs. secondary intervention and the need to avoid weight reduction in healthy children:

> Because our intervention was aimed at all children at the school and not only at those with excess body weight, restriction of energy intake was not an option. (51)

The lack of change in the Pathways Study was also true using bioelectrical impedance measures of body fatness, with an equation developed and validated specifically for the study population.

Simonetti D'Arca *et al*. (47) reported an increase in underweight prevalence but do not explain the result. The discussion focuses on the reduction in overweight and obesity. The intervention was a health education programme in three schools. The study compared two methods of transmitting nutrition-related health information, written vs. multimedia, to a third control school. Overweight, obesity and underweight were defined based on BMI, although the criteria for defining each weight category were not given. Underweight prevalence in the Multimedia Action School increased from 14.4% to 16.1%. Simultaneously, obesity prevalence was reduced from 13.3% to 11.7% and overweight prevalence went down from 27.0% to 23.7%. It is not stated whether the increase in underweight prevalence for the Multimedia Action School was statistically significant, in comparison with the Written Action and Control Schools. However, the increase in underweight as a percentage of baseline (11.3%) is much higher than the same percentage of baseline for the Written Action School (1.3%) and Control School (3.6%). These changes may be related to the lower baseline prevalences in the other two schools. At the beginning of the study underweight in the Multimedia Action School was 14.4% as compared with 21.8% in the Written Action School and even higher (23%) in the Control School.

Kain *et al*. (39) found that overweight/obese children had a lower reduction in BMI *Z*-score in the intervention group than that in overweight controls (–0.16 vs. +0.03). In normal weight children the intervention resulted in a change of – 0.07, which was similar to –0.06 in controls. Underweight children had an increase in the average by +0.15 BMI *Z*-score compared with +0.07 compared with controls. However, in separate analysis assessing the intervention impact on under-nutrition Kain *et al*. (39) found a significant reduction in Height for Age *Z*-score associated with the intervention for girls.

Overweight/obesity

Three studies showed an increase in relative weight for height measures associated with the intervention. Sallis *et al*. (59) explain the statistically significant positive increase in BMI for boys and girls as being related to an increase lean body mass resulting from increased physical activity.

> In this cohort of children, the adjusted mile run and sit-up scores indicated that boys and girls in the intervention conditions made significant improvements in more than one fitness component. These finds suggest that muscle mass probably increased in the intervention condition. (59)

Furthermore, the Killen *et al*. (63) study also showed an increase in BMI for boys in the intervention group compared with the control group in spite of reductions in skin-fold thickness for both groups. Webber *et al*. (57) also found an increase in BMI for African American children in the intervention group that was slightly more than in the control group. The absence of an intervention effect and/or the ethnic differences in outcome may be related to the onset of puberty. 'The important hormonal and other changes associated with puberty may well mask the potential intervention effects.' (57)

Although James *et al*. (38) do not report on the intervention effect on underweight, nor do they report an increase in BMI or overweight/obesity, the results shown do indicate results relevant to healthy outcomes. The intervention led to a reduction in the prevalence of overweight/obesity. This change in obesity prevalence was fond in spite of there being no significant change in the overall mean BMI, as compared with controls.

Additional information that contributes to knowledge

Dietary vs. physical activity interventions

McMurray (42) tested the effectiveness of interventions that included only an education intervention, only an exercise intervention, and an exercise plus education intervention. Of these three types of interventions it was the exercise-only group that was shown to be effective and that this effect was only observed using skin-fold measures. Vandongen *et al*. (49) found the opposite, showing a significant reduction in triceps skin-folds in the group receiving the fitness plus school nutrition programmes as compared with controls. The other five programmes, fitness only, school nutrition only, school nutrition plus home nutrition, and home nutrition only did not result in significant reductions in skin-folds or BMI measures. Unfortunately other studies that have tested differences in parts of

interventions were not effective in any of the components (50, 52).

Delivery of the intervention

Simonetti D'Arca *et al*. (47) tested two different types of intervention delivery. The Multimedia Action School involved distributing printed material, audiovisuals, and discussion meetings with families and teachers. The Written Action School received only printed materials that were distributed among pupils, teachers and families. In the first school there was a statistically significant decrease in obesity and overweight whereas in the written action there was no change. The Child and Adolescent Trial for Cardiovascular Health (CATCH) study (53), comparing interventions targeting school-based or school plus family-based interventions, was not effective.

Target population

These studies indicate potential differences in intervention effects according to gender, age and ethnicity. Five studies showed differences in the effectiveness in boys vs. girls. Of these, three were effective in girls and not boys (35, 36, 62, 63) and two were effective in boys but not girls (39, 46). The two studies that were effective only for boys indicate these results may be related to the physical activity focus. The Sallis article explains the gender difference as an expected result related to an intervention focusing primarily on physical activity (59) . The Kain study also notes that boys responded better to the physical activity intervention, as measured by cardiorespiratory fitness (39). Kain *et al*. (39) further tested for an interaction between the intervention effect and age for children between first and eighth grade. They tested for interaction and found no differences in the intervention effect by age. It is unclear if their results would have been different had the authors tested, separately, the intervention effect on 8–10-year-old children separately from the younger and older children. Only the CATCH study reported on ethnicity. Unfortunately, the CATCH study was not found to be effective in any ethnic group but was, in fact, associated with a statistically significant increase in BMI and skin-fold measures in African American children compared with controls (57). This result was not seen in the White or Hispanic children.

Integrating overweight/obesity prevention into existing initiatives

The final assessment was to consider whether or not the interventions integrated the programme into existing initiatives. A number of obesity and overweight prevention programmes were integrated with smoking cessation programmes. Of the 10 studies with a smoking cessation component seven were effective for obesity prevention (33, 35, 37, 42, 48, 63, 65) and three were not (50, 53, 60). Of the four studies using the 'Know Your Body' Programme two were effective (48, 65) and two were not (50, 60). A number of programmes were physical activity interventions integrated into the school's existing physical education programmes. Of these eight were effective (34, 35, 37, 39, 41, 42, 46, 52, 62) and four were not (51–53, 59) Five studies (46, 51–53, 58, 64) made adaptations to existing school lunch programmes but only one was effective (46).

Sustainability

Most of these studies were primary prevention programmes with a school-based intervention (34, 35, 37–41, 45, 47, 48–52, 60, 62). Of these 75% (12 out of 16 studies) are effective. Two programmes involved a component of secondary prevention, targeting high-risk children (33, 43). Although the secondary intervention involves additional costs, both of these programmes were effective. It was not possible to compare the studies with others in terms of cost-effectiveness, as there was not sufficient information in the published articles related to the budget for the programme.

Costs are an important aspect of sustainability. Donnelly *et al*. (52) designed their intervention to maximize effect without increasing resources or personnel. Although this programme was not effective by body weight outcome measures, the changes to the school lunch programme resulted in statistically significant improvements in diet according to multiple measures. Furthermore, serving healthier food did not reduce student participation rates for the school lunch programme. Sallis *et al*. (46) identify costs related to changes in the school food services as the single largest policy barrier. 'Schools took a financial risk when introducing new products, especially perishable fruits, and they were unable to conduct marketing activities… to build demand for low-fat products.'(46, p. 216). Flores *et al*. (35) give a full accounting of costs, $1500 for Dance for Health, a 12-week intervention shown to be effective in girls. However, the low-cost approach is not always effective as shown by Simonetti D'Arca *et al*. (47). A lower cost intervention involving distributing well-produced printed material was not effective whereas a similar dietary education programme including audiovisuals and discussion meetings with teachers and parents led to reductions in overweight and obesity prevalence (47).

Additional barriers to effectiveness and sustainability relate to community level factors not addressed by the interventions. Bush *et al*. (50) provide insights into the difficulties faced by education-based prevention programmes related to the stigmatization of obese children.

> Teachers are unlikely to emphasize weight problems because of the embarrassment to obese children. Unless weight has been lost, there is little motivation for obese children to participate in a program that provides them with negative feedback at three of the five screening stations, i.e. weight for height, triceps skinfolds, and fitness. (50, p. 478)

Furthermore, in as much as children may feel stigmatized, the programme may also stigmatize teachers. Bush *et al.* (50) point out that although the programme was designed to prevent smoking and obesity, all of the health teachers involved were smokers and most were obese. Other studies do not report the overweight/obesity prevalence of the persons teaching the classes or other socio-demographic characteristics of those implementing the intervention. Nor do the interventions report the obesity prevalence or lifestyle behaviours of adult role models, such as parents, teachers or community leaders. These factors may be important to children's perceptions of education-based messages, community support, and long-term sustainability of the programme.

Two studies address the issues of school burdens related to overweight/obesity prevention. Additional limitations to sustainability are concerns about limited time in the school curriculum. Bush *et al.* (50) commented on teacher burden. As a result of this burden, the level of support provided to the teachers by researchers was greater than expected, and included in-class assistance or even taking over the teaching. Furthermore, Dwyer *et al.* (34) address possible concerns of parents, faculty, and staff that the additional burden of a school-based physical activity programme may take away from the school curriculum and negatively impact academic performance. This affects implementation and sustainability, as 'schools are unlikely to introduce an extra item into the curriculum, regardless of the health benefits, if the academic performance of their students is likely to suffer'. Thus, Dwyer *et al.* (34) measured academic performance and found no detrimental effects. Furthermore, the programme had widespread support by parents and teachers and the programme was adopted by 60% of all primary schools in the State of South Australia.

Discussion

Our inclusion criteria were kept broad in order to include interventions focusing on 'health promotion' as well as 'prevention' of obesity and obesity-related behaviours. This broad based review, including both promotion and prevention programmes, confirms the results of earlier reviews focusing primarily on obesity prevention alone. Fifty-six per cent of the interventions included in this review were found to be effective in reducing overweight, obesity or adiposity measures for at least one subgroup. More than half of the studies reviewed by Campbell *et al.* (27) and Hardeman *et al.* (29) also showed a significant effect in at least one subgroup. Like previous reviews, we included only interventions with published results. Thus, including interventions with a shorter duration, non-randomized design, and including broad-based health promotion programmes did not diminish the relative proportion of successful interventions. We expected there to be a greater bias against the publication of smaller studies lacking significant results.

Including school-based programmes relevant to obesity or obesity-related behaviours with different study designs, aims and methodological approaches allows a comparison of results across these types of approaches. The inclusion of smaller studies did not increase the relative proportion of effective interventions although there was a larger sample size mean from studies categorized as 'effective'. The larger sample size for 'effective' vs. 'non-effective' studies is consistent with expectations based on statistical power. Nevertheless, we do not know the results of interventions that remain unpublished. Another limitation is the difficulty in comparing outcomes that are reported in different ways, including height for weight as well as skin-fold measures. This prevented us from pooling the results of the studies for a quantitative assessment of effect estimates, such as in a meta-analysis. Thus, instead of creating a definition of effectiveness based on a uniform change in intervention outcome measures this review was limited to a dichotomous comparison of the studies as 'effective' or 'not effective'. However, the results considering direction of effect for studies with no statistically significant results did not show a clear pattern in terms of direction of effect. An equal number of these studies increased, decreased or had no impact on BMI/skin-fold measures.

Additional analysis of studies reporting both skin-folds data as well as height for weight data contribute further to the understanding of intervention effects. Five interventions that are effective according to skin-fold measures are not effective using age-adjusted height for weight outcomes. Studies with both measures have the added advantage of being able to provide a clearer picture of the intervention effect on body composition. Given an intervention focusing on increasing physical activity, a significant reduction in skin-folds can occur in the absence of a change in height for weight or BMI centiles. Such a result may, in fact, be a positive indication. Killen *et al.* (40) show an increase in BMI simultaneous to reductions in skin-fold thickness. This result indicates that reductions in adiposity can occur while maintaining or even increasing children's lean body mass.

The fact that five studies showed different results by gender indicates a need for further tailoring of these interventions by gender. Another intervention found a trend of increasing BMI in African American children but no such trend for Caucasian or Hispanic children (57). The potential for ethnic differences in intervention effects warrants further investigation. The differences in results by gender and ethnicity may also be partly related to differences in maturation that are not adequately measured. However, the results might also indicate the need to better tailor primary prevention programmes to the individual needs of children, or according to gender and ethnicity. The Kiel

Obesity Prevention Study (KOPS) does provide an example of tailoring to the individual needs of children by including a secondary prevention component for high-risk children (43). However, such tailoring is rarely combined with primary prevention programmes. Further research is needed to determine whether a prevention programme combining primary and secondary prevention, such as the KOPS study, is a cost-effective means of preventing overweight and obesity in children.

The results in Table 6 show the prevalences of non-effective and effective studies according to the factors identified as important. Table 6 shows that effective studies have a lower percentage of many of these factors. For example, the effective interventions are less likely to intervene on diet and activity, less likely to target the physical environment, less likely to include the broader community, less likely to target family-level factors, and are less likely to link sectors that would otherwise be separate. These findings underlie the limitations of a purely quantitative comparison. These dichotomous variables measure only which components are included in the intervention. However, whether or not a study addresses diet and activity may be less important than how the intervention addresses diet and activity. Furthermore, most studies do require active participation from the children. An education-based intervention might directly alter children's activity via physical education programmes, or an education-based intervention might simply encourage children to be more active. Likewise, dietary interventions may directly alter the intake of children through the school lunch programme or they may be education-based interventions teaching children about healthy foods and encouraging them to make healthy choices. An intervention programme that targets diet and activity only through educational materials, or through in-class instruction, will be categorized as intervening on diet and activity. Such programmes were also categorized as intervening on activity both inside and outside school because the materials apply to behaviour after school.

In fact, more direct interventions address more targeted behaviours and tend only to intervene in the school environment. On the other hand, education programmes tend to cover materials that address multiple aspects of children's overweight and obesity-related behaviours. On the other hand, a simple approach intervening on only one behaviour can also succeed. For example, all three programmes (43, 44, 62) that attempt to reduce television viewing were effective, even when this was done through education. Although this is a small number of studies ($n = 3$) it indicates the need for inclusion of television viewing and illustrates potential for education programmes to impact behaviour. Two of these trials were implemented in the USA where, compared with other countries, children watch more hours of television, the number of television sets per household is higher, and there are more advertisements shown. Reducing TV viewing is an aspect of obesity intervention to be included in future trials where television viewing is intense. Finally, our categorizations only identify programmes that actively involve the family in some way. Parental involvement differs from one study to the next and level of involvement is difficult to compare. Thus, the extent to which caregivers involvement contributes to programme effectiveness, based on the articles reviewed here, is not clear. However, parental involvement should be encouraged, as parental support is helpful for the continuation of most school-based programmes.

Although evidence suggests that eating behaviours are shaped by care-givers (66) few broad-based interventions target parents or the home environment. Golan and Crow (66) describe the role of parents in the aetiology and prevention of weight-related problems, as role models and through determining the home environment. Furthermore, care-givers directly determine a child's lifestyle, environment and body weight through food selection, home eating patterns, meal structure, responsiveness to child's feeding cues, and general parenting styles (66). Future interventions need to address the psychological and environmental influences of the home environment through education and active involvement of parents, even in a school-based intervention. Treatment studies show that family-based interventions combining education with behaviour modification are most successful (66, 67). Similar methods could be applied to a prevention model. For example, parental participation, education and active involvement could be achieved through parent–teacher organizations.

In spite of the limitations of quantitative comparisons, Table 5 does serve to illustrate factors that no intervention programme addresses. No intervention programmes address the economic environment and none are tailored to the community level or address regional or national level factors. In fact, economic, community and regional/national level factors are extremely difficult to address and any changes made at these levels would be difficult to measure for effectiveness. More thought needs to be given to finding ways of implementing and testing such large scale changes. Furthermore, although more than half of all interventions do address family-level factors these are not tailored. No primary intervention programmes are tailored to family level factors although Müller *et al.* (43) include tailoring for high-risk households.

The final results shown in Table 5, comparing the mean participation rates and sample sizes, indicate some difference between effective and non-effective interventions. Effective interventions have a lower participation rate as compared with the non-effective interventions. This finding raises the concern that the effective studies are drawing from a sample of highly motivated participants. Furthermore, the lower mean number of schools in combination with the higher mean sample size may indicate that effective

interventions are done in fewer, larger schools. Thus, the target population is more likely to be homogenous in comparison with interventions done in multiple small schools. Homogeneity of the target group, according to ethnicity, income, social class or cultural beliefs may be particularly relevant to an intervention that relies heavily on education-based approaches. It is more difficult to develop a health promotion programme or a prevention programme for a heterogeneous group with widely varying health beliefs related to diet and activity. Finally, comparisons of mean duration time indicate that effective interventions have a relatively shorter duration time. It is not clear whether this finding is an artifact of publication bias (non-effective studies with a longer follow-up period being more likely to be published) or if a longer follow-up actually diminishes the positive results.

The results did not show any indication of a specific ideal age for intervention. Because the interventions included here are narrowly targeted, by age, it is difficult to characterize the age differences in the results. The finding that a majority of the ineffective interventions include children in the 8–10-year-old age range warrants further study. Naturally, the limitations of sample size are an obstacle to drawing conclusions based on these comparisons. However, future studies targeting a broader age range could test whether the 8–10-year-old age group requires a specific approach.

An intervention study by McMurray *et al.* (42) compared different components of an intervention programme, namely an exercise programme alone, education alone, or exercise plus education. The study showed that exercise alone was effective whereas the same exercise programme combined with education was not. Did the education programme take away from the exercise effect, as these results suggest? Unfortunately, the quality of this education programme is unclear because the content is not described. Other education programmes, showing an increase in BMI and skin-folds in some ethnic groups relative to controls (57), warrant further study. These results, taken together, indicate the need to further explore the specific messages that are included in education programmes. Some education programmes may include messages that increase the risk of overweight and obesity for some children.

The dichotomous classifications of programme sustainability, based on whether a programme puts a structure in place and whether the intervention could be continued with minimal financial inputs, is a limited measure of sustainability. Additional studies are needed into the costs of continued monitoring and additional costs of adapting the programme in response to changes in the environment. In the Simonetti D'Arca example given previously (47), a low cost alternative was not shown to be effective. In addition, primary prevention programmes should be compared against secondary prevention and combined primary and secondary prevention programmes to determine cost effectiveness for implementation on a wide scale. Additional studies are also needed to measure the costs and benefits of these interventions, as well as potential adverse effects.

Only three of these 25 articles included results related to weight loss, underweight prevalence or specific impact for the underweight children. Underweight is usually defined as a low body-weight percentile compared with the reference charts according to height, age and gender. More attention needs to be given to whether or not overweight and obesity prevention might contribute to childhood underweight. Studies need to present the frequency distribution for the outcome measures, as Caballero *et al.* (51) and Müller *et al.* (43) have done, or show the results separately for underweight, normal weight and overweight/obese children, as Kain *et al.* (39) have done. In this manner the intervention effect can be clearly seen from both ends of the population distribution. Furthermore, more attention should be given to how preventing programmes achieve effective results. In Fig. 1a,b we present a hypothetical case of the frequency distribution of a population with excess overweight and obesity.

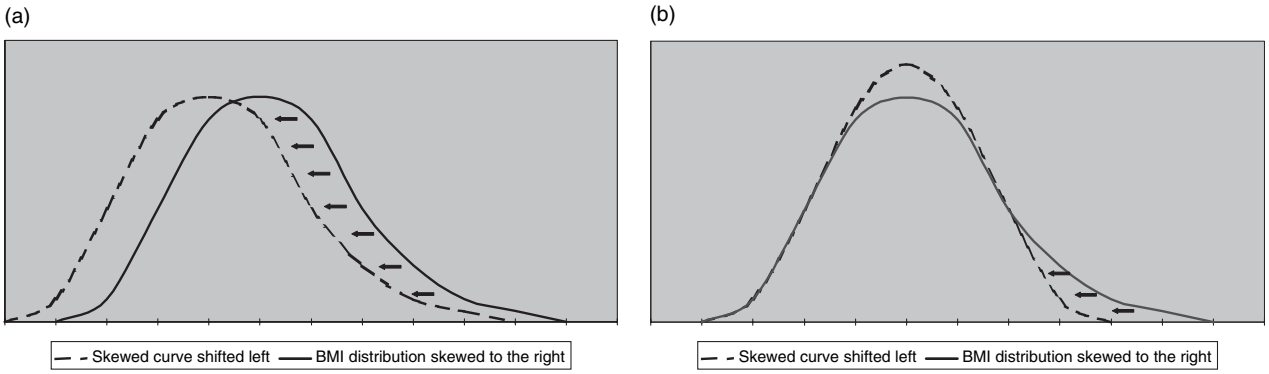

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Figure 1 Preventing obesity by shifting the skewed curve to the left (a) and by normalizing the curve (b).

Overweight and obesity interventions seek to prevent the excess overweight and obesity as seen in Fig. 1a,b. However, two very different types of intervention programmes might both result in an effective change in overweight and obesity. The first method is to simply reduce body weight overall by shifting the mean to the left (Fig. 1a). This method addresses excess overweight and obesity but only by shifting the whole curve and thus adds to underweight and under-nutrition. A second method requires preventing the excess overweight and obesity in a targeted way to address overweight and obesity without shifting the curve (Fig. 1b). Such a programme identifies and addresses only those risk factors that are specifically related to causing obesity and overweight. In a primary prevention programme where there is no excess overweight/obesity the goal should be to maintain a normal distribution. This requires a very specific targeting to prevent overweight/obesity-related behaviours without contributing to weight loss in other healthy children. Two studies show results that are potentially consistent with the targeting describe in Fig. 1b. First is the Kain study (39) reporting a reduction in BMI *Z*-scores for overweight children simultaneous to an increase in BMI *Z*-scores for underweight children. James *et al.* (38) reports results that may also indicate a specific targeting of the overweight/obese children, with no statistically significant change in the mean in spite of a significant reduction prevalence of overweight/obesity. Thus, both the Kain and the James interventions are consistent with an intervention approach Fig. 1b.

In the event that there is already excess overweight and obesity in the population, it may be necessary to include a secondary prevention programme for children who are most at risk. Two concerns regarding obesity prevention programmes are related to eating disorders and the potential for mental and emotional harm to obese children. There is very little information about a relationship, if any, between intervention programmes and eating disorders. Eating disorders could be a possible adverse effect of some types of intervention programmes focusing on weight reduction or weight maintenance. Eating disorders have been assessed separately only for the Planet Health study (68) showing a beneficial effect of the intervention. Thus, an intervention shown to be effective against overweight/obesity was also associated with reductions in eating disorders. No other studies had separate assessments of eating disorders. The relationships between children's emotional well-being and the onset of overweight and obesity has not been assessed in most interventions. Interventions must be careful not to single out children at risk, or contribute to the emotional and mental distress of children who are already overweight/obese.

The evaluation presented here indicates that, when physical activity is included, outcome measures based on weight and height (e.g. BMI) may be inappropriate because of an increase in lean body mass. We propose that a best practice for obesity prevention is an intervention that includes both physical activity and diet, is aimed at sustainability of the infrastructure, and is tailored to the circumstances of the target school. Evaluation of the intervention should include appropriate measures of body fatness for the particular age, sex and ethnicity group targeted in the intervention. Results should be reported not only as changes in percentiles overweight and obese children, relative to the control, but also in terms of the population distribution for adiposity and weight/height measures, in comparison with the controls.

The rationale for this review was based on the arguments by Gill and Lissner (69) that there is enough indirect evidence to support a *belief* in prevention and therefore sufficient evidence to act. The interventions reviewed here are not limited to one or two isolated studies that have worked but were carried out in countries as diverse as Russia, Australia, the USA, Greece, Germany, Italy and Israel. The diversity of interventions shown to be effective adds to the likelihood of finding a suitable programme that can be adapted to a particular community or region. Given the existence of a handful of proven, effective interventions, immediate action and continued research are not mutually exclusive. Both goals can be achieved through implementation of large-scale (randomized) controlled trials. Thus, we have sufficient information to provide the foundation for action on a larger scale.

The small number of studies, each using a different methodology and targeting different aspects of obesity-related behaviours, precludes drawing clear and definite conclusions. It is not clear which aspects of interventions are most likely to succeed on a large scale. Quantitative comparisons indicate that effective studies focus on a limited number of factors. Furthermore, the fact that both of the studies that included a television intervention were effective warrants further investigation. In spite of the differences in results and methodology, the interventions in this review provide a great deal of information about how to improve interventions in the future. Based on these results, the following are recommendations to improve future interventions:

1 Future interventions should take body composition measures such as skin-folds as well as height and weight to better assess body composition changes.

2 More attention should be given to improving the participation rates of interventions.

3 Greater attention should be given to the difficulty of targeting an intervention to a heterogeneous group, as exists in larger schools.

4 Health promotion messages should be tailored appropriately according to ethnicity, gender and age.

5 Interventions should directly alter the physical or social environment, such as improving the physical education programme or changing the school canteen.

6 More attention given to long-term sustainability, such as incorporating the intervention into the school curriculum.

7 The frequency distribution for BMI and adiposity measures should be reported to present the impact of the intervention on the whole target population.

8 Authors should assess the possible impact of the intervention in terms of adverse effects, such as stigmatizing obese children or increasing the potential for eating disorders.

9 We recommend evaluation and publication of all interventions. Even interventions with an imperfect study design, small sample size, and with no effective results in terms of behaviour change or outcome measures can be used to improve and inform future interventions.

The interventions reported here indicate that non-effective programmes can be improved and effective interventions can be broadened and extended. In spite of very restrictive criteria for success, based on statistically significant improvement as compared with controls, over half of the interventions reviewed were found to be effective. Although the pessimists may point to the glass and say that it is nearly half empty, let us not forget that it is also more than half full. We already have examples of interventions that work, the cornerstones of building up interventions on a larger scale. Thus, there is no need to reinvent the wheel. There are multiple examples of successful interventions (Table 4). Four interventions showed an effective outcome both in terms of BMI as well as by skin-fold measures (40, 62, 65, 70). All of these four interventions intervened on activity, and two included an intervention on television (62, 70). Reducing television viewing in children is a simple approach that targets a single behaviour. Two such interventions have shown promising results, with effective outcomes based on BMI and skin-fold measures, compared with control schools. Another effective intervention was the James *et al*. study (38) with a clear and simple message of reducing consumption of carbonated beverages. These interventions can be used as a starting point to be adapted and improved.

Large-scale interventions can be implemented based on programmes that have worked. Ongoing monitoring and evaluation is necessary to further develop and improve such interventions and to fine-tune existing interventions in order to determine, more precisely, what works and what does not. Reversing the trends towards increasing overweight and obesity, or even holding the current trends constant, will not be an easy task. Investments are needed to implement large-scale childhood overweight and obesity prevention initiatives. The necessary investments are not only a financial commitment, from all sectors of society, but an investment in time, effort and emphasis. Overweight and obesity prevention programmes can be sustained only through ongoing support from multiple sectors in society, including parents, teachers, school administrators, industry and government agencies. The problem of childhood obesity is too extensive, and the consequences too severe and costly, to postpone intervention.

Transparency statement

This review was commissioned by the Weight Management in Public Health Task Force of the European Branch of the International Life Sciences Institute (ILSI Europe). Industry members of the Weight Management in Public Health Task Force are: Ajinomoto Europe, Groupe Danone, Coca-Cola European Union Group, Eurasia and Middle East, Kraft Foods R & D Inc., Masterfoods, Nestlé, Procter & Gamble, Südzucker, Tate & Lyle Speciality Sweetners, Unilever. For further information about ILSI Europe, please call +32 2 771 00 14 or email info@ilsieurope.be. The opinions expressed herein are those of the authors and do not necessarily represent the view of ILSI or ILSI Europe.

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Appendix: collection of the original list of articles

Step 1: Medline search using each of the three key works + childhood + intervention + BMI, separately

Results: 45 studies of which 13 were interventions.

Step 2: interventions found through Internet searches and personal contacts

Results: 18 intervention studies.

Step 3: references included in other review papers

Robinson *et al*., two Epstein papers on obesity treatment.
Story *et al*. References 9–20, not including studies that are secondary prevention focusing on overweight/obese children.
Hardeman *et al*. 36–46, not including References from adults or unpublished references.
Mueller *et al*. 2001, Additional references 5,6 & 13–21.
Campbell *et al*. 25–31, with 4 articles that have already been included.
Dietz *et al*., Reference 8 duplicates; 8 articles.
Campbell from Cochrane report, no new additions.
Leupker *et al*. 1999, 5 new articles.

Step 4: other references found through the individual author searches from authors already included in the above literature

Cortez *et al*. 2001
Gittelsohn 1999
Fitzgibbon ML, Prewitt TE *et al*. (1998)
Fitzgibbon ML, Stolley MR *et al*. (2002)
Hawkins JD, Fitzgibbon JJ (1993)

Stolley MR, Fitzgibbon ML *et al*. (2003)
Bush *et al*. 1989 'Know Your Body' program
Epstein *et al*. 2002,2001,1997
French 2003, French 2997, Hannan 2002
McKenzie 1997
Sallis 1993 & 1997
McKenzie 2001
Webber 1995
Perry *et al*. 1990 & 1997

Step 5: the total reference list from the above process resulted in 115 articles including 13 duplicates. The final count was 102 references:

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Step 7: additional new publications added in 2003

1. Caballero *et al.* 2003 (51)
2. Sallis *et al.* 2003 (46)

Step 8: articles excluded in 2003

1. Goodwin *et al.* 1988 is not a primary prevention programme.
2. MacFarlane 1993 is an editorial and not an intervention.
3. CDC study (Bicycle to school) does not have any anthropometric outcome.
4. Sahota 2001 (A) reports on the same study as Sahota 2001 (B).
5. Zakus 1981 is a treatment programme and not primary prevention.
6. Stolley 2003 gives baseline data only.
7. Stolley 1997, does not report results for anthropometric outcomes.
8. Mo-Suwon focuses on pre-school children (kindergartens).
9. Henry *et al.* is a pilot study and, as yet, unpublished.
10. Ramsay *et al.* is a strength training study and, thus, has a very narrow focus.
11. Puska *et al.* study does not report on anthoprometric for children.
12. Seltzer 1978 focus only on obese kids and, thus, is not a primary prevention programme.
13. Tell 1987 is an observational study, not an intervention.
14. Walter *et al.* 1989, is an overview of the Know Your Body studies with information from pilot studies that are secondary prevention programs.
15. Killen *et al.* 1988 provides the same data as Killen *et al.* 1989
16. Sallis 1989 is a background paper, not an intervention.
17. Foster *et al.* 1985 as a secondary obesity prevention targeting overweight school children.
18. Manios *et al.* 1999 as a repeat of the information from Manios *et al.* 1998.
19. Nader *et al.* 1996 a follow-up of CATCH study without any additional intervention.
20. Leupker *et al.* 1999 results from the CATCH study reported also in Webber *et al.* 1999 (57).

Step 9: additional publications found in the updated search, August 2005

1. James *et al. BMJ* 2004; **328:** 22 (38)
2. Kain *et al. IJO* 2004; **28:** 483–493 (39)
3. Vandongen *et al. Prev Med* 1995; **24:** 9–22 (49)

Step 10: the following articles were excluded in the updated search in August 2005

1. Dennison *et al. Arch Pediatr Adolesc Med* 2004; **158**: 170–176, focus on pre-school children, no anthropometry outcomes.
2. Harvey-Berino *et al. Obes Res* 2003; **11**: 606–611, intervention focus on pre-schoolers.
3. Pangrazi *et al. J Sch Health* 2003; **73**: 317–321, no baseline data.
4. NeuwmarkSztainer *et al. Prev Med* 2003; **37**: 41–51, is not primary prevention but rather a treatment programme.
5. Chomitz *et al. Arch Pediatr Adolesc Med* 2003; **157**: 765–772, is not primary prevention, the focus is on children most at risk.
6. Trudeau *et al. Am J Hum Biol* 2000; **12**: 207–213, has no baseline data for outcome evaluation.
7. Simon *et al. IJO* 2004; **28**: S96–S103, does not report on anthropometric results.
8. Kumanyika *et al. Ethn Dis* 2003; **13**(1 Suppl. 1): S88–S91, excluded as a pilot study.
9. Beech *et al. Ethn Dis* 2003; **13**(Suppl.. 1): S40–S53, excluded as a pilot study.
10. Kumanyika *et al. Ethn Dis* 2003; **13**(1 Suppl. 1): S15–S29, excluded as a pilot study.
11. Robinson *et al. Ethn Dis* 2003; **13**(Suppl. 1): S65–S77, excluded as a pilot study.
12. Rochon *et al. Ethn Dis* 2003; **13**(Suppl. 1): S6–S14, excluded as a pilot study.
13. Story *et al.* 2003 *Ethn Dis* 2003; **13**(Suppl. 1): S54–S64, excluded as a pilot study.
14. Story *et al.* 2003 *Ethn Dis* 2003; **13**(Suppl. 1): S78–S87, excluded as a pilot study.
15. Baranowski *Ethn Dis* 2003; **13**: S30–S39, excluded as a pilot study.
16. Warren *et al. Health Promot Internation* 2003; **18**: 287–296, excluded as a pilot study.