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Prevention of overweight and obesity in early life

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Childhood obesity is a serious challenge for public health. The problem begins early with most excess childhood weight gained before starting school. In 2016, the WHO estimated that 41 million children under 5 were overweight or obese. Once established, obesity is difficult to reverse, likely to persist into adult life and is associated with increased risk of CVD, type 2 diabetes and certain cancers. Preventing obesity is therefore of high importance. However, its development is multi-factorial and prevention is a complex challenge. Modifiable lifestyle behaviours such as diet and physical activity are the most well-known determinants of obesity. More recently, early-life factors have emerged as key influencers of obesity in childhood. Understanding risk factors and how they interact is important to inform interventions that aim to prevent obesity in early childhood. Available evidence supports multi-component interventions as effective in obesity prevention. However, relatively few interventions are available in the UK and only one, TrimTots, has been evaluated in randomised controlled trials and shown to be effective at reducing obesity risk in preschool children (age 1–5 years). BMI was lower in children immediately after completing TrimTots compared with waiting list controls and this effect was sustained at long-term follow-up, 2 years after completion. Developing and evaluating complex interventions for obesity prevention is a challenge for clinicians and researchers. In addition, parents encounter barriers engaging with interventions. This review considers early-life risk factors for obesity, highlights evidence for preventative interventions and discusses barriers and facilitators to their success.

Obesity prevention: Infants: Preschool children: Nutrition

Obesity is one of the most serious health problems facing today's children. Worldwide, levels are unacceptably high and continue to rise in many countries[1]. Most excess weight in childhood is gained early, during the preschool years[2]. Globally, more than forty million children under age 5 are currently estimated to be overweight or obese[1]. Obesity affects preschool children from both low- and high-income countries[1]. In England, for example, the recent national child measurement programme found that almost a quarter of children measured on starting school were already overweight[3]. This is a serious concern as once established obesity tracks into later childhood[4] and adulthood[5] and is difficult to reverse. Obesity is linked to poorer health outcomes in children, including asthma[6] and sleep apnoea[7] and obese adults are at increased risk of CVD, type 2 diabetes and some cancers[8]. Reducing the risk of obesity therefore is a priority for public health. Achieving this reduction is a challenge for clinicians, researchers and strategists working in obesity prevention.

Obesity is a complex condition with multi-factorial causes. At its simplest, obesity results from an imbalance between energy intake and expenditure that, if sustained over a long period, leads to weight gain. While genetic factors increase susceptibility to weight gain, the current 'obesogenic' environment, where energy-dense foods are highly available and sedentary behaviours widespread, is a major contributor to the development of obesity[9].

Obesity rates in children vary widely according to where they live. For example, the prevalence in children

Abbreviation: RCT, randomised controlled trial.
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under 10 is higher in southern compared with northern European countries[10]. There is a strong relationship between socioeconomic status and obesity[1]. This relationship is complex but in developed countries such as the UK children of low socioeconomic status are worst affected. Obesity rates also vary widely within countries. For example, in the UK, 5·1 % of preschool children living in the London borough of Kingston-upon-Thames were obese compared with 12·7 % in the Midlands city of Wolverhampton, according to the National Child Measurement Programme[3]. Rates even differed between local authority regions within the same cities. In London, for example, 13·8 % of preschool children in Brent were obese compared with only 5·1 % in Kingston[3]. Obesity prevalence was higher in towns and cities (9·9 %) compared with rural areas (7·9 %), suggesting that, in the UK, urban children are most at risk[3].

Modifiable lifestyle factors in adulthood such as diet and physical activity are the main determinants of obesity. However, strong evidence suggests that factors in early life also play a major role in its development[11]. The aim of this review is to summarise risk factors for obesity in early life, including infancy (birth to 12 months) and preschool (1–5 years). The review will highlight evidence for preventative interventions, discuss challenges for researchers developing and implementing them and consider barriers restricting parental engagement.

Risk factors for obesity in early life

Risk factors for obesity are both genetic and environmental[12]. Human subjects are predisposed to obesity through genes that have been conserved throughout evolution and favour hunger over satiety[13]. This is clearly demonstrated by the coexistence of obesity in members of the same family. However, families live together and share similar lifestyles, and obesity is, therefore, likely to result from interactions between genes and environment[14]. Environmental factors influence obesity risk from early in life. Strong evidence now supports developmental factors as important contributors to obesity risk; these are described and discussed later.

Developmental risk factors most strongly associated with obesity include larger size at birth, formula feeding rather than breast-feeding, rapid early growth, less healthy dietary behaviours, low physical activity and high sedentary behaviours, as reviewed by Woo *et al.*[11]. Maternal factors strongly influence birth weight; both high pre-pregnancy BMI[15] and excessive gestational weight gain are independently associated with higher birth weight[16]. Infants with high birth weight (>4 kg) or born large for gestational age have a higher risk of obesity compared with those of lower birth weight[17]. This suggests that starting pregnancy with a BMI in the normal range and avoiding excessive gestational weight gain may help to reduce the risk of obesity in infants[16]. Lifestyle interventions are one approach to reducing gestational weight gain in pregnancy.

Interventions to improve diet and exercise during pregnancy are successful in limiting excessive gestational weight gain[18]. For example, a systematic review including a meta-analysis of forty-nine randomised controlled trials (RCT) found a 20 % reduction in gestational weight gain for mothers taking part in lifestyle interventions (average risk ratio 0·80, 95 % CI 0·73, 0·87)[18]. This was confirmed in a later meta-analysis that included individual participant data from more than 12 000 women[19]. Evidence for benefits of lifestyle interventions in pregnancy on obesity risk in infants from these two meta-analyses was not so strong. Incidence of large for gestational age infants was lower in intervention compared with control mothers. However, the difference between groups was not significant[18,19]. The UK (UPBEAT) trial, included in these reviews, found no difference in large for gestational age infants between intervention and control mothers[20]. However, intervention children had lower body fat compared with controls at age 6 months (difference in sub-scapular skinfold thickness z-score: 0·26 SD, 95 % CI −0·49, −0·02, P = 0·03)[21]. This suggests possible benefits of the intervention for obesity risk. Collectively, findings from these reviews support interventions to improve diet and lifestyle in pregnancy as beneficial for maternal and child health. However, evidence for a protective effect of interventions in pregnancy on obesity risk in children is limited.

Infant feeding is an important risk factor for childhood obesity. A protective effect of breast-feeding against obesity has been reported in many observational studies[22]. The strongest association is seen with exclusive and a longer duration of breast-feeding. The protective effect of breast-feeding is proposed to be due to the relative undernutrition and slower pattern of growth in breast-fed compared with formula-fed infants that has been suggested to programme susceptibility to obesity[23]. Rapid growth in infancy is strongly associated with increased risk of obesity, as summarised in several systematic reviews[24–26]. However, nutrition and growth are closely linked and it is difficult to separate their effects on obesity risk. The mechanisms through which nutrition and growth influence obesity risk are not well understood but are likely to include the effects on endocrine systems regulating appetite, food intake, energy storage and fat deposition[27]. Available evidence supports the promotion of breast-feeding as one public health intervention that could help to stem the rise in obesity. The complementary feeding period when infants are no longer exclusively milk-fed is another critical period when infants are at risk of obesity through inappropriate feeding practices.

Complementary feeding and risk of obesity

From about 6 months, foods other than milk are needed to meet the nutritional needs of the rapidly growing and developing infant[28]. During complementary feeding, the diet is expanded to include a wider range of foods aiming to establish a diet that meets requirements without being excessive in energy or specific nutrients. This is important for healthy growth and development. Furthermore, complementary feeding is a transitional

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period when lifelong dietary habits are established and taken forward into later childhood[29,30]. Therefore, this period is important for both short- and long-term health. Not surprisingly, higher consumption of energy-dense foods during complementary feeding has been linked to rapid weight gain and increased risk of obesity[28]. In particular, higher protein shows this association[31]. Protein intake increases markedly (from about 5 to 15 % of energy intake) when solid foods are introduced[31].

The age at introduction of complementary foods has been the main focus of research in this area. Evidence that age at complementary feeding influences obesity risk is based largely on observational studies[26,28]. However, systematic reviews have found that early introduction of complementary foods (before 4 months) is linked to an increased risk of obesity[32,33]. For example, a systematic review with meta-analysis found that starting complementary foods before 4 months carried a 30 % higher risk of obesity in childhood compared with a later introduction at 4–6 months (relative risk of obesity, 1·33; 95 % CI 1·07, 1·64)[33]. As most included studies were observational, the influence of other factors previously associated with obesity risk in children, such as lifestyle behaviours and educational status of parents, could not be ruled out; neither could a causal relationship be established. Therefore, it is currently unclear whether early complementary feeding leads to overweight and obesity or if larger infants are introduced to complementary foods at a younger age.

A final point concerns how complementary foods are given. In recent years baby-led weaning, an approach to complementary feeding that encourages self-feeding in infants, has gained popularity[34]. Early observational studies found that infants weaned using this approach were more satiety-responsive[35] and less likely to be overweight in later childhood[35,36] compared with those weaned using a standard approach. However, a recent study using a more rigorous RCT design found no difference in obesity risk in early childhood between children randomised to baby-led weaning as infants compared with controls following standard advice (difference in BMI z-score at age 2, 0·16; 95 % CI −0·123, 0·45)[34]. Interestingly, a lower satiety response was found in the baby-led weaning group at 24 months. This may be important as low satiety responsiveness has been associated with rapid growth and increased obesity risk in previous studies[37,38]. While data from these studies are not strong enough to base public health recommendations on regarding best practice for complementary feeding, they support the need for further research to clarify relationships between complementary feeding method and risk of obesity. Beyond complementary feeding, the preschool diet has also been a focus of research into the development of childhood obesity.

Diet and nutrition in preschool children and risk of obesity

Dietary habits in preschool children have changed considerably since the onset of the obesity epidemic. National surveys and several large studies consistently report that the diets of young children do not comply with recommendations[39,40]. Notably, diets are low in fruit, vegetables and fibre and high in saturated fat and sugar. Given that obesity is largely the result of an energy imbalance, many studies have focused on energy intake as a risk factor for obesity[41]. However, studies investigating this relationship in children are inconclusive. Some studies have found that energy intake is higher in obese compared with healthy weight children[42,43] while others report the opposite[44,45]. Reports of a lower energy intake in obese compared with non-obese children are surprising and counterintuitive. However, these may be explained by methodological errors. For example, biases in the dietary assessment are common[41]. In particular, obese individuals are known to underestimate energy intake[46]. This is likely to apply to children where estimates of dietary intake rely on parental reports that may not be accurate[47]. In addition, dietary assessment in young children is difficult to do well as food wastage is high and meal patterns erratic[48].

Limitations of study design may also obscure relationships between dietary exposures and obesity outcomes. For example, many studies reviewed here may have lacked the power to detect small differences in energy intake sufficient to influence weight gain[49]. This is important as relatively small excesses in energy intake if sustained over a longer period, can lead to energy imbalance and weight gain[49]. Another possible explanation is that lower energy expenditure rather than higher energy intake is the main determinant of obesity[50]. However, studies using objective measures of energy intake (e.g. doubly labelled water) do not support this[46].

In summary, available evidence is insufficient to support an association between higher energy intake and obesity risk in young children. However, energy balance is key to achieving and maintaining a healthy weight. Therefore, avoiding excessive energy intake in young children is recommended. Defining optimal energy intake in this age group is difficult. More studies using objective measures of energy intake would be helpful to inform energy needs of preschool children, but these are expensive and difficult to carry out in young children. Regular growth monitoring, using charts based on data from breast-fed infants growing under optimal conditions (i.e. the WHO multi-centre breast-fed growth reference), is a practical approach that can be used to identify children gaining weight more rapidly and at an increased risk of obesity.

Macronutrient intake and obesity risk in preschool children have also been widely studied[51–55]. Evidence for associations of fat and carbohydrate with increased obesity risk is weak. For example, no consistent associations between the amount and type of fat consumed by preschool children and obesity risk were found in studies investigating this, as reviewed by Agostoni and Caroli[54]. Similarly, evidence for an association of carbohydrate with obesity risk was also lacking in a recent systematic review by Patro-Golab *et al.*[55]. An increase in sugar consumption in preschool children, at the same time as the obesity epidemic, has prompted research into high-sugar foods and the association of these with obesity risk[39]. In particular, sugar-sweetened beverages have been a focus[56].

Evidence for associations of sugar-sweetened beverages with obesity risk in children was reviewed most recently by Scharf and DeBoer[56]. Studies were mainly observational and included multiple age ranges[56]. A small number of prospective studies focused on preschool children[57–60]. These studies consistently reported a higher risk of overweight and obesity in consumers of sugar-sweetened beverages.

Experimental evidence in this age group is limited and confounding effects of unmeasured or unaccounted for variables that affect both sugar-sweetened beverage consumption and obesity outcomes cannot be ruled out. RCT in this area are difficult to conduct for ethical reasons[60]. However, trials are possible in children with established sugar-sweetened beverage consumption. In one such study in the Netherlands, 4–11-year-old children who regularly drank sugar-sweetened beverages were randomised either to continued consumption or to a control group drinking artificially sweetened drinks[60]. BMI increased less in the artificially sweetened drinks group during the 18-month intervention period (difference in BMI increase 0·13 SD (95 % CI −0·21, −0·05))[60]. Further research is needed before firm conclusions can be made regarding the effects of sugar-sweetened beverages on obesity risk in young children. However, in view of the concurrent rise in sugar intake and obesity prevalence, high-sugar foods are likely to contribute to obesity risk in this age group and advice to reduce intake in line with national[61] and international[62] guidelines is warranted.

Evidence for an association of high-protein intake in preschool children and increased obesity risk is stronger than for other macronutrients[31]. A recent meta-analysis including thirteen studies found that protein intake between 6 months and 3 years was associated with a higher BMI later in childhood (pooled effect size: 0·28 BMI *z*-scores, 95 % CI 0·20, 0·35)[63]. In one study of more than 2000 children, higher protein intake at 21 months was associated with increased risk of obesity at 5 years (1 % higher energy from protein associated with a 0·043 unit increase in BMI)[64]. Similarly, the Generation R study in about 3000 children from the Netherlands found that protein intake at 1 year predicted higher BMI and fat mass in later childhood (10 g/d higher protein predicted a 0·05 SD increase in BMI and 0·06 SD increase in fat mass)[65].

Mechanisms underlying associations of protein with obesity risk are unclear. However, one proposed mechanism is that high-protein diets promote faster growth through programming effects on insulin-like growth factor-1[31]. Evidence is currently limited to a small number of observational studies and further research is needed to confirm this hypothesis.

Beyond specific foods and nutrients, overall dietary patterns have captured the interest of researchers investigating diets in preschool children and obesity risk.

Dietary patterns in preschool children and risk of obesity

Dietary patterns are derived from food intake data using, for example, principal component analysis. This analytical method reduces large data sets to fewer variables by combining highly correlated factors. Foods commonly consumed together are combined to produce dietary patterns that are named according to the predominating foods. Dietary patterns have been shown to emerge early in childhood and to become established by age 3 years[66]. Once established, dietary patterns are stable and track through childhood[67]. This is a concern as less healthy dietary patterns, characterised by high intake of energy-dense foods and low intake of fruit, vegetables and fibre, are associated with obesity in children[68]. Tracking of unhealthy dietary patterns is therefore likely to increase this risk.

Studies investigating associations of dietary patterns with obesity risk in infants and preschool children are limited and findings inconsistent. For example, a recent study reported that a dietary pattern characterised by the later introduction (between 5 and 7 months) of dairy foods and high use of ready-prepared baby foods in infancy was associated with faster growth between 1 and 3 years[69]. However, a study in Australia found no association of dietary patterns in toddlers aged 14 months with growth or BMI in later childhood[70]. Dietary patterns in preschool children provide useful information on diet quality. However, more research is needed before firm conclusions can be made regarding influences of specific dietary patterns on obesity risk in this age group.

As discussed earlier, excessive weight gain is the result of an imbalance between energy taken in from food and beverages and energy expended during day-to-day activities. Energy intake depends on several factors including the amount and frequency of food consumed. Recent research has investigated associations between portion size, meal frequency and obesity risk in young children.

Portion size

Children's portions have increased markedly in size over the past three decades in line with the sharp rise in obesity[71]. Studies have found that from an early age, children consume more when offered larger servings. One of the earliest studies to investigate this found that providing larger portions to preschool children led to higher food and energy intake[72]. Interestingly, the association was only seen in older preschool children (from 5 years). Offering larger portions to 3-year-old children did not increase intake suggesting that appetite control is strongest in younger children and may be over-ridden by age 5[72]. Evidence for an association of increased meal size with obesity risk comes from a recent UK study. Syrad *et al.* found that larger meal size in toddlers was associated with faster growth from 2 to 5 years[73]. Available evidence supports that offering larger portions influences energy intake and disrupts appetite regulation in preschool children. However, more studies are needed to confirm these associations and provide information to guide portion size advice for preschool children. Evidence informing relationships between meal frequency and obesity risk in preschool children is limited. Only two studies have investigated this and found no consistent relationship[72,73].

In summary, evidence supports diet during preschool as important in the development of obesity. The strongest evidence is for an association of higher protein in preschool with an increased risk of childhood obesity[31,63]. Evidence for an association of energy intake with obesity risk is inconclusive. Further research is needed to inform appropriate portion sizes for preschool children taking individual variation into account. More information on dietary patterns across the preschool age range is needed to improve understanding of dietary quality and its influence on obesity risk.

Nutrition and diet influence one component of energy balance. On the other side of the equation, however, physical activity is also an important consideration when assessing obesity risk.

Physical activity and sedentary behaviours in preschool children

Studies and surveys consistently report that many preschool children do not meet recommendations for daily physical activity[74–76]. For example, in the UK, only 10 % of children aged 2–4 years met recommendations for 3 h physical activity daily in 2012. This is a concern as studies consistently report that low levels of total physical activity are associated with a higher risk of obesity in children, as reviewed by te Velde *et al.*[76]. Less is known regarding the intensity of physical activity (i.e. low, moderate or high intensity) that is most protective against obesity. Some studies have found that physical activity at a vigorous level is most strongly associated with a lower risk of obesity[77]. However, these were mostly cross-sectional and unable to show a causal relationship. More research is needed to define the intensity of physical activity needed to protect against preschool obesity.

Not surprisingly, a low level of total physical activity is associated with more time spent sedentary, another independent risk factor for obesity[78]. Preschool children are spending excessive time in sedentary behaviours, as reviewed by Downing *et al.*[79]. For instance, time spent sedentary, including engaging with television and other media, ranged from 37 to 330 min daily in 2-year-old children[79]. Until recently, little was known about relationships between screen time in preschool children and obesity risk in later childhood. However, a study from Canada has shed some light on this. An extra hour and a quarter spent watching television at preschool age was associated with a 13 % increase in BMI as a teenager[80].

Shorter sleep duration in early childhood (<10 h) has been suggested as a risk factor for obesity, as reviewed by Chen *et al.*[81] The mechanism is unclear but is proposed to operate through effects of shorter sleep on appetite[81]. Sleep plays a central role in appetite regulation and energy balance. In children under 10 years, shorter sleep duration was associated with an almost 60 % higher risk of overweight and obesity (pooled OR 1·58, 95 % CI 1·26, 1·98). However, most studies were cross-sectional and few focused on preschool children. One large study from the UK that did include preschool children found that shorter sleep duration (<10·5 h) was associated with a higher risk of obesity at 7 years (OR 1·45; 95 % CI 1·10, 1·89)[82]. Further research would be helpful to confirm this finding and its relevance to diverse populations.

The causes of obesity in early life are complex and no one causal factor has so far been identified. Evidence supports lifestyle factors, including diet, physical activity and related behaviours as targets for interventions. The aim of interventions in this age group is to prevent rather than treat obesity by reducing risk. Available evidence suggests that this can best be achieved by optimising nutrition and growth in infancy and instilling healthy lifestyle behaviours (e.g. dietary and physical activity related) that are taken forward into later childhood. Interventions to prevent obesity in early life are discussed in the following sections.

Interventions for the prevention of obesity in early life

Given that risk factors for childhood obesity present early in life, prevention strategies should target infants, toddlers and preschool children. However, in 2006, there were only six reports of interventions aiming to prevent obesity in preschool children, as reviewed by Flynn *et al.*[83]. Since then this has increased markedly as summarised in several systematic reviews[17,84,85]. Systematic reviews have focused either on infants and toddlers up to age 2 years or on preschool children (age 1–5 years).

Interventions in children under 2 years

Interventions to reduce obesity risk in the first 2 years of life are mostly behavioural and target responsive parenting and feeding, or family lifestyle[85]. Those addressing responsive feeding, where mothers respond appropriately to infant cues of hunger or satiety, have so far had the greatest impact on obesity risk[85].

Responsive parenting interventions have found benefits for obesity risk in the short term. For example, healthy beginnings, an intervention to encourage responsive parenting in Australian mother–infant pairs, led to a lower BMI at 2 years (mean difference in BMI between intervention and control groups: 0·29 units, 95 % CI 0·55, 0·02; $P = 0·04$)[86]. Similarly, children in the intervention arm of the NOURISH responsive parenting intervention, also in Australia, had a lower BMI at age 14 months compared with controls (mean difference in BMI: 0·19 units)[87]. In both trials, effects on BMI were not sustained at later follow-up[88,89]. This suggests that

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obesity prevention programmes need to be continued or maintained during the preschool years.

The intervention nurses starting infants growing on healthy trajectories study is an ongoing longitudinal RCT evaluating a responsive parenting intervention. The intervention focuses on the first 6 months of life and aims to reduce the risk of overweight in infancy by preventing rapid early growth. Initial results are promising; infants in the intervention arm gained weight more slowly between birth and 28 weeks compared with controls (mean conditional weight gain score −0·18; 95 % CI −0·36, −0·001) and were less likely to be overweight at 1 year (5·5 *v.* 12·7 %; P = 0·05)[90]. Importantly, this effect did not depend on infant feeding method (predominantly breast-fed or not), suggesting an independent effect of growth on obesity risk. Longer follow-up at age 3 will inform whether the effects of this intervention are sustained.

A small number of studies in infants have focused on non-behavioural interventions. These have manipulated formula milk composition to investigate the effects of early nutrition on the risk of later obesity. In one large RCT, infants fed a protein-enriched formula had a higher BMI at 1 year compared with those given a standard infant formula[91]. At longer term follow-up when children were 6 years old, obesity risk was more than double in infants receiving the higher protein formula compared with those fed a standard formula (95 % CI for the difference in BMI: 1·12, 5·27; P = 0·024)[92]. This suggests that lowering the protein content of infant formulas could help to reduce the risk of later obesity in children who are not breast-fed.

Interventions in preschool children

In the UK, guidance for the prevention of childhood obesity is provided by the National Institute for Health and Care Excellence[93]. The National Institute for Health and Care Excellence recommends that interventions should include advice on achieving a healthy diet, encourage physical activity and incorporate strategies for behaviour change. However, there are currently no full reports and only one published abstract[94] of successful interventions for the prevention of obesity in preschool children that meet these guidelines in the UK. Multi-component interventions in other countries, based on similar guidance to the National Institute for Health and Care Excellence, have reported some success as reviewed by Ling *et al.*[84].

The systematic review by Ling *et al.* identified twenty-six randomised interventions in preschool children (age 2–5 years), thirteen of which were preventative. Reports were mainly from the USA, Canada, Australia and Europe[84]. Most interventions were school-based and involved parents either directly or indirectly. Nineteen studies used a theoretical framework, mostly based on social cognitive theory, to guide the intervention. Eighteen studies included both physical activity and dietary behaviour change components. Standardised mean differences in BMI between intervention and control groups were calculated and effect sizes estimated. The pooled effect immediately the following intervention was a reduction of 0·19 BMI units (95 % CI −0·28, −0·09, P < 0·001). Importantly, sustained effects, up to 12 months following the intervention, were larger: −0·21 BMI units (95 % CI −0·35, −0·08, P = 0·002). This suggests lasting effects of interventions, possibly as a result of behaviour modifications that may have delayed effects. Several multi-component programmes are available in the UK. These include, MEND 2–4, Health Exercise Nutrition for the Really Young and TrimTots as discussed later.

The MEND 2–4 programme includes nutrition, physical activity and behaviour change components and is delivered to parents and preschool children in ten weekly sessions. The intervention has been evaluated in an RCT in Australia. No effect on BMI was found at 6 and 12 months after completion[95]. Benefits were found for vegetable and snack food intake and satiety responsiveness immediately post-intervention. However, these were not sustained at long-term follow-up[95].

Health Exercise Nutrition for the Really Young is an 8-week community-based programme that aims to improve parenting skills and lifestyles in preschool children. Health Exercise Nutrition for the Really Young has been evaluated as part of service provision using parent-reported questionnaire data. Improvements in dietary behaviours, physical activity and children's screen time were found. Anthropometric data were not collected due to concerns that reference to weight might deter participation[96]. There are currently no published data from RCT to support Health Exercise Nutrition for the Really Young as a childhood obesity prevention intervention. However, a feasibility study and a larger scale trial are planned to evaluate the programme for this purpose[97].

TrimTots is a 24-week multi-component programme for obesity prevention in preschool children with an emphasis on family participation and learning through art and play. To my knowledge, TrimTots is the only preschool intervention for obesity prevention that integrates the National Institute for Health and Care Excellence recommendations in a single comprehensive programme that has been evaluated in an RCT and shown to be effective at reducing obesity risk.

TrimTots was evaluated in two small-scale RCT. Trial 1 included high-risk children with BMI at or above the 91st centile or whose weight had crossed centiles upwards on the UK 1990 growth reference. Trial 2 recruited children irrespective of weight status or early growth. In trial 1, BMI was significantly lower at the end of the programme in the intervention group compared with waiting list controls (mean difference in BMI z-score: −0·9; 95 % CI −1·4, −0·4, P = 0·001). This effect was sustained in thirty-nine children followed up 2 years after completing the intervention. BMI was lower in children after participation in the programme compared with baseline (mean difference in BMI z-score: −0·3, 95 % CI −0·6, −0·1, P = 0·007). In trial 2, BMI was lower in the intervention group compared with controls immediately following participation (mean difference in BMI z-score: −0·3; 95 % CI −0·8, 0·3, P = 0·3)[94].

The aim is to evaluate TrimTots further in a cluster RCT to assess feasibility and efficacy in a larger population. However, developing a complex intervention for obesity prevention in preschool children is demanding and there are many barriers to its successful design, development, delivery and evaluation, as discussed later.

Developing a complex intervention for prevention of obesity in preschool children

Developing, piloting, evaluating, reporting and implementing a complex intervention is a lengthy process[98]. Barriers are active throughout that affect both researchers and participants. For instance, securing funding to develop and test an intervention is a major obstacle for researchers from the outset. While funders cover the costs of research, this usually does not include interventions to be evaluated. Therefore, funding for interventions must be obtained from alternative sources such as charities and philanthropic organisations. Further challenges for researchers working in public sector institutions include a lack of resources needed to implement successful interventions on a large scale. In addition to problems encountered by researchers, studies have identified barriers to engagement (participation and completion) of parents in community-based interventions (programmes).

Potential barriers to successful interventions

Financial, time-related and social costs have all been cited by parents as barriers to engagement in family-based childhood obesity prevention programmes, as reviewed by Arai *et al.*[99]. Financial costs were mainly incurred through taking time off work and in travelling to attend programmes. Additional costs related to buying the healthier foods advised in programmes and adopting a healthier lifestyle (e.g. taking part in recreational activities). Time costs were mostly related to accommodating programme attendance into busy lives.

Social costs were also important to parents. These included strains on family life and relationships that led to reduced attendance at programmes. Further, some parents were reluctant to take part in obesity interventions believing their child would be stigmatised[100]. Socioeconomic factors also influence attendance at interventions. Advantaged families are more likely to engage in programmes compared with those in less secure positions[101]. Conversely, families have identified aspects of interventions that act as triggers and encourage engagement. Understanding these would help inform the design and implementation of interventions and increase their chance of success.

Facilitators to successful interventions

Parents who perceive their child to be at high risk of obesity are more likely to engage in interventions. Obese children are reported to suffer psychological stress as a result of bullying and stigma associated with their weight status[102]. This is a concern to parents who may be highly motivated to attend interventions to protect the health of their child.

Other factors reported by parents to encourage their attendance at obesity prevention programmes include opportunities to meet and compare notes with other parents and to work as a group[103]. Parents commonly report finding it easier to make changes in a group setting[103]. Practical sessions such as cooking, portion size exercises, shopping, outdoor activities and hearing about real-life experiences are all well received and liked by parents. Additionally, dedicated time spent with their child, helpful programme staff, learning and gaining new knowledge and skills and enthusiastic leaders have all been cited as positive factors encouraging attendance. Overall, programmes that are fun, interactive and able to engage parents and children are the most likely to be successful.

Conclusions

Strong evidence supports developmental and lifestyle factors as influential in obesity risk in infants and preschool children. Optimising nutrition and growth in infancy and establishing healthy lifestyles in the preschool years could help to reduce this risk. Multi-component interventions targeting feeding and parenting styles in infants and diet and physical activity in older preschool children have shown some success in reducing obesity risk. Interventions based on theoretical frameworks that include behaviour change strategies are more likely to succeed. Interactive programmes in group settings are most likely to engage families. Programmes should be tailored to meet the needs of families and children. Evaluation in rigorous studies, including long-term follow-up is essential to assess immediate and sustained effects of interventions. Early interventions should ideally begin in infancy and continue through the preschool years to maximise the chance of success.

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Conflicts of Interest

The author is a director of TrimTots Community Interest Company, a not for profits social enterprise.

Authorship

The author was solely responsible for all aspects of preparation of the present paper.

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