REVIEW ARTICLE

Controlling childhood obesity: A systematic review on strategies and challenges

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Background: Childhood obesity is a global health problem with short- and long-term health consequences. This systematic review presents a summary of the experiences on different family-, school-, and clinic-based interventions. **Materials and Methods:** Electronic search was conducted in MEDLINE, PubMed, ISI Web of Science, and Scopus scientific databases. We included those studies conducted among obese individuals aged up to 18 years. Our search yielded 105 relevant papers, 70 of them were conducted as high quality clinical trials. **Results:** Our findings propose that school-based programs can have long-term effects in a large target group. This can be related to this fact that children spend a considerable part of their time in school, and adopt some parts of lifestyle there. They have remarkable consequences on health behaviors, but as there are some common limitations, their effects on anthropometric measures are not clear. Due to the crucial role of parents in development of children's behaviors, family-based interventions are reported to have successful effects in some aspects; but selection bias and high dropout rate can confound their results. Clinic-based interventions revealed favorable effects. They include dietary or other lifestyle changes like increasing physical activity or behavior therapy. It seems that a comprehensive intervention including diet and exercise are more practical. When they have different designs, results are controversial. **Conclusion:** We suggest that among different types of interventional programs, a multidisciplinary approach in schools in which children's family are involved, can be the best and most sustainable approach for management of childhood obesity.

Key words: Adolescent, child, control, obesity, prevention

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INTRODUCTION

The epidemic of childhood obesity is no more limited to high-income countries,[1-8] and has become as one of the most important global health problems of the 21th century.[9] The World Health Organization (WHO) experts have estimated that there are 43 million overweight children under the age of 5 and by 2020 more than 60% of global disease burden will be the result of obesity related disorders.[2,10] Childhood obesity is associated with several short term and long-term health hazards as cardiovascular diseases, hypertension, type 2 diabetes, fatty liver disease, orthopedic problems, low self-esteem, etc.[11,12] Childhood obesity can reduce life expectancy by 2-5 years.[2] Moreover, the increasing trend of obesity has enormous economic outcomes.[13] Two main underlying causes of excess weight are genes and environment.[14,15] Although both genes and environment have a role in an obesity epidemic, gene defects needs to time to show their phenotype; so obesogenic environment is responsible for obesity.[11]

Primordial/primary prevention of pediatrics obesity and establishment of a healthy lifestyle behaviors from early life are the favored against the epidemic of obesity at the global level.[16]

Effective interventions for prevention and control of childhood obesity should be considered for different aspects.[11,17-24] Experts recommend specific eating and physical activity (PA) behaviors through counseling.[14] Along with clinic-based interventions, researchers have attempted to manage obesity by virtue of family, community, school, and after school programs. Based on Cochrane review of obesity prevention programs in children, most of the well-designed interventions had positive results especially in 6-12-year-old children.[25] Clearly targeted interventions for children and population-based approach for adolescents may be useful and make economic sense. The purpose of this investigation was to systematically review the effects of various clinical-, family-, and community-based interventions targeting the control of childhood obesity and make a suggestion for future interventions.

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MATERIALS AND METHODS

Literature search

Relevant literature reporting the interventions for controlling excess weight in children and adolescents was identified through electronic search of papers published from 2000 to 2012 in MEDLINE, PubMed, ISI Web of Science, and Scopus. Keywords such as "childhood obesity", "overweight," "weight disorder," "intervention," "treatment," "management," "control," "PA," "nutrition," "behavior therapy," and "diet therapy" were used. The searches yielded 1768 articles.

Study selection and eligibility criteria

Having removed duplicates, the relevant papers were selected in three phases. In the first and second phases, titles and abstracts of papers were screened and irrelevant papers were excluded. In the last phase, the full text of recruited papers was explored deeply to select only relevant papers. All these three screening phases were done by two independent reviewers (RK and FA). Discrepancies were resolved by consultation and consensus.

Studies were included if they met the following criteria: Studies on 2-18-year-old children; community, family, school, and clinic interventions or a combination of them; English language; and conducted among obese or overweight children and adolescents. Systematic reviews, meta-analysis, and editorials were excluded. Articles were firstly assessed on their abstracts and 234 were removed.

Data extraction and abstraction

The required information that was extracted from all eligible papers was as follow:

(i) General characteristics of the study (first author's name, publication year, study year, study design, sampling method,
(ii) Characteristics of the study population (age and sex of studied participants and sample size, follow-up),
(iii) Type and duration of the intervention, measure(s) used to assess child weight, and
(iv) Main finding. One reviewer (FA) extracted the data while another (RK) randomly selected 10% of them and checked their extracted data.

The selection process of our systematic review is presented in Figure 1.

RESULTS

The interventions were categorized as school-based, family-based, and clinic-based programs as described below:

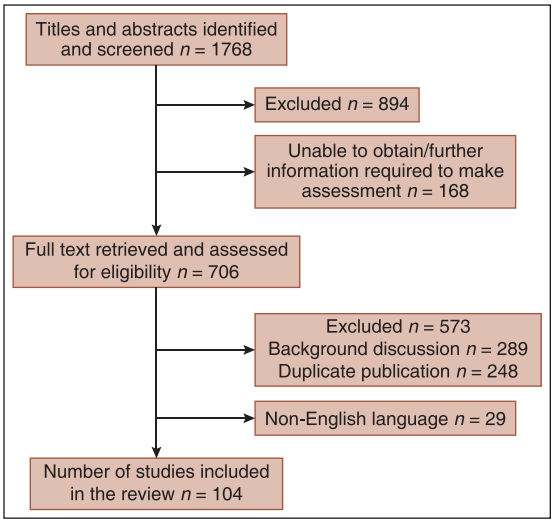

Figure 1: Flow chart of study selection process

School-based programs

A summary of the school-based obesity prevention and control programs is presented in Table 1. In brief, such interventions are suggested to be feasible and effective;[26] because students spend a considerable part of their time in school,[27] moreover teachers and peers can be engaged in such programs.[28] These kinds of programs can improve health behaviors in a large target group. They are characterized by nutritional education and changes in dietary habits, as well as increase in PA through structured programs.[29] Findings of various studies proposed that the effects of such interventions will be preserved for several years after intervention.[30-32] This effect has been of special concern about consuming fruits and vegetables, and healthy snacks, as well as increased PA. Nevertheless, the impact of school-based programs on obesity prevention is controversial and remains to be determined by large studies with long-term follow-up research. Some studies have not evaluated the effect of intervention on anthropometric measures,[27,33,34] but they have shown positive impacts on eating and activity behaviors. The most common limitation of these studies is presenting self-reported data, non-randomized selection of schools, short duration of study, and not masking the interventional groups.

Family-based programs

Reaching a healthy weight is not successful unless children have support for making healthy behavior choices; obviously, providers of this support are families. Family is an applicable target for health promoting interventions. Family-based intervention programs are considered as one of the most successful methods for obesity treatment or prevention.[59] Engaging parents in childhood obesity prevention programs may make weight loss easier for children; because they can provide confirmatory conditions to help their children to choose

Table 1: School-based weight control studies

Author, year, country	Design	Study participants	Duration of intervention	Type of intervention	Outcome	Results
Contento *et al*., 2010, USA[27]	Pre-post, cluster randomized intervention-control	11-13 years old children	8-10 weeks	Behavioral education	Energy balance-related behaviors	Intake of less sweetened beverages and packaged snacks, smaller portion of fast food, increased walking, and decreased screen time
McMurray *et al*., 2002, USA[26]	2_2 factorial design with three treatment groups and a control group	11-14 years old children	8 weeks	ExO, EdO, and combined EE	Weights, and skinfold thicknesses and BMI	BMI did not change significantly, sum of skinfolds enhanced less in exercise groups
Bayer *et al*., 2009, Germany[35]	Randomized, controlled trial	3-6 years old children	6 months	Behavioral intervention (increase of regular PA and modify food and drink consumption habits	Prevalence of overweight and obesity	Children who intake high fruit and vegetable enhanced, prevalence of overweight and obesity were not statistically different between groups
Neumark-Sztainer *et al*., 2003, USA[36]	Randomized, controlled trial	9th and 10th grade girls	8 months	Increased PA, nutritional and social support	PA, eating patterns, self-perceptions, and BMI	A positive effect on PA level, eating habits, and self-image but no impact on BMI
Going *et al*., 2003, USA[37]	Multicentered, randomized trial	10.5±0.08 years old children	3 years	Increased frequency and quality of physical education	School's mean PBF	No significant difference in PA level or PBF between groups
Donnelly *et al*., 2009, USA[38]	Cluster randomized, controlled trial	9th and 10th grade children	3 years	Vigorous PA	BMI, daily PA and academic achievement	No significant differences in BMI or BMI percentile changes between groups but doing >75 min of exercise per week resulted in significantly less enhancement in BMI
Kipping *et al*., 2010, England[33]	Pilot cluster randomized controlled trial	9-10 years old children	5 months	Nutrition education, increase of PA, decrease of TV viewing	Dietary behaviors	More intake of fruit and vegetable and healthy snacks
Mauriello *et al*., 2010, USA[39]	Randomized, controlled trial	9th, 10th, or 11th grade adolescents	1 year	PA, fruit and vegetable consumption, and limited screen time	BMI	Less overweight children in intervention group
Bürgi *et al*., 2012, Switzerland[40]	Cluster-randomized controlled trial	4-6 years old children	1 year	PA, nutrition, media use and sleep	BMI, aerobic fitness, %BF and WC	Reduction of BF but not BMI and improved fitness
Sevinç *et al*., 2011, Turkey[41]	Field-type intervention	1st-7th grade children	8 months	Groups were randomly divided into PA and nutrition education, nutrition education, and control	BMI	Less BMI increase in intervention groups
Greening *et al*., 2011, USA[42]	Randomized controlled trial	6-10 years old children	9 months	Education about nutrition and PA	Adiposity, nutrition knowledge, dietary habits	A significant decline in BF percentage and improvement in dietary fat intake
Shah *et al*., 2010, India[34]	A school-based intervention program	8-18 years old children	29 months	Education about nutrition, PA, healthy cooking	Knowledge and behavior	Rise in knowledge especially in 8-11 years old children
Muckelbauer *et al*., 2009, Germany[43]	Randomized controlled cluster trial	Second and third grades of elementary schools	10 months	Increase in water consumption by water fountains installation	Body weight and beverage consumption	Decline of overweight relative frequency
Fung *et al*., 2012, Canada[44]	–	Grade 5 students	3 years	Healthy eating and active living strategies	Dietary intake, PA, BMI	Fruit and vegetable intake and PA enhanced, calorie intake declined, children were less obese
Sigmund *et al*., 2012, Czech Republic[45]	Non-randomized longitudinal intervention	6-9 years old children	2 years	PA programs	PA levels, body weight and BMI	1 year later, the odds of being overweight or obese in children was three times lower and these odds declined with the duration of the intervention
Thivel *et al*., 2011, France[46]	Randomized, controlled trial	6-10 years old children	6 months	PA program	BMI, WC, skinfold thickness, cardiorespiratory fitness	No effect on anthropometric measures but improvement in aerobic and anaerobic fitness

(*Continued*)

Table 1: (*Continued*)

Author, year, country	Design	Study participants	Duration of intervention	Type of intervention	Outcome	Results
Plachta-Danielzik *et al*., 2011, Germany[30]	Randomized, controlled trial	6 years old children	1 year	Nutrition education, increase in PA and decrease in TV consumption	BMI-SDS and overweight, %FM and WC, their z-scores, food intake	After 8 years, there were favorable and sustained results on BMI-SDS which were most notable in students of high socioeconomic status families
Bacardí-Gascon *et al*., 2012, Mexico[28]	Quasi-experimental randomized cluster controlled trial	2nd and 3rd grade elementary school children	6 months	Decrease in sedentary behavior, nutrition education	BMI z-score, WC, overweight and obesity prevalence	At 6 months differences were observed in BMI and after 24 months, BMI z-score and WC enhanced and abdominal obesity declined
Foster *et al*., 2008, USA[47]	Randomized controlled cluster trial	4-6th grade school children	2 years	Meal supply, nutrition education, nutrition policy, social marketing, parent outreach	Weight, BMI z scores, dietary intake, PA	50% decline in overweight incidence but not obesity
Plachta-Danielzik *et al*., 2007, Germany[32]	Randomized, controlled trial	6 years old children	1 year	Nutrition education, increase in PA and decrease in TV consumption	BMI percentiles, healthy eating index	Cumulative incidence of overweight after 4 years was less only in children's of high socioeconomic status families
Johnston, 2010 *et al*., Texas[48]	Participants were randomized to either the ILI or SH	10-14 years old adolescents	1 year	Increasing healthy eating and PA using behavioral strategies to individualize the plans which was parent-guided in SH and trainer guide in ILI group	Weight, TSF, zBMI	zBMI and TSF declined more in ILI children after 1 and 2 years
Jiang *et al*., 2007, China[49]	–	7-10 years old children	3 years	Nutrition and PA education for children and parents	Weight, BMI	Obesity and overweigh preponderance declined
Lubans *et al*., 2010, Australia and New Zealand[29]	Multi-component school-based intervention	14-18 years old adolescents	6 months	Sport sessions, PA and nutrition handbooks, interactive seminars, lunch-time activities, leadership sessions, and pedometers for self-monitoring	Weight, BMI	Significant interaction impact on BMI, BMI z-score, and BF at the end of study
Duncan *et al*., 2009, England[50]	Circuit-based training	10-11 years old children	6 weeks	Polymeric type exercises	Body image, BM, BMI	BMI declined significantly
Vissers *et al*., 2008, Belgium[51]	Multidisciplinary school-based lifestyle intervention	16-18 years old adolescents	6 months	Nutrition counseling and active healthy life style	Weight, BMI, WC	Mean weight decline after the study was 2.23 kg
Klein *et al*., 2010, Germany[52]	Low threshold health promotion intervention	4-5 years old children	6 months	Meeting for parents and educator about healthy lifestyle	Body weight, BMI	BMI declined but only in boys
Kang *et al*., 2008, Korea[53]	Two-group pre-test/ post-test design	4-6th grade students	8 weeks	Group education, phone counseling, obesity management points for mothers	Self-control behavior, obesity index, abdominal circumference	Decline in obesity index, abdominal circumference, and BF percent
James *et al*., 2007, England[54]	–	7-11 years old children	1 year	Education about healthy diet and decrease consumption of carbonated beverages or no intervention	Weight, BMI z scores, WC	3 years after the intervention, BMI z-score reduced in intervention group but obesity prevalence extended in both groups
Caballero *et al*., 2003, USA[55]	Randomized, controlled, school-based trial	3-5th grade children	3 years	Change in dietary intake, increase in PA, healthy eating education	Weight, triceps and subscapular skinfold thicknesses, Percentage BF, PA, Knowledge, attitudes, and behavior, dietary intake	No significant changes in anthropometric outcomes

(*Continued*)

Table 1: (*Continued*)

Author, year, country	Design	Study participants	Duration of intervention	Type of intervention	Outcome	Results
Rosado *et al*., 2008, Australia and New Zealand[56]	Randomized clinical trial	6-12 years old children	12 weeks	Four different treatments: 1 serving of RTEC for breakfast or 1 serving of RTEC for breakfast and dinner or 1 serving of RTEC for breakfast plus nutrition education or no intervention	Anthropometry, body composition	Body weight, BMI and total BF fell off significantly in the RTEC and nutrition education group
Spiegel and Foulk, 2006, USA[57]	Multidisciplinary elementary school-based intervention	4th and 5th grade children	1 school year	PA and healthy behavior education	BMI, weight	Significant positive changes in BMI, enhancement of fruit and vegetables consumption and PA
Gleason and Dodd, 2009, USA[58]	Cross-sectional	1st–12th grade children	–	School Breakfast Program and National School Lunch Program	BMI, BMI percentiles, BMI z-scores	Only school breakfast participation was associated with less BMI

ILI = Instructor-led intervention; SH = Self-help; ExO = Exercise only; EdO = Education only; EE = Exercise and education; PA = Physical activity; RTEC = Ready to eat cereal; BMI = Body mass index; TSF = Tricep skinfold; WC = Waist circumference; SDS = Standard deviation score; PBF = Percent body fat; FM = Fat mass; BF = Body fat; BM = Body mass

healthy behaviors, furthermore they are important role models for their children.[60] It is difficult for parents to know and accept that their child has excess weight, and that recommended diets would not have adverse health effect for their children;[61] therefore, they often do not comprehend the necessity of obesity prevention. Families are able to construct children's lifestyle habits, perhaps through their "parenting style" and management of "family functioning."[62] Table 2 shows family-based interventions for management of childhood obesity. As it demonstrates, most of these programs were successful in decreasing body mass index (BMI) z-score and some health consequences of overweight. After participation of parents in these kinds of programs, their children consumed more fiber and were less sedentary. In some cases, significant decrease in fat mass is documented, as well.[63,64] It has shown that low parental confidence predicts dropout rate from family-based behavioral treatment.[65] The main limitation of family-based studies is the small sample size, high dropout rate, no follow-up data, and selection of motivated families.

Clinic-based programs

Table 3 presents a summary of clinic-based weight management programs conducted in the pediatric age group. Although most researchers have tried low calorie-low fat diets for treating obesity, experts have recommended to consider a diet with balanced macronutrients.[14] Nevertheless, different dietary changes have been tried to control excess weight in children and adolescents. High protein (HP) diets seems to make more satiety, but two studies did not confirm their advantage versus standard diets.[90,91]

In studies in which diet, exercise or both of them were taken into account, nutrition plus PA had more effect on anthropometric indices.[99,103,124] One study showed that combination of aerobic and strength training along with diet therapy results in BMI decrease in comparison with strength training plus diet recommendation.[127] A successful experience is reported about the favorable effects of zinc supplementation on anthropometric and metabolic indices.[102,133]

Obesity behavioral therapy has different parts such as motivational interviewing, goal setting, positive reinforcement, monitoring, and cognitive restructuring.[134] Most of behavioral therapies had positive consequences on weight, BMI, or dietary and PA habits.[92,98,107,108,116]

All interventions that consisted of nutrition, exercise, and counseling had significant effects on body weight or other obesity-related factors[84,93,96,100,101,105,109,111-115,117,118,120,128,135] except for a study, which had beneficial effects only on obesity related behaviors.[97] The main limitation of some of these studies is lack of comparison with the control group, and short-term follow-up of participants, and the uncertain sustainability of such kinds of interventions.

DISCUSSION

This review evaluated three different approaches in childhood obesity management. As the design of most studies is a clinical trial, it makes their comparison easier. Schools are a safe place for learning healthy skills and continuing them during life. Most (29/32) of the papers reported a positive effect of school-based intervention on dietary habits or anthropometric measures. One of negative effects of this kind intervention is discrimination resulted from stigmatization. This may persuade them to get involved in healthier lifestyle or might have opposite results. All of the studies conducted in the family setting (n = 26), had favorable results on obesity criteria. Although some of them had negligible effects. Clinic-based intervention had different methods but almost the same results.

Table 2: Family-based studies for controlling childhood obesity

Author, year, country	Design	Study participants	Duration of intervention	Type of intervention	Outcome	Results
Danielsen *et al*., 2013, Norway[66]	Consecutive randomization procedure	7-13 years old children	12 weeks	Cognitive behavioral weight management program	BMI SDS	Mean BMI SDS reduced 0.18 units that was sustained after 12 months follow-up
West *et al*., 2010, Australia[67]	Randomized repeated measures design	4-11 years old children	12 weeks	Increasing parents' skill in managing children behaviors	BMI z-score, weight, lifestyle behavior	BMI z-score and unhealthy behavior were less
Vos *et al*., 2012, Holland[68]	Randomized clinical trial	11-15 years old teenagers	3 months	Nutritional and psychological counseling through CBT	Weight, BMI-SDS	Significant fall in BMI-SDS after the study and 1 year later
Sacher *et al*., 2010, UK[69]	Randomized controlled trial	8-12 years old children	21 weeks	Group educational and PA sessions	Body weight, height, and WC	WC and BMI z-score reduced significantly after the study and 6 months later
Teder *et al*., 2012, Sweden[70]	Single-group pre- and post-intervention feasibility study	8.3-12-years old children	2 years	Education about healthy eating, PA and problem solving	Change in standardized BMI, change in the W/H	Standardized BMI declined with no change in W/H ratio
Edwards *et al*., 2006, UK[71]	Pre- and post-treatment assessment for four consecutive treatment groups	8-13 years old children	6 months	Advice on modify micro environment of home	Change in BMI-SDS, change in percentage of BMI median centile for age, sex and height	Children turned a loss of 8.4% in BMI that was sustained after 3 months
Bean *et al*., 2012, USA[72]	Randomized controlled pilot	6-11 years old children	1 year	Parenting skill and role modeling to improve healthy habits	BMI percentile, dietary records	An increment in children's fiber intake and parents' protein consumption in whereas no impact on children's BMI percentile
Gunnarsdottir *et al*., 2012, Iceland[73]	Epstein's FBBT	7.5-13.6 years old children	18 weeks	Advice on whole family lifestyle change	Height, weight, reports of psychological well-being	BMI-SDS declined particularly in children with clinical range score of social anxiety
Kalavainen *et al*., 2012, Finland[63]	Randomized clinical trial	7-9 years old children	6 months	Interactive functional activities and lectures about healthy lifestyle	BMI, body composition	Weight/height ratio and FM reduced and lean BM increased
Melin and Lenner, 2008, Sweden[74]	–	7 years old children	1 year	Dietary and PA advice and unstructured exercise	Changes in wellbeing, life style and BMI z-score	Mean BMI z-score declined, a good or fair dietary advice adherence was seen in children who their z-score reduced or sustained respectively
Kalavainen *et al*., 2007, Finland[75]	Randomized controlled intervention study	7-9 years old children	6 months	Routine counseling through booklet or family-based group treatment (behavioral and solution-oriented therapy)	Change of weight for height, changes in BMI and BMI-SDS	Group treatment resulted in losing more W/H and less BMI and BMI-SDS, after 6 months, differences between groups still were visible
Hughes *et al*., 2008, Scotland[76]	Randomized, controlled trial	5-11 years old children	6 months	Best-practice behavioral program or standard care (control)	BMI z-score, weight, fat distribution, quality of life, and height z-score	No significant impact on BMI z in intervention group but 12 m after the study, they had significant less weight increment
Avery *et al*., 2012, UK[77]	Family-based group program	11-15 years old adolescents	8 months	Encouragement of whole family for adopting healthier lifestyle habits	Height, weight, BMI z-score	A mean (SD) BMI z-score change of 0.22 units
Looneyand Raynor, 2012, USA[78]	Family-based behavioral pediatric weight management randomized controlled trial	5-9 years old children	6 months	3 treatment: Increase in growth monitoring with feedback, decrease in snack foods and sugar-sweetened beverages, and increase in fruits and vegetables and low fat dairy	Relationship between changes in fruits and vegetables, snack foods, and energy intake	No relationship between fruits, vegetables and snack food intake, reduction in snack food ingestion were significantly associated with less energy intake but increment in fruits and vegetables consumption were not
Garipağaoğlu *et al*., 2009, Turky[79]	Randomized, controlled trial	6-14 years old children	3 months	Induce healthy eating behavior and reduce sedentary habits plus hypocaloric diet through group treatment or individual treatment	Weight, BMI SDS	Significant reduction in BMI-SDS in both groups that was sustained 1 year later in group treatment, significant more fruit and vegetable intake and decline in carbonated beverages drinking in both groups

(*Continued*)

Table 2: (*Continued*)

Author, year, country	Design	Study participants	Duration of intervention	Type of intervention	Outcome	Results
Pinard *et al*., 2012, USA[80]	Mixed quantitative and qualitative pilot study	8-12 years old children	3 months	Parent behavior change, role modeling, home environmental change	Weight, BMI	BMI z-score decreased whereas lean muscle mass increased
Golley *et al*., 2007, Australia[81]	Single-blinded, randomized, controlled trial	6-9 years old children	12 months	3 groups: Parenting-skills training, family lifestyle change, wait-listed control	BMI, and waist-circumference z-score	BMI z-score fell off by 10% in family involved group and 5% in two other groups, WC z-score reduced in treatment groups
Jiang *et al*., 2005, China[82]	Randomized controlled trial	Grade 7-9 school children	2 years	Dietary behavior modification, goal setting, increase in PA	Weight, BMI-SDS	Significant differences in alteration of BMI and BMI-SDS between groups
Stark *et al*., 2011, USA[83]	Pilot randomized controlled trial	2-5 years old children	6 months	Behavioral intervention for increasing healthy eating and activity or enhanced standard care	Weight, BMI z-score and BMI percentile	Significant more decline of BMI z-score percentile and weight which was sustained 1 year later in behavioral treatment program
Skelton *et al*., 2008, USA[84]	–	2-18 years old children	12 months	Cognitive behavioral modification, nutrition and PA education	BMI, BMI z-score	Significant decline in BMI z-score
Papadaki *et al*., 2010, Netherlands, Denmark, United Kingdom, Greece, Germany, Spain, Bulgaria, and Czech Republic[85]	Randomized clinical trial	4-18 years old children	26 weeks	5 ad libitum diets: LP/LGI, LP/HGI, HP/LGI, HP/HGI, control	Weight, BMI	Significant reduction in proportion of overweight to obese children percentage in HP/LGI group
Berkowitz *et al*., 2011, USA[86]	Randomized controlled trial	13-17 years old adolescents	12 months	Meal replacement in life modification program or isocaloric conventional diet	Weight, percentage change in initial BMI	Significant increment in weight loss and BMI decrement in meal replacement group, no difference between groups in BMI change percentage in weight maintenance period
Epstein *et al*., 2008, USA[87]	Randomized controlled trial	8-12 years old children	24 months	Reducing high fat, high sugar foods or increasing healthy food groups	Weight, BMI, zBMI	More decrement in z-BMI that was sustained and greater decline in parents concern about child weight
Duggins *et al*., 2010, USA[88]	Randomized controlled effectiveness trial	5-17 years old children	12 months	Nutrition classes only or YMCA program (exercise) plus nutrition classes	Weight, year change in BMI-for-age percentile	YMCA participants had a mean increment of 0.3 BMI units in comparison with an enhancement of 0.6 BMI units in the other group
Savoye *et al*., 2011, Sweden[64]	Parallel-group, randomized controlled trial	8-16 years old children	12 months	Intensive lifestyle intervention or clinic control group	Weight, BMI, PBF, total BF	Treatment impact was sustained after 24 months in treatment group for BMI z-score, BMI, BF percentage, and total BF mass
Davis *et al*., 2011, USA[89]	–	10 years old children	2 months	Nutrition, exercise, behavior sessions through telemedicine or physician visit	Weight, BMI, BMI percentile	A small change in BMI of both groups

FBBT = Family-based behavioral treatment; CBT = Cognitive behavioral therapy; LP = Low protein; LGI = Low glycemic index; HGI = High glycemic index; HP = High protein; BMI = Body mass index; BF = Body fat; PBF = Percent body fat; SDS = Standard deviation score; W/H = Waist:height ratio; WC = Waist circumference; SD = Standard deviation; PA = Physical activity; FM = Fat mass; BM = Body mass

Table 3: Clinic-based weight control studies for children and adolescents

Author, year, country	Design	Study participants	Duration of intervention	Type of intervention	Outcome	Results
Bauer *et al*., 2010, Netherlands[92]	Clinical trial	7-12 years old children	12 weeks	CBGT and then SMS-based maintenance treatment for 36w	BMI-SDS	Significant decrease of BMI-SDS by 0.20 units during CBGT and the decline of BMI-SDS by 0.07 units during the SMSMT (non-significance)
Knöpfli *et al*., 2008, Switzerland[93]	Multidisciplinary inpatient program	12-15 years old adolescents	12 weeks	Daily PA, low calorie diet, behavior modification	Weight, BF	All attendees dropped off a significant quantity of weight and BF

(*Continued*)

Table 3: (*Continued*)

Author, year, country	Design	Study participants	Duration of intervention	Type of intervention	Outcome	Results
Yackobovitch-Gavan *et al*., 2009, Israel[94]	Randomized clinical trial	6-11 years old children	12 weeks	3 groups: ExO, diet only, and combination of diet and exercise	Weight, BMI, BMI-SDS, body composition	BMI, BMI-SDS and FM decline were significantly higher in the diet including groups
Rezvanian *et al*., 2010, Iran[95]	Randomized, triple masked, placebo-controlled clinical trial	10-16 years old children	12 weeks	4 groups: Metformin, fluoxetine, a combination of the two drugs, or placebo	Weight, BMI, BMI-SDS, WC	BMI reduced significantly in all intervention groups, WC declined significantly in the metformin receivers
Alexy *et al*., 2006, Germany[96]	Clinical trial	5-14 years old children	1 year	PA plus a course on nutrition and behavior therapy in comparison with a longitudinal study	Weight, BMI, BMI-SDS	A significant positive impact on weight, BMI, and BMI SDS and more consumption of carbohydrate and lower fat intake
Taveras *et al*., 2011, USA[97]	Randomized controlled trial	2-6 years old children	1 year	Primary care restructuring for children and motivational interviewing for parents	BMI, obesity related behaviors	Little non-significant BMI change, more decline in screen viewing, a bit more decrease in fast food and sugar-sweetened beverage drinking, significant impacts on girls' BMI and low income families
Bloom *et al*., 2013, Australia[98]	Pilot randomized controlled trial	6-12 years old children	6 weeks	CAAT or a wait-list group	Weight, BMI	Treatment had a significant, short term impact on the BMI and 6 months later, children's BMI did not go up significantly but the difference between basement and follow-up BMI was no more visible
Ben Ounis *et al*., 2009, Tunisia[99]	Clinical trial	12.7-13.9 years old adolescents	2 months	3 groups: Hypocaloric diet program, individualized training program, and hypocaloric diet combined with training program	Weight, waist and hip measures, PBF, and BMI	Weight and FM decline were more significant in the diet combined with training program group
Dreimane *et al*., 2007, USA[100]	Clinical trial	7-17 years old children	12 weeks	Interactive nutrition and exercise sessions with behavior modification	Weight, BMI velocity, BMI, and BMI z-score	BMI, BMI z-score, BMI velocity, and had a reduction along the treatment
Chen *et al*., 2006, USA[101]	Clinical trial	10-17 years old adolescents	2 weeks	Lifestyle modification in children who were placed on a high-fiber, low-fat ad libitum diet plus daily aerobic exercise	Weight, BF percentage, BMI	Significant reduction of body weight and modest decline in BMI and BF percentage
Kelishadi *et al*., 2010, Iran[102]	Triple-masked, randomized, placebo-controlled, crossover trial	60 obese children aged 6-10 years	8 weeks	20 mg of elemental zinc or placebo	BMI z-score	In zinc group the mean weight, BMI, BMI z-score reduced significantly whereas these variables went up in the other group
Lisón *et al*., 2012, Spain[103]	Randomized controlled trial	6-16 years old children	6 months	Hospital clinic group-based (GRX) and home-based (HOX) exercise-Mediterranean diet intervention or a control group	Weight, B, WC	Significant decrement in BF percentage and BMI z-score in all intervention groups and significant decline in WC in HOX
Krebs *et al*., 2010, USA[104]	Randomized clinical trial	12-18 years old adolescents	12 weeks	2 groups: HPLC or low fat diet	BMI z-score	Significant BMI-Z decline in both groups that was significantly more for the HPLC

(*Continued*)

Table 3: (*Continued*)

Author, year, country	Design	Study participants	Duration of intervention	Type of intervention	Outcome	Results
Kirk *et al*., 2012, USA[105]	Randomized controlled trial	7-12 years old children	3 months	3 groups: LC, RGL, or standard PC diet plus weekly dietary counseling and biweekly group exercise	BMI z-score, WC, PBF	Lower BMI z-score in all diet groups which was sustained at 6 months with interchangeable results for BF percentage and WC
Gately *et al*., 2007, UK[91]	Randomized controlled trial	12.3-15.1 years old children	4 weeks	A standard or HP diet group	BMI, BMI-SDS, PBF, FM, FFM, WC	Diet had no additional impact, considering all children together there were significant weight loss, BMI-SD, FM, FFM, BF percentage, and WC
Speroni *et al*., 2008, USA[106]	Pilot hospital-based community program	8-12 years old children	12 weeks	Weekly exercise sessions and three nutrition presentations	BMI, BMI percentile, WC	Average BMI, BMI percentile, and WC decline
Ford *et al*., 2009, Sweden[107]	Randomized controlled trial	9-17 years old children	12 months	A computerized device to reduce speed of eating and total food intake plus standard lifestyle modification therapy	BMI-SDS, BF -SDS, change in portion size and eating speed	Significant less mean BMI SDS, meal size and BF -SDS which the former was sustained 6 months later
Tan-Ting and Llido, 2011, the Philippines[108]	Hospital based multidisciplinary weight loss program	5-17 years old children	3 months	Modification of dietary intake and eating habits, PA increment, and explore eating motivation	Weight, BMI, BMI z-score, WC, BF	BMI z-score, BMI, weight, WC, and BF decline
Kelishadi *et al*., 2012, Iran[109]	Clinical trial	2-18 years old children	24 weeks	Exercise, diet education and behavioral modification	Weight, BMI, WC	All anthropometric measurements mean declined significantly
Satoh *et al*., 2007, Japan[110]	Clinical trial	9.5-12.5 years old children	6 months	MNBC once per month or no intervention	Nutritional balance, BMI	Overweight percentage significantly declined in treatment group and nutritional balance was seen for beans and sugar
Savoye *et al*., 2005, USA[111]	Clinical trial	11-16 years old adolescents	1 year	Nutrition education, exercise and behavioral modification	BMI z-score, BF percent, and self-concept	BMI z-score, BF percentage reduction while self-concept score enhanced
Reinehr *et al*., 2009, Germany[112]	Randomized controlled trial	10-16 years old adolescents	1 year	Lifestyle intervention (suitable diet, PA, behavior therapy)	BMI-SDS, WC	Significant SDS-BMI and WC decrease
Adam *et al*., 2009, Germany[113]	Clinical trial	8-15 years old children	1 year	Inpatient therapy (diet, nutritional education, exercise, behavior therapy) followed by a home-based outpatient treatment (including a structured exercise program)	Weight, BMI-SDS, eating behavior	BMI-SDS reduced significantly and a significant exploratory analyses positive results were seen for behavior changes and weight loss
Nemet *et al*., 2005, Israel[114]	Randomized prospective study	6-16 years old children	3 months	Combined dietary-behavioral- PA intervention	BMI z-score, BMI, weight, dietary and leisure time habits	Significant weight, BMI, and BF percentage decline which was sustained after 1 year
Reinehr *et al*., 2010, Germany[115]	Randomized controlled trial	8-16 years old children	6 months	PA, nutrition education and behavior counseling	BMI, WC, skinfold thickness, BMI-SDS, FM	BMI-SDS of 94% of children in treatment group reduced, similar results were observed for FM, skinfold thickness, and WC
Weigel *et al*., 2008, Germany	Controlled clinical trial	7-15 years old children	1 year	PA, nutrition education and coping strategies	BMI z-score, FM	BMI, BMI z-score, and FM declined
Tsiros *et al*., 2008, Australia[116]	Randomized controlled trial	12-18 years old adolescents	20 weeks	CBT (improving diet and activity habits and teaching strategies to maintain new health behaviors)	Body composition, hip and WC, weight, BMI	Significant decline in FM, BM, I weight, hip circumference, and abdominal fat in treatment group

(*Continued*)

Table 3: (*Continued*)

Author, year, country	Design	Study participants	Duration of intervention	Type of intervention	Outcome	Results
Murer *et al*., 2011, Switzerland[117]	Multidisciplinary weight-loss program	12-16 years old adolescents	2 months	Moderate calorie restriction, daily PA, and a behavior modification	Weight, BMI, BF	14.8% and 22.8% loss of body weight and FM respectively
Lofrano-Prado *et al*., 2009, Brazil[118]	Multidisciplinary lifestyle therapy	13-19 years old adolescents	24 weeks	Medical, dietary, exercise and psychological programs	Weight, BMI, body composition	Significant decline in BMI, FM, and BM without any changes after the end of study except for girls' FM
Fajcsak *et al*., 2008, Hungary[119]	Pilot clinical trial	10-12 years old children	6 weeks	Replacement of at least 50% of the HGI foods with LGI foods plus weekly nutrition counseling	Anthropometric and body composition measures	Unchanged body weight and BMI score but significant decrease in % BF, non-significant reduction in FM, increase in muscle mass and FFM
Kelishadi *et al*., 2009, Iran[120]	Clinical randomized trial	5-6 years old children	6 months	3 groups: Isocaloric DR, caloric restricted regimen, no recommendation education sessions about healthy lifestyle for all groups	BMI-SDS, WC, PBF	BMI-SDS and WC declined significantly in all participants, 3 years later, mean WC increased less in DR group and BF percentage had a significant decrement in all groups but kept on lower than the baseline measurements
Rosado *et al*., 2008, Mexico[56]	Randomized controlled trial	6-12 years old children	12 weeks	4 treatments: One serving of RTEC at breakfast, 2 servings of RTEC at breakfast and dinner, one serving of RTEC plus a nutrition education guide, no treatment	Weight, body composition	Only RTEC + nutrition education group had no weight increment, they also revealed an unadjusted decline of total BF
Mohn *et al*., 2005, Italy[121]	Prospective/ longitudinal study	7.6-10.7 years old children	6 months	Hypocaloric diet	BMI, WHR, FM	Along the treatment period, a significant reduction in FM, WHR, and BMI were seen which enhanced again during the follow-up period
St-Onge *et al*., 2009, USA[122]	Randomized clinical trial	8-10 years old children	16 weeks	High or low milk consumption plus dietary counseling on healthy eating for both groups	Weight, BMI, body composition	Pediatrics' height and weight in all participants enhanced, because of that there was a trend toward BMI decline
Duckworth *et al*., 2009, UK[90]	Randomized clinical trial	9-18 years old children	1 month	SP diet or HP diet in a camp	Body composition, BMI-SDS score	Significant changes of all measures over time except for lean BM and no significant impact of diet group on any body composition or anthropometric values
Kelishadi *et al*., 2008, Iran[123]	Randomized clinical trial	12-18 years old children	6 weeks	Aerobic PA plus dietary advice	Weight, waist and hip circumferences, BMI and BMI-SDS	BF percentage, BMI, and WC declined
Ribeiro *et al*., 2005, Brazil[124]	Randomized clinical trial	8-12 years old children	4 months	Hypocaloric diet or hypocaloric diet plus exercise training	Weight, BMI and z-score	Diet + exercise training showed a significant decline in weight, BMI z-score, and BMI
Woo *et al*., 2004, China[125]	Randomized clinical trial	9-12 years old children	6 weeks	Dietary modification only or diet plus a supervised structured exercise program	Weight, BF content, WHR	WHR decreased in all children whereas there was no significant changes in BF, lean BM, and BMI

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Table 3: (*Continued*)

Author, year, country	Design	Study participants	Duration of intervention	Type of intervention	Outcome	Results
Togashi *et al*., 2002, Japan[126]	Clinical trial	6-15 years old children	–	Children had to consume 75-80% of the energy requirement for their age at 5:2:3 ratios from carbohydrate, protein and fat along with mild-intensity exercises and improve their eating habits	Weight, RW	After 1.0±0.9 years of follow-up mean RW had a significant decrement
Nemet *et al*., 2005, Israel[114]	Randomized controlled trial	6-16 years old children	3 months	Combined dietary and exercise program OR control	Weight, BMI percentile, triceps and subscapular skinfold, PBF	Significant decline in BF percentage, weight, and BMI in treatemnt group
Davis *et al*., 2009,[127]	Pilot of a randomized controlled trial	14-18 years old girls	16 weeks	3 intervention groups: Control, nutrition only, and a N + ST, N + CAST	Weight, BMI, BMI z-score, body composition	Significant impact of intervention on BMI, BMI z-scores, weight, and total BF along a 3% decline in the N + CAST group compared with a 3% increment in the N + ST group
Madsen *et al*., 2009, USA[128]	Randomized clinical trial	8-19 years old children	12 weeks	Watch lifestyle intervention after a low glycemic load diet	BMI z-score	Children who had lower weight at baseline, had also more BMI z-score reductions
Kelishadi *et al*., 2010, Iran[129]	Clinical trial	12-16 years adolescents POMA or POMN	2 months	Lifestyle modification (exercise, diet education and behavior modification)	WC, weight, bmi, triceps skinfold	BMI and WC declined in obese pediatrics whereas mean BF mass declined in all participants
Skelton *et al*., 2008[84]	Clinical trial	2-18 years old children	–	Cognitive behavioral modification, nutrition and PA education, training, and support	BMI, BMI z-score	No changes in median BMI, and a significantly enhancement in mean BMI whereas a significant decline of BMI z-score
Ventura *et al*., 2009, USA[130]	Randomized control trial	Grades 9 through 12 children	16 weeks	3 groups: Control, nutrition-only group (decrease in added sugar consumption and an increase in fiber consumption) or N + ST group	Weight, BMI, BMI percentiles, whole BF, soft lean tissue	Consumption of more fiber had a significant relationship with BMI and visceral fat decline
Gately *et al*., 2005, UK[131]	Summer residential weight-loss camp	9-18 years old children	6 weeks	A daily schedule of six 1-h, skill-based, fun, PA sessions, moderate dietary restriction, and group-based educational sessions	Weight, BMI, BMI SDS, WC, hip circumference	Children's BF, BM, BMI SDS, and waist and hip circumferences declined in camp
Waling *et al*., 2010, Sweden[132]	Randomized, open trial	9-12 years old children	1 year	Group sessions about food and PA or no intervention	Energy intake, macronutrients and refined sugar intake	Energy intake declined significantly in both groups, in the treatment group, 11% reduction in energy intake relative to TEE and an increment in sucrose intake was seen, fat intake enhanced and carbohydrate intake reduced in control group

POMA = Phenotypically obese metabolically abnormal; POMN = Phenotypically obese metabolically normal; N + CAST = Nutrition and combination of aerobic and strength training; N + ST = Nutrition plus strength training; HP = High-protein; RTEC = Ready to eat cereal; LGI = Low glycemic index; HGI = High glycemic index; CBT = Cognitive behavioral therapy; MNBC = Model nutritional balance chart; PC = Portion controlled; RGL = Reduced glycemic load; LC = Low-CHO; HPLC = High protein, low carbohydrate diet; CAAT = Children's appetite awareness training; CBGT = Cognitive behavioral group treatment; BMI = Body mass index; SDS = Standard deviation score; TEE = Total energy expenditure; BF = Body fat; WC = Waist circumference; PBF=Percent of body fat; FM = Fat mass; FFM = Fat free mass; WHR = Waist-to-hip ratio; RW = Relative weight; DR=Dairy-rich diet; BM = Body mass; PA = Physical activity; SP = Standard protein; SMSMT = Short message service based maintenance treatment; ExO = Exercise only

Some studies had no effects on anthropometric index. However, they had resulted in dietary habits or physical fitness improvement.[35,36,46,55,72,97,78,132] One explanation for this can be self-reported dietary intake and PA data. On the other words, children may not pay attention to the instruction they were given.

Teachers can train students how to choose nutritious and low-calorie foods. In addition, exercise training can be reinforced in the school curriculum.[14] Most students with excess weight prefer to eat fatty, sweetened, and salty snacks; they also choose fast foods as their first meal preference. If attendants get involved in obesity prevention programs, they can provide an environment for children to purchase healthy snacks and foods. Families can also make a circumstance which facilitates dietary and behavioral changes. Furthermore, if parents recognize the importance of weight control, they will be motivated to persuade their children for weight control. Families, especially mothers, are the best paradigm for children to learn a healthful eating pattern and activity habits.[136] Through family meals, children can eat more whole grains, fruits, vegetables, low fat milk, and consume less sweets and unhealthy fats. Parents should involve kids in preparing food to make a positive effect on their attitudes toward obesity prevention. It seems that the family has a key role in long-term weight control.[71] It has been shown that if family confidence is low, rate of dropout from weight loss programs will increase.[65] In this regard, providing parenting styles and skills as well as child management strategies are really critical.[81,137] Principally clinic-setting programs have brought nutrition, PA, and education or counseling together to achieve their goals and they have demonstrated long lasting results.[138] Most experts advise a low calorie low fat diet for obesity management; but they may have side-effects such as binge eating.[139] Actually weight loss is allowed in severe obesity and in other cases weight maintenance is an appropriate policy.[114] Some studies recommend HP or low carbohydrate diets because they cause more satiety.[140] A review article revealed that low carbohydrate *ad libitum* diets are as effective as calorie restricted diets.[140] In addition, a Cochrane review showed that low fat diets have no extra advantages in comparison with other diets with calorie restriction.[141] Another review article revealed moderate effect of exercise on adiposity and not on BMI.[142] Clearly, PA is efficient when lasts for more than 60 min, is moderate to vigorous, and is done in all weekdays.[134] As low calorie diets are harmful for growth, and complying with them is difficult, some studies suggested that vigorous exercise can be a suitable substitute for diet therapy.[137,139] As always emphasized, to be effective, PA should be considered as an enjoyable fun, and should be integrated into daily lifestyle. Obesity causes mental problems in children and adolescents,[118] so behavior therapy seems to be vital. It sounds that group treatment is more successful than individual ones;[75,79] specifically when parents are engaged. Counselors should persuade children and adolescents to eat breakfast, to have structured meal plan to increase consumption of fruits, vegetables, and family meals, as well as to decrease the intake of sweetened beverages, calorie-dense foods, and eating out, as well as reducing the sedentary behaviors and the screen time.[14,91] Counselors also need to teach families about healthy shopping and cooking habits. Unfortunately, most studies did not show favorable effects, many of them had small sample sizes or had short-term follow-up or lacked of the control group. Managing extra group support sessions or using technologies such as E-mail or SMS for monitoring weight losers can be a good idea.[63,92,143]

CONCLUSION

The findings suggest that among different types of interventional programs for management of childhood obesity, a multidisciplinary approach in schools in which children's family are involved, can be the most feasible and effective approach. As teachers and parents are the best role models, it will be easier to accustom children with healthy dietary, PA, and behavioral habits. Future studies are needed to determine the long-term effects and sustainability of different programs.

AUTHORS' CONTRIBUTION

FAS contributed in the conception of the work, conducting the review, revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work. RK contributed in the conception and design of the work, drafting and revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work.

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