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Review Article

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Obesity Prevention Programs in Children: The Most Effective Settings and Components. A Literature Review

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Abstract

Overweight and obesity are now the most common childhood disorders in Europe. These disorders can cause social, psychological and physiological health problems in childhood and are linked to obesity and poor health outcomes later in life. The present review will examine the importance of the preventive intervention setting; including family based programmes, primary care settings, community settings and primary schools. The review also identifies the most effective components of obesity prevention interventions designed for children, including healthy eating and physical activity (PA). Evidence suggests that out of all the intervention settings, obesity prevention programmes are the most successful when delivered in the primary school setting. Furthermore, there is strong evidence to show that combined dietary and PA interventions are the most effective components to include in such strategies but these programmes tend to be delivered over short time frames. Definite conclusions as to the effectiveness of such programmes at preventing overweight and/or obesity are therefore not available. Without long-term delivery of these interventions, overweight, obesity and unhealthy behaviours are at risk of continuing, which could have both immediate and long term health implications.

Keywords

Obesity prevention, Ireland, Primary school children, Intervention

Introduction

Overweight and obesity are now the most common childhood disorders in Europe [1]. These disorders can cause social, psychological and physiological health problems in youth and are linked to obesity and poor health outcomes later in life [2]. In 2016, the WHO [3] estimated that 41 million children aged 0-5 years were overweight or obese, this figure has increased from 4.2% in 1990 and based on current trends, is estimated to increase further to 9.1% by 2020. The prevalence of overweight and obesity among children and adolescents aged 5-19 has also increased considerably from just 4% in 1975 to over 18% in 2016 [3]. Previous Irish statistics have shown that an alarming 19% of nine year olds were overweight and a further 7% obese [4] and environmental and lifestyle factors, specifically poor diet, physical inactivity and sedentary behaviour, are recognised as the primary drivers of the condition [5]. Furthermore, the WHO have recently predicted that Ireland will become the most overweight WHO nation by the year 2030 [6].

Childhood obesity has significant adverse effects on health; both short-term and long-term [7]. Physical health consequences include sleep-disordered breathing and asthma, orthopaedic problems, fatty liver disease, type 2 diabetes

and cardiovascular risk factors, including hypertension [8]. Complications related to obesity are not only physical but also psychological and social, with such problems including depression, anxiety, stigmatisation, discrimination and body dissatisfaction [8] all reported. In addition to the many serious health impacts, obesity also has a significant negative economic impact, costing the Irish state an estimated 1.13 billion euro [9] in 2009.

In order to change the habitual activities of children across the nation, healthcare research needs to be translated into practice [10]. Families, primary-care, schools and communities represent important settings for obesity prevention efforts in children. Effectively preventing obesity in childhood may also prevent the onset of adult obesity and reduce chronic disease [11]. The present review will examine the importance of the preventive intervention setting; including family based programmes, primary care settings, community settings and primary schools. It will also identify the most effective components of obesity prevention interventions designed for children.

In October 2014, a computer search was conducted through MEDLINE, Google Scholar, Cochrane Library, Elsevier and CIT's online journal databases using the key terms "obesity," "overweight" and "children," "prevention," "intervention," "Ireland," "primary school," "primary care," "community" and "family". Inclusion criteria included studies that assessed obesity prevention intervention for primary school children, five to twelve years of age, where data was collected between 1995 and 2014. Additional articles were identified by searching each article's reference section and CIT's database and included studies from America, the UK, Australia, Europe and Ireland. These searches yielded a total of twenty eight articles that were included in the present analysis.

Obesity Prevention Intervention Settings

Family based settings

Families have the ability to influence and shape child behaviours on a daily basis. Therefore, experts suggest that family involvement in the prevention of childhood obesity may provide greater behaviour changes and sustainable weight loss over time compared to interventions without parental involvement [12]; as does overall support from family and friends [13]. Family based settings include the child and atleast one family member, usually a parent, participating in the intervention with the child. Engaging parents in childhood obesity prevention programmes may make weight loss easier for children, with evidence suggesting parents help their children to choose healthy behaviours and are important role models for their children [14]. Although the family unit is seen as one of the major influences in shaping children's eating and PA patterns, evidence-based strategies for engaging parents in obesity prevention efforts are lacking [15]. Such strategies may include family-based education programmes, which teach parents how to provide a positive food environment for their children [16]. However, there is conflicting evidence surrounding the success of family-based interventions and few studies have addressed the effectiveness of these approaches and their potential to influence a parent's ability to improve children's dietary intake [17].

Evidence from Gruber and Haldeman [18] suggests family-based intervention programmes are one of the most successful methods for obesity prevention. Contrastingly, Showell et al., argues that family-based obesity prevention studies fail to demonstrate a significant effect on weight outcomes [19] and have limited effects on anthropometric and metabolic outcomes [20]. Little evidence exists for solely family-based interventions, therefore a total of five papers are selected for inclusion in this review [21-25]. All studies were randomised control trials (RCTs), and reported on either a diet intervention (n = 3) or a combined diet and PA intervention (n = 2). None of the five studies detected a statistically significant beneficial effect of intervention on body mass index (BMI) or other weight outcomes; including percentage body fat, waist circumference and skinfold thickness. However, positive effects were seen in some eating behaviours (increased fruit and vegetable consumption [21,22,25], increased nutrient intake [23, 24] and a reduction in sweets consumed [21, 22]. In the study by French et al. [22], households were targeted over a 12 month period to try and increase fruit and vegetable consumption, decrease portion size and limit high calorie snacks and takeaways. Intervention components included researcher led group sessions (6 x 2 hour sessions on education and PA) and a television locking device. Results revealed significant declines in television viewing, snacks/sweets intake, and dollars per person spent eating out. The study by Lappe et al., was designed to determine whether calcium-rich diets cause excessive weight gain in 9 year old girls [23]. In total, 59 girls were randomly assigned to either a calcium-rich diet, supplying at least 1,500 mg of calcium per day, or asked to continue consuming their usual diet. Reported findings showed that a calcium-rich diet significantly improved overall nutrient intake; with increases in intakes of protein, vitamins A and D and magnesium also evident. There were, however, no reported differences in body mass, fat mass or BMI (ibid).

Epstein et al., targeted parents and children by instructing them to either increase their fruit and vegetable intake or decrease their intake of high-fat/high-sugar foods [21]. The intervention was reported to significantly increase fruit and vegetable intake (high nutrient density foods) while also decreasing children's consumption of high-fat/high-sugar (low nutrient density) foods. The intervention also prevented increases in the percentage of overweight children [21]. Thompson et al., explored the viability of an eight week, internet-based obesity prevention programme as an effective channel for promoting healthy diet and physical activity behaviours in the home setting among 73 African American girls, aged 8-10 years [25]. Although no significant effect was observed on BMI, statistically significant increases were observed in fruit, vegetable and juice consumption and PA [25]. In the study by Paineau et al. [24], participants were assigned to either a control (n = 394) or to one of two intervention groups. Participants from the intervention groups were educated on either (i) reducing fat or increasing complex carbohydrate intake (n = 280) or (ii) reducing both fat and

sugar intake, whilst also increasing complex carbohydrate intake (n = 275). Both groups received monthly family dietary phone counselling by a trained dietician and internet-based monitoring for eight consecutive months. Compared with the control group, the intervention groups reduced their total fat intake to < 35% of total energy intake and reduced their total sugar intake (by 25%) compared to their initial intake. The intervention groups also increased their intake of complex carbohydrate to > 50% of total energy intake and these changes in turn reduced their overall energy intake and improved macronutrient intake close to those recommended. However, the intervention had no effect on children's BMI, fat mass or body weight (ibid).

Findings therefore suggest that, despite the clear importance of family involvement, family-based interventions are not effective in preventing obesity but can be successful in altering eating patterns. Engaging and supporting parents is an essential part of the approach to promoting healthy weight and lifestyle behaviours in children but parents can be a difficult group to engage [26]. The time commitment required of parents to attend educational sessions is frequently cited as a barrier for this type of intervention, often resulting in lower recruitment and higher attrition rates [27, 28]. To overcome some of these barriers, a review by Li et al., suggests employing methods that are more convenient for parents, such as online learning and social media platforms [29] however a lack of computer literacy may serve as an additional barrier [30].

Primary care based setting

Primary care based interventions refer to children attending medical professionals in a clinical setting. The primary care setting offers the opportunity to influence children and parents, encourage healthy lifestyle behaviours and improve weight status (through interventions) among children [31]. Paediatric primary care is regarded as an important setting for obesity prevention efforts as medical professionals often follow children over their entire childhood and adolescence, allowing the potential for long-term efforts and follow-up [32]. However, the majority of published studies in primary care focus on obesity treatment, rather than prevention, and there is a distinct lack of research in the area aimed at primary school children [33]. In fact, a review of primary care childhood obesity prevention and treatment interventions by Seburg et al., found out of 18 included studies, all studies were designed to treat, not prevent, obesity [34]. Primary care settings as a preventive intervention, are a more common setting for younger children who haven't yet started primary school [35-37] as medical professionals often have regular contact with children at this age.

Due to the lack of research amongst primary school children in this setting, only two completed studies of primary care based interventions are included in this review. The PACE+ (Patient-centred Assessment and Counselling for Exercise + Nutrition) study included 878 participants, aged 11-15 year olds [38]. Subjects assigned to the intervention group took part in a computer-assisted diet and PA assessment followed by counselling in a primary care setting, which was followed by 12 months of mail and telephone counselling. Compared with the control group, girls and boys in the nutrition and PA intervention increased servings of fruits and vegetables, decreased their consumption of saturated fat and increased their participation in PA, while also reducing sedentary behaviours. However, no between-group differences were seen in BMI [38], which is consistent with findings from other family-based interventions [22, 25]. The Maine Youth Overweight Collaborative (MYOC) programme study's primary aim was to evaluate the impact of a brief primary-care-based intervention on BMI-z score for healthy, overweight and obese children [39]. The healthcare provider delivered the '5,2,1,0' healthy habits message (five servings or more of fruit and vegetables; 2 hours or less of screen time; 1 hour or more of PA; and zero sugar-sweetened beverages [SSBs] daily) during one well-child visit. Children attended well-child visits, from birth to age 21, which included a complete physical exam and parents were provided with information on strategies to improve care, prevent health problems and help keep their child healthy [40]. Results showed no impact of the intervention on BMI *z*-score for participants aged 5-18 years, in the healthy weight (50^{th}-85^{th} percentile, n = 506) or overweight (85^{th}-95^{th} percentile, n = 216) categories. A shortcoming of this intervention, was its duration; one, 4-6 minute visit is unlikely, on its own, to improve BMI [39].

Two further studies (i) the Healthy Homes/Healthy Kids (HHHK) [33] and (ii) e-health tool [41], are still ongoing and are also aiming to prevent obesity by improving nutrient intake and increasing PA. The goal of the HHHK is to evaluate the efficacy of a relatively low-cost primary care-based obesity prevention intervention aimed at 5 to 10 year old children who are at risk of obesity [33]. This intervention combined brief counselling with a paediatric primary care provider and follow-up telephone coaching that supported parents in making changes at home to support healthful eating, activity patterns, and body weight. To date, no findings have been published for this study.

The Avis et al., study designed a technology-based application, using the SBIRT approach (Screening, Brief Intervention, and Referral to Treatment) [41]. The application was designed for use in a primary-care setting for children aged 5-17 years, to enhance parents support for children's healthy lifestyle behaviours and encourage the use of online resources and community services for childhood obesity prevention. The widespread use and availability of the internet highlights its potential value as a vehicle to deliver obesity prevention interventions [42]. The SBIRT can also guide parents of children with unhealthy weights to access information and health services to improve their children's weight status and associated health risks [41]. Overall, findings from this project will examine the effectiveness of the SBIRT intervention across primary care-based settings. There are also no results currently published for this study.

Interventions to prevent obesity need to be accessible, affordable, and scalable in order to reach a large target audience yet clinic based interventions are often not feasible because of barriers associated with accessibility, transportation, and cost [43]. Similar to the family-based programmes, primary care based obesity prevention programmes do not show support

for changes to BMI, however there is a need for more research [44]. While primary care setting interventions alone may not be sufficient to prevent obesity, they represent an important place where messages to improve nutrition and PA can create awareness and motivate change that can be reinforced across community sectors in a powerful way [45]. More effective primary care interventions embedded in broader multisector approaches including families, schools and communities, with the potential to significantly improve BMI, need to be developed [39].

Community settings

Community-based interventions are usually included as part of a school-based intervention, with few interventions being implemented in the community alone. The Be Active Eat Well (BAEW) was a three year, community-based obesity prevention intervention in primary school children aged 4-12 years, that used a multi-strategy (promoting healthy eating and PA) and multi-setting (community and household) approach [46]. The findings show that the intervention was successful in modestly slowing unhealthy weight gain (by about 1 kg) and waist gain (by about 3 cm) in children, however, the changes were still not of sufficient magnitude to reduce the incidence of overweight or obesity [46]. Although mean BMI changes were modest, community-based interventions need to continue monitoring obesity promoting influences and behaviours, as small individual changes may result in large population effects [47].

In contrast to the above evidence, a systematic review by Wang et al., concluded that interventions implemented in the community alone fail to produce significant effects [48]. Yet, this review went on to further state that community-based interventions that included a school component were more successful in preventing obesity [48]. Two community-based interventions that also included a school component [49, 50] significantly decreased BMI *z*-score in children. Based primarily in the community, the Healthy Living Cambridge Kids [49] (HLCK) (n = 1858) and Shape UP Somerville [50] (SUS) (n = 1178) also targeted the school, family and individuals and included city policies and community awareness campaigns to promote healthy eating and active living for 5-11 year olds. These studies both used collaborative community-based participatory research (CBPR) initiatives, with members of the community participating in all aspects of the research. The HLCK intervention resulted in a significant decrease in mean BMI *z*-scores ($p < 0.001$), and a significant decline in prevalence of obesity, from 20.2 to 18.0% ($p < 0.05$), and SUS also reported a significant decrease in BMI *z*-score ($p = 0.001$). These results highlight the importance of both community and school resources in influencing body mass changes in children. This emphasises the importance of the community as part of a multiple setting intervention, including schools, in reducing childhood overweight and obesity, more so than single-component interventions located in the community alone [51]. The review by Wang et al., [48] supports recommendations made by the WHO [52] that encourage community-based interventions to be included as part of multi-component interventions, applied across multiple settings and tailored to the local environment.

Primary School Setting

The school environment has the potential to make important differences in children's health and presents a number of opportunities for intervention [53-56]. For this reason, primary schools have been a popular setting for the implementation of interventions as they offer continuous, intensive contact with children and the school infrastructure, policies, curriculum and teachers have the potential to positively influence the health of a child [57]. Children spend approximately six hours per day at school and its setting allows large numbers of children to take part in an intervention at any given time [58]. The importance of targeting ecological domains (including the built environment and community) beyond the individual has also previously been highlighted [5, 59, 60].

Schools have an important role in the prevention of childhood obesity however there are a number of considerations when designing school based interventions [61]. Waters et al., suggests that for interventions to be successful, they have to be integrated into the school curriculum, include both healthy eating and PA, and provide support for teachers and parents [2]. Some of the most successful school-based interventions, have included a parenting component, whereby parents are involved in the intervention via newsletters, workshops and homework [62-65]. These interventions have resulted in positive changes in diet, PA and BMI [66]. An example of a successful school based, parent involvement intervention is the Child and Adolescent Trial for Cardiovascular Health (CATCH) programme [67]. This was delivered to low income elementary school children, primarily Hispanic, and included a family component with activity packs that students took home to complete with their parents and participation in 'family fun nights' at the school. This parental component supplemented the classroom curriculum and the intervention reduced overweight, or the risk of overweight among both boys and girls [67]. Similarly, the HEALTH-E-PALS intervention was a school-based programme to promote healthy eating and PA in children aged 9-11 years [68]. It included 12 classroom sessions, a family programme and changes in food provided by school shops and lunch boxes. HEALTH-E-PALS increased students' nutritional knowledge and decreased their purchase and consumption of high-energy snacks and beverages, however there were no changes in PA or BMI post intervention [68].

Research from a systematic review of 32 studies, with over 52,000 participants, reported that school-based interventions demonstrate more convincing evidence of their effectiveness in reducing BMI than primary care and home-based settings [69]. Research also shows that school-based interventions that are greater than 12 months in duration are more likely to be successful as they become embedded in the curriculum and in the behaviours of the school and parents [70]. Guerra et al., also report that interventions longer than six months in duration and those that include parental involvement were identified as the most effective [71]. However, the implementation of

long-term interventions in most school districts may not be economically feasible [72].

The WHO's Health Promoting Schools (HPS) framework recognises the importance of the school environment in encouraging healthy behaviours and combatting obesity [73]. The HPS framework promotes health in schools and addresses the whole school environment, including the curriculum, physical environment, policies and engaging with families and the wider community [74]. The HPS framework has been shown to increase PA, fitness and fruit and vegetable intake in school students [73] and supportive partnerships between researchers, schools and families is crucial to the success of these programmes [73]. Overall, there is sufficient evidence to support the idea that combined healthy eating and PA interventions implemented in schools prevent obesity [48].

Evidence suggests that of all the intervention settings, obesity prevention programmes are the most successful when delivered in the primary school setting. Individual components of school-based obesity interventions will be discussed in more detail below.

Table 1: Summary of primary school based interventions to promote healthy eating.

Study Reference, Country	Intervention Title (if available)	Study Design	Aims	Effect of Intervention
Anderson et al. (2005) [88] Scotland		• RCT • One academic year • Two primary schools • N = 129 participants, Age 6-7, 10-11 years • Provided FV and nutrition education materials	• To increase FV consumption. • To assess impact of whole school intervention.	• Increased fruit intake by 50 g/day*. • No increase in vegetable consumption. • Improved participant's knowledge about FV.
Laurence et al. (2007) [89] Australia	The Fresh Kids	• Interrupted time series design • Two year period • Four primary schools • N = 691 participants, Age 6-12 years • Followed the WHO HPS framework • Periodic lunch box audit	• To assess the effectiveness of the HPS framework to increase FV and water consumption. • To reduce risk factors associated with childhood obesity.	• Increase in the proportion of children bringing fresh fruit (25-50%)*. • 45% increase in the proportion of children bringing water (15-60%)*. • Decrease of between 8 and 38% in the proportion of children bringing sweet drinks*. • Sustained results 2 years post-intervention.
James et al. (2007) [91] UK	Christchurch obesity prevention programme (CHOPPS)	• RCT • One year intervention • Six primary schools • N = 644 participants, Age 7-11 years • 4 x 1 hour nutrition education sessions	• To reduce consumption of carbonated drinks. • To increase water consumption.	• O/w and obesity increased by 7.5% in control group. • O/w and obesity decreased by 0.2% in the intervention group*.
Te Velde et al. (2008) [87] Norway, Spain & the Netherlands	The Pro children intervention	• RCT • One year intervention • Sixty-two schools • N = 1472 participants, Age 10-11 years • Followed WHO HPS framework, targeting the curriculum, environment and family/community	• To increase knowledge/awareness of healthy eating. • To increase FV consumption. • To increase FV availability at home.	• FV intake increased by 20%*. • 2 year follow up effect only remained in Norway.
Foster et al. (2008) [92] USA	Nutrition Policy	• 2 years • Age 9-12 years • N = 1349 participants • Nutrition Policy and education through curriculum, parent education meetings and nutrition workshops.	• To improve the school food environment and dietary intake.	• 50% reduction in the incidence of o/w*. • Significantly fewer children in the intervention schools (7.5%) than in the control schools (14.9%) became overweight after 2 years*.
Evans et al. (2013) [90] UK	Project Tomato	• RCT • 10 months • 54 primary schools • Age 7-8 years • N = 65812 participants • Lesson plans for teachers	• To increase FV consumption.	• No increase in FV consumption.
Viggiano et al. (2015) [93] Italy	Kaledo	• RCT • 20 week intervention • 20 schools • N = 3110 participants, Age 9-19 years	• To test efficacy of Kaledo, a board game, developed to increase nutritional knowledge and improve dietary behaviour.	• Improved nutrition knowledge. • Improved dietary behaviour. • Positive effect on the BMI z-score*.

*Asterisk denotes statistical significance at $p < 0.05$, ** denotes significance at $p < 0.01$, O/w = overweight.

Components of School-Based Obesity Prevention Interventions

Healthy eating

Balanced nutrition and the promotion of healthier eating habits are key to addressing the problem of overweight and obesity in children [75]. In addition, whilst chronic disease tends to emerge in adulthood, disease precursors and behaviour patterns are established during childhood [76]. Both national [77] and international evidence [74] suggests that obese children are more likely to become obese adults, suggesting that surveillance and promotion of health behaviours should start early in life [76].

It is well established that eating a diet rich in fruit and vegetables has numerous health benefits [78] including helping to maintain healthy blood pressure, lowering blood cholesterol levels and lowering the risk of heart disease [79] due to these foods having high concentrations of fibre, vitamins, minerals and antioxidants [80]. There is also growing evidence that fruit and vegetable consumption in children may protect against a range of childhood illnesses [3]. The role of fruit and vegetables in combatting overweight and obesity is related to their low energy density, high dietary fibre content, and associated high satiety effect [81]. Fruit and vegetables are important sources of a wide range of vital micronutrients, yet, in Ireland, the National Children's Food Survey (NCFS) highlighted low fruit and vegetable intakes among children aged 5-12 years, with only 10% of children meeting the WHO guideline [82]. Such eating habits are likely to contribute to the rising levels of childhood obesity [83].

Healthy packed lunches are one way of increasing children's fruit and vegetable intake and ensuring recommended nutrient intakes are met. The need to improve the quality of food brought to school is particularly evident, given UK research indicating that primary school packed lunches often consist of foods that are high in fat, sugar and sodium [84]. Similar findings were reported in Ireland whereby a study in children aged 5-12 years [85] found higher than recommended intakes of fat, saturated fat, salt and added sugars in school lunch boxes. On a population level, the eating habits of Irish people have changed, with homemade nutritious food frequently being replaced with convenient foods that are high in fat, calories and sugar [75], thus reinforcing the need for a nutrition component to be included in obesity interventions for children. These interventions aimed at improving the diet of Irish children must also focus on changing parents' behaviour so that parents provide healthy foods in their child's lunchbox [86].

Table 1 outlines studies that aimed to improve healthy eating in primary school children. The majority of studies focused on increasing fruit and vegetable consumption. The Pro-children intervention [87] reported an increase in both fruit and vegetables by 20%, while Anderson et al., reported an increase in fruit consumption by 50 g but no increase in the amount of vegetables eaten [88]. The Fresh Kids intervention in Australia [89] increased the proportion of children bringing fruit (post-intervention 25-50%) and water (15-60% post-intervention) to school and also decreased the proportion of children bringing sweet drinks (ranging between 8-38%). However, Project Tomato [90], after implementing 12 healthy eating lessons, found no increase in fruit and vegetable consumption. Differences in the strategies used, duration and implementation of the intervention may have influenced the effectiveness of these programmes.

Three of the studies included reported a positive effect on weight outcome [91-93]. The Christchurch Obesity Prevention Programme (CHOPPS) aimed to reduce the amount of carbonated beverages consumed [91]. Significant differences in the proportion of overweight children in the control (7.5% increase) versus intervention groups was found after the 12 month intervention, however, two years after the completion of the study, this difference was no longer significant [91]. Similarly, 'Kaledo', a board game, developed for health promotion delivery in school, improved nutrition knowledge and dietary behaviour over 6 months (once per week for 20 weeks). The intervention also resulted in a positive effect on the BMI z-score (0.34) in the intervention group compared to the control group (0.58) after eighteen months [93]. Likewise, a school nutrition policy intervention [92] aimed to improve the school food environment and dietary intake of primary school children and resulted in a 50% reduction in the incidence of overweight, with significantly fewer children in the intervention (7.5%) versus control schools (14.9%) being overweight after 2 years. These three studies support the evidence for including a healthy eating component in school-based interventions aimed at preventing obesity.

A healthy eating component may improve nutrition and increase fruit and vegetable consumption however, the strength of evidence is low that school-based healthy eating interventions prevent obesity and overweight in children, as less than 50% (three of the eight studies included) reported a positive effect on body mass outcomes. Nevertheless, Gentile et al., suggests it is likely that longer-term studies are needed to record changes in BMI resulting from these modifications in eating patterns [94].

Physical activity

Regular participation in PA in childhood has many benefits including improvements in mental health, cognition and general academic performance. It also assists with weight control and social development, reduces anxiety and depression and adds to quality of life [95]. Furthermore, active children are more likely to choose other healthy behaviours [95]. Engaging in regular PA is widely accepted as an effective preventative measure for a variety of obesity-related chronic diseases including diabetes, metabolic syndrome and cardiovascular diseases [96]. Vigorous PA, defined as requiring much effort, causing rapid breathing and significantly increasing heart rate [74], can reduce overall body fat while simultaneously increasing bone and muscle mass [96]. While physical fitness (the ability to carry out tasks without undue fatigue and includes cardiorespiratory endurance, muscle strength,

muscle endurance, flexibility and body composition) [97] is an important predictor of physical and psychological health in young people [98]. Studies have also shown that children who display high levels of physical fitness are also more likely to perform better academically [99].

Increasing the PA levels of children is of particular importance as children who are physically active are more likely to be active as adults and less likely to be unhealthy [100]. The vast majority of children (75%) in Ireland, however, do not meet the National PA Guidelines [101], with Ireland's most recent PA Report Card for Children and Youth showing only 22% of 8-11 year olds meeting the PA guidelines of 60 minutes of moderate to vigorous physical activity (MVPA) every day [102]. Objective data on this behaviour in Ireland, however, remains limited.

Although a recent review by Love et al., [103] found strong evidence that current school-based PA interventions did not increase young people's daily PA, the wider health

Table 2: Summary of primary school interventions to promote physical activity

Study Reference, Country	Intervention Title	Study Design	Aims	Effect of Intervention
Lazaar et al. (2007) [104] France		• CCT (controlled clinical trial) • 6 months, 19 schools • N = 425 participants, Age 6-10 years • 2 weekly PA sessions of 1 h each	• To evaluate the effect of PA on body composition.	• In girls, significant positive effect on all anthropometric variables* except BMI. • In boys, only BMI z-score** and fat-free mass** were positively affected.
Reed et al. (2008) [109] Canada	Action Schools! BC	• RCT • 12 months, 8 schools • N = 268 participants, Age 9-12 years • Additional 75 mins PA per week	• To increase daily PA without disrupting the academic curriculum. • To improve CVD risk factors.	• 20% improvement in cardiovascular fitness*. • Reduced systolic blood pressure (5.7%)*.
Donnelly et al. (2009) [110] USA	Physical Activity Across the Curriculum (PAAC)	• RCT • 3 years • N = 1490 participants, Age 7-9 years • 90 mins per week of MVPA	• To increase PA by teaching existing academic lessons through PA. • To reduce increases in overweight and obesity.	• No change in BMI over 3 years. • Levels of exposure to PAAC lessons (≥75 minutes) were associated with smaller increases in BMI*. • 27% increase in MVPA. • Improvements in academic achievement*.
Kriemler et al. (2010) [105] Switzerland	KISS (Kinder-Sportstudie)	• RCT • 12 months, 15 schools • N = 502 participants, Age 6-7 & 10-11 years • PA lessons, breaks and homework	• To assess the effectiveness of KISS on physical and psychological health.	• At 12 months, improvements in body composition, aerobic fitness and PA*. • At 3 years only aerobic fitness benefits maintained. • Psychological quality of life did not change significantly.
Salmon et al. (2010) [106] Australia	Switch-Play	• RCT • 12 months • N = 311 participants, Age 10-11 years • 2 intervention components: Behavioural modifications and FMS	• To prevent excess weight gain. • To improve FMS. • To reduce time spent in screen behaviours. • To increase participation in PA.	• Behaviour modification/FMS group recorded significantly lower BMI*. • The FMS only group increased MVPA**. • BM group increased vigorous PA**. • No reduction in screen behaviours.
Resaland et al. (2011) [108] Norway	Sogndal School Intervention study	• CCT • 2 years • N = 256 participants, Age 9 years • 60 min per day PA	• To increase cardiorespiratory fitness (CRF) via PA intervention (60 minute per day) carried out at a moderate intensity.	• Improved children's CRF, the mean VO_2 peak was 3.6 (2.5-4.6) mL/kg/min more than the control group**. • Greatest impact in children with initial low CRF levels.
Thivel et al. (2011) [107] France		• RCT • 6 months • N = 457 participants, Age 6-10 years • 2 additional PA sessions per week	• To assess the effectiveness of a 6-month physical activity programme on body composition and physical fitness.	• No improvement in anthropometric measurements. • Anaerobic and aerobic fitness were significantly improved*.

*Asterisk denotes statistical significance at $p < 0.05$, ** denotes significance at $p < 0.01$.

Table 3: Summary of primary school interventions to promote healthy eating and physical activity

Study Reference, Country	Intervention Title	Study Design	Aims	Effect of Intervention
Luepker et al. (1996) [121] USA	Catch	• RCT • 3 years • 96 schools • N = 5106 participants, Age 8-9 years • 5-12 weeks classroom lessons	• To prevent cardiovascular disease by improving BMI by enhancing school lunches and increasing MVPA during physical education (PE).	• No significant change in BMI. • Decreased total fat content of school lunches (39% to 32%)**. • Increased MVPA in PE (40% to 50%)**.
Manios et al. (1998) [63] Greece		• CCT • 3 years, 40 schools • N = 1046 participants, Age 5-6 years • 13-17 hours of nutrition classes per year • 2 x 45 min PE sessions per week	• To improve children's diet, fitness, and physical activity. • To evaluate the effect of intervention on chronic disease risk factors.	• Significant improvement in BMI** at 3 years. • No significant improvements in nutrition or PA.
Gortmaker et al. (1999) [116] USA	Planet Health	• RCT • 2 years • 10 schools • N = 1560 participants, Age 11 years • Planet Health sessions taught in class through existing curriculum	• To increase FV consumption. • To decrease consumption of high-fat foods. • To increase MVPA. • To decrease television viewing.	• Reduced prevalence of obesity among girls (p = 0.03). • FV consumption increased among girls (0.32 servings per day)**. • Reduced television hours among both girls (-0.58 hours)** and boys (-0.40 hours)**.
Sahota et al. (2001) [122] UK	APPLES	• RCT • 10 months, 10 schools • N = 636 participants, Age 9-11 years • Modify school meals and teacher training • School Action plan	• To assess the effectiveness of Active programme promoting lifestyle in schools (APPLES) designed to improve both diet and physical activity.	• Modest increase in consumption of vegetables (0.3 portions per day)*. • No improvement in BMI, diet, physical activity or psychological state.
Sallis et al. (2003) [117] USA		• RCT • 2 years, Age 11-14 years • 24 schools (mean enrolment 1109 students) • Increase PA during PE classes • Provide low fat foods in school	• To evaluate the effectiveness of the intervention on PA and fat intake.	• Significant reduction in BMI among boys*. • No significant change in BMI for girls. • Significantly increased physical activity for boys**. • No reduction in fat intake.
Caballero et al. (2003) [123] USA	Pathways	• RCT • 3 years, 41 schools • N = 1704 participants, Age 7.6 (0.6) years • Implemented through curriculum, family involvement and school lunches	• To reduce % body fat by improving dietary intake and increasing physical activity.	• No significant difference in weight, BMI or % body fat. • Body fat increased by 7% (approx.) in both groups. • Decreased fat intake (31.1% compared with 33.6%)**. • Improvement in food and health related knowledge and behaviours**.
Kain et al. (2004) [118] Chile		• CCT • 6 months, 5 schools • N = 3086 participants, Age 10.6 (mean) years • Nutrition education for children and parents • 90 mins additional PA per week	• To improve measures of adiposity and physical fitness through nutrition education and increasing PA.	• Positive effect on BMI was observed in boys for BMI Z**. • Physical fitness increased significantly in boys** (for each test) and girls** (for each test).
Graf et al. (2005) [119] Germany	Step Two	• CCT • 9 months, 7 schools • N = 1678 participants, Age 8.2 (1.3) years • Additional health and PA lesson	• To improve health education and increase PA using the STEP TWO programme and to investigate the relationship of increased BP with parameters of obesity.	• Lower BMI increase (p = 0.069).

Spiegel et al. (2006) [65] USA	Wellness, Academics and You (WAY)	• RCT • 6 months, 16 schools • N = 1013 participants, Age 9-11 years	• To increase fruit and vegetable consumption and PA and evaluate the effectiveness of the WAY programme on BMI.	• Change in BMI in the intervention group was an increase of 0.1606 while the control group's mean BMI increased by 0.5210**. • 2% reduction in overweight.
Rush et al. (2011) [124] New Zealand	Project Energize	• RCT • 2 years, 124 schools • N = 1352, Age 5 and 10 years • Whole school nutrition & PA programme, 20 mins per day	• To reduce weight gain and chronic disease risk factors by increasing healthy eating and quality PA.	• Reduced accumulation of body fat in younger children*. • Reduced rate of rise in systolic BP in older children*.
Fung et al. (2012) [125] Canada	APPLE (Alberta Project Promoting active Living and healthy eating) Schools	• Quasi-experimental • 3 years, 10 schools • Age 10-11 years • Allocation of a school health facilitator	• To increase physical activity and improve nutrition.	• Increase vegetables (by 0.39 servings per day)*. • Decreases in total energy intake (237 kcals per day)**. • Increase in reported MVPA*. • Changes in obesity prevalence only borderline significant.
Grydeland et al. (2013) [120] Norway	HEIA (Health in Adolescents)	• RCT • 20 months, 37 schools • N = 700 participants, Age 11 years • 5 classroom nutrition & PA sessions • 10 minute PA & fruit and vegetable breaks once per week	• To increase physical activity, decrease sedentary time and improve dietary behaviours and measure their effect on anthropometric outcomes.	• Beneficial effect on BMI* and BMIz** in adolescent girls, but not in boys.
Merrotsy et al. (2018) [126, 127] Ireland	Project Spraoi	• RCT • 20 months, 1 intervention, 1 control school • N = 101, aged 6 and 10 years • Nutrition & PA sessions once per week	• To increase PA, improve CRF, improve dietary intake, nutritional knowledge, BP, BMI, WHtR.	• Improvement in dietary intake (fibre & protein)*, nutritional knowledge*, WHtR* and BP*.

*Asterisk denotes statistical significance at $p < 0.05$, ** denotes significance at $p < 0.01$.

benefits of such interventions warrant consideration. Table 2 summarises studies that aimed to increase PA in primary school children. Three of these studies [104-106] reported a positive effect of a PA intervention on BMI in the intervention group compared to the control group. In the other studies, while no significant changes in BMI were found, significant improvements were reported for anaerobic and aerobic fitness [107], cardiorespiratory fitness [108, 109] and daily PA [110]. Improvements were also seen in systolic blood pressure [108] and academic achievement [110]. Consequently, by significantly increasing the amount of PA amongst participants, these interventions have achieved multiple beneficial health effects [104-110].

Healthy eating and PA interventions

Although some studies, involving either a PA or a healthy eating component, showed positive effects on adiposity outcomes [111], combined nutrition and PA interventions seem to be more successful in preventing obesity in primary school children [48]. Furthermore, a combined approach may also help to prevent the comorbidities associated with obesity [112], encouraging children to establish long-lasting healthy habits. In addition, interventions that are implemented over a longer term (> 12 months) appear to be more effective in improving BMI compared to short term interventions (< 12 months) [113]. School-based interventions that include a healthy eating and/or PA component may help prevent children becoming overweight [48] by improving knowledge and attitudes, behaviour and physical outcomes. Evidence has shown that knowledge, attitude, and habit may be relevant mediators of dietary intervention effects [114] and according to ecological models of health behaviour, appropriate opportunities and settings that facilitate particular forms of activity, such as walking, help individuals achieve sufficient levels of PA for health benefits [115].

Table 3 describes studies aimed at improving nutrient intake and increasing PA among primary school children. Seven of these studies [63, 65, 116-120] showed a significant improvement in mean BMI in the intervention compared with the control groups, however there were significant gender differences. Manios et al., carried out a diet and activity intervention in primary school children in Crete, which

showed a significant improvement for BMI and skinfold thickness measurements at 3 and 6 years post intervention, compared to the control group [63]. This significant result was maintained at 10 year follow-up [64]. The study by Gortmaker et al., reduced the prevalence of obesity in girls but not boys [116], while Sallis et al., [117] and Kain et al., [118] both demonstrated significant improvements in the BMI of boys in the intervention groups but not amongst the girls. The study (Step Two programme) from Germany [119] reported a lower increase in BMI and waist circumference in the intervention group, while the WAY programme [65] significantly reduced the risk of developing overweight and reduced overweight in the intervention group by 2%. A more recent study, also showed a significant improvement in BMI but this was only found in girls [120].

Six additional studies [121-125] did not demonstrate a significant improvement in BMI, however other health related outcomes (PA, healthy eating and anthropometric measurements) were measured. Fung et al., demonstrated an increase in PA levels [125] and Leupeker et al., saw MVPA levels increase [121]. Furthermore, Rush et al., reported a reduced accumulation of body fat in younger children and a reduced rate of rise in systolic BP in older children in their study [124]. The CATCH intervention [121] decreased the total fat content of school lunches, while a more recent intervention significantly decreased the daily total fat intake in the intervention group [123]. Fung et al., also reported an increase in the consumption of fruits and vegetables, as well as a decrease in energy intake [125] amongst intervention participants, however the only significant finding in Sahota et al's., intervention was a modest increase in the amount of vegetables consumed [122]. Project Spraoi (pronounced spree) [126], Ireland's first fully evaluated PA and nutrition primary school intervention, was effective in improving some aspects of dietary intake (fibre, protein), nutritional knowledge, waist to height ratio and BP in older (10 year old) children. Consequently, although interventions that combine healthy eating and PA appear to have mixed success in improving BMI, they have achieved other important, multiple beneficial health effects.

Conclusion

In summary, evidence for the role of the obesity prevention intervention setting is variable and conflicting. Yet, evidence suggests that out of all the intervention settings, obesity prevention programmes are the most successful when delivered in the primary school setting. Furthermore, there is strong evidence to show that combined dietary and PA interventions are the most effective components to include in such strategies but programmes tend to be delivered over short time frames. Without long-term delivery of these interventions, overweight, obesity and unhealthy behaviours are at risk of continuing, which could have both immediate and long term health implications.

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