NIHR | Policy Research Unit in Obesity

OPRU Briefing Paper - Assessing the effectiveness of obesity interventions in the early years: a systematic review and meta-analysis of the international evidence

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Key message – study context

The early years (0-5 years) are an important period for healthy growth and development. Lifestyle behaviours adopted at this age are likely to be carried forward into adult life. It is a public health and policy priority to identify lifestyle interventions that can support healthy growth and reduce the risk of excess weight gain early in the life course.

Previous research has shown that multi-component interventions can be successful at treating overweight or obesity in children, particularly older children, but evidence to support the effectiveness of universal interventions for young children (aged 0-5 years) is limited.

To synthesise the evidence base, we conducted a systematic review and meta-analysis assessing the effectiveness of obesity interventions both in the UK and internationally.

The UK evidence has been previously reported, this report details the international literature (including the UK evidence where inclusion criteria were met).

We focused on robust interventions that met the following criteria:

- Included all children irrespective of weight status
- Were of at least six months duration
- Included both diet and physical activity components
- Were conducted in high-income countries
- Included a control group

We found 37 studies that were eligible for inclusion in the review, 15 of which reported adjusted zBMI as an outcome and were eligible for meta-analysis.

Key findings

- Out of the 37 studies, 28 reported reductions in anthropometric outcomes (such as BMI, zBMI, BMI percentile, or fat mass) for the intervention group compared to the control group; 12 of which were significant but many of these trials had small sample sizes.
- Our meta-analysis showed a small but significant effect of interventions in reducing zBMI compared to control [-0.03 (95% CIs: -0.06, -0.00)]. We note this effect size is small, but it is important to remember that the studies included both children who are not living with overweight or obesity as well as those who were, i.e., effects are likely to be small.
- We carried out subgroup analyses but found that the intervention duration and length of follow-up had no impact on the effect size.
- We conclude that robust interventions that encourage healthy growth in the early years have small but promising effects in young children in reducing zBMI and other anthropometric outcomes when compared to control.
- Universal interventions in the early years have the potential to support the wider obesity reduction strategy and support healthy growth.

Executive summary

Background

According to the World Health Organisation, 39 million children younger than 5 years globally had overweight or obesity in 2020. Obesity tracks strongly through childhood, adolescence, and into adulthood with associated comorbidities. Lifestyle behaviours, including diet and physical activity, also track, so it is important to support families to adopt healthy behaviours for their children early in life with effective interventions.

Careful design and robust evaluation of interventions through randomised control trials (RCTs) is important to determine their effectiveness and can provide insight into the implementation and scale-up of interventions in 'real world' contexts.

Following our systematic review that assessed the effectiveness of obesity interventions in the UK for children aged 0-5 years, we were asked by the Department of Health and Social Care to summarise the international evidence.

Aim

Our aim was to systematically review and synthesise the international evidence for robust obesity interventions that promote healthy growth in children aged 0-5 years.

Executive summary

What we did

- We searched nine databases for studies relating to individual-, family- or community-based interventions in all languages published during the years 2011-2021.
- The population of interest was children aged 0-5 years.
- The interventions of interest were universal (included all children regardless of their weight status), and multi-component (included both diet and physical activity components).
- Studies evaluating the effectiveness of breastfeeding or complementary feeding interventions were excluded, as they focus on developmental origins; outcomes for these interventions also do not tend to include weight change of the child.
- Studies were required to include a control group (no intervention or usual care) for comparison.
- We included studies that reported change between the intervention and control group for any measured anthropometric outcome (i.e., zBMI, BMI percentile, BMI, fat mass).
- Interventions were required to be of at least six months duration. Only RCTs, quasi-experimental studies, or studies with before and after implementation, considered to be of a robust design, were included, and we restricted searches to high-income countries to allow comparison with the UK.

Summary of findings

- We identified 37 studies reporting 34 interventions.
- Most interventions (n=16) were delivered in the United States.
- Out of the 37 included studies, 32 were RCTs. Most interventions (26) were conducted in community settings (e.g., preschools, kindergartens, day care centres, childcare centres), four were home-based, one was a mobile intervention delivered to parents via an app, and five were delivered across multiple settings.
- Intervention duration ranged from six to 39 months.
- Seven studies reported follow-up between four months and two years after the intervention ended.
- Meta-analysis of the 15 trials that reported adjusted zBMI as an outcome showed that, compared to controls, interventions reduced zBMI by -0.03 (95% CIs: -0.06, -0.00), which was statistically significant (p=0.03).
- The zBMI change was adjusted for different variables in each study, often for demographics and baseline BMI. Effects sizes were not found to vary by intervention duration or follow-up duration.

Background

According to the World Health Organisation (WHO), internationally 39 million children younger than 5 years were living with overweight or obesity in 2020.[1] In some high-income countries, such as the USA, UK, Australia, and Canada, childhood obesity prevalence remains high. For example, in England, the prevalence of obesity among children aged 4-5 years was 10.4% in 2022[3] and in the USA, it was 12.7% among children aged 2-5 years during 2017-2020.

Obesity is associated with many short- and long-term health conditions.[5–8] Inequalities in obesity are increasing and children living in the most deprived areas are the worst affected.[3] Obesity tracks strongly through childhood, adolescence and into adulthood with associated comorbidities.[7,9] Among children living with obesity, 55% are likely to maintain their weight status in adolescence, while 80% of adolescents with obesity are likely to have obesity in early adulthood.[8]

The preschool years are a period when the most excess weight gain occurs, with risks for obesity in later life.[9] For these reasons, the early years represent an opportune time to implement interventions that support healthy growth. Multi-component (i.e., both with diet and physical activity components) interventions can be effective when targeting children with overweight or obesity,[10,11] there is also evidence that preventative interventions can be effective for older children,[12,13] but the evidence for preventative interventions in the early years is limited.

1. World Health Organization. Obesity and overweight. Published 2021. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight

2. Bentham J et al. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. *The Lancet*. 2017;390(10113):2627-2642. doi:10.1016/S0140-6736(17)32129-3

3. National Child Measurement Programme, England 2020/21 School Year. NHS Digital. Accessed November 15, 2022. https://digital.nhs.uk/data-and-information/publications/statistical/national-child-measurement-programme/2020-21-school-year

4. Stierman B et al. National health and nutrition examination survey 2017–march 2020 prepandemic data files-development of files and prevalence estimates for selected health outcomes. *Natl Health Stat Rep*. 2021;2021(158). doi:10.15620/cdc:106273

5. Umer A et al. Childhood obesity and adult cardiovascular disease risk factors: a systematic review with meta-analysis. *BMC Public Health*. 2017;17(1):683. doi:10.1186/s12889-017-4691-z

6. Rankin J et al. Psychological consequences of childhood obesity: psychiatric comorbidity and prevention. *Adolesc Health Med Ther*. 2016;7:125-146. doi:10.2147/AHMT.S101631

7. Abdelaal M et al. Morbidity and mortality associated with obesity. *Ann Transl Med*. 2017;5(7):1-12. doi:10.21037/atm.2017.03.107

8. Simmonds M et al. Predicting adult obesity from childhood obesity: A systematic review and meta-analysis. *Obes Rev*. 2016;17(2):95-107. doi:10.1111/obr.12334

9. Geserick M et al. Acceleration of BMI in early childhood and risk of sustained obesity. *N Engl J Med*. Published online 2018. doi:10.1530/ey.16.11.5

10. Colquitt JL et al. Diet, physical activity, and behavioural interventions for the treatment of overweight or obesity in preschool children up to the age of 6 years (Review). *Cochrane Database Syst Rev*. Published online 2016. doi:10.1093/pch/pxz006

11. Nordlund S et al. Effect of obesity treatment interventions in preschool children aged 2-6 years: A systematic review and meta-analysis. *BMJ Open*. 2022;12(4). doi:10.1136/bmjopen-2021-053523

12. Bleich SN et al. Systematic review of community-based childhood obesity prevention studies. *Pediatrics*. 2013;132(1):201-210. doi:10.1542/peds.2013-0886

13. Bleich SN et al. Interventions to prevent global childhood overweight and obesity: a systematic review. *Lancet Diabetes Endocrinol*. 2018;6(4):332-346. doi:10.1016/S2213-8587(17)30358-3

Aims

There is evidence that lifestyle behaviours track over time and, if established early in life, dietary and physical activity habits often remain through childhood and beyond.[14,15,16] Intervening in the preschool years has the potential to foster healthy dietary and physical activity behaviours and lay healthy foundations for later life. Early years are a key timeframe for policymakers and public health to support and enable healthy lifestyles.

Following our recent review of obesity interventions in the early years in the UK, this review considers the international evidence.[17] Specifically, we focus on robust interventions that have been implemented in high-income countries and are comparable to the UK economically.

AIM OF THIS REVIEW

The aim was to systematically review and synthesise the international evidence for robust obesity interventions that promote healthy growth in children aged 0-5 years.

14. Lioret S et al. Dietary patterns track from infancy to preschool age: Cross-sectional and longitudinal perspectives. *J Nutr*. 2015;145(4):775-782. doi:10.3945/jn.114.201988
15. Luque V et al. Unhealthy dietary patterns established in infancy track to mid-childhood: The EU childhood obesity project. *J Nutr*. 2018;148(5):752-759. doi:10.1093/jn/nxy025
16. Mikkilä V et al. Consistent dietary patterns identified from childhood to adulthood: The Cardiovascular Risk in Young Finns Study. *Br J Nutr*. 2005;93(6):923-931. doi:10.1079/bjn20051418
17. Michalopoulou S et al. OPRU Briefing Paper - Assessing the effectiveness of obesity interventions in the early years in UK studies: a systematic review. Link.

Methods

Inclusion criteria and study selection

In November 2021, nine databases were searched for studies relating to individual, family, or community-based obesity interventions (See Appendix 1 for search terms and search strategy).

i) We excluded publications prior to 2011 as we wanted to reflect current or recent interventions and programmes within the current landscape of childhood obesity,

ii) We applied no restrictions in country of the intervention and language of publication,

iii) We were interested in obesity prevention or treatment interventions,

iv) We were interested in interventions that targeted children aged 0-5 years and their families,

v) We included studies that reported anthropometric outcomes (i.e., zBMI, BMI percentile, BMI, fat mass) either as a primary or as a secondary outcome, as these measures are the most robust way of assessing effectiveness,

vi) We included intervention studies or randomised controlled trials, quasi-experimental studies, and studies that had a before/after implementation design if they compared an intervention to a control group or the pre- vs the post-intervention effect.

Methods

We also wanted to select **robust interventions** (based on NICE guidance), from contexts that would be broadly comparable to the UK. We set the following additional criteria for the interventions:

i) They were required to be universal, i.e., include children of any weight status

ii) To have both diet and physical activity components as NICE recommends

iii) To last for at least for six months[18,19]

iv) To be conducted in high-income countries (HIC)

v) To have a control group for comparison. Given that the early years represent a period of rapid growth, interventions may be effective if they slow weight gain rather than encourage weight loss

vi) Not be related to breast/formula-feeding interventions as these are linked to the field of developmental origins

18. Ho M et al. Effectiveness of Lifestyle Interventions in Child Obesity: Systematic Review With Meta-analysis. *Pediatrics*. 2012;130(6):e1647-e1671. doi:10.1542/peds.2012-1176

19. Cook-Cottone C et al. *A Meta-Analytic Review of Obesity Prevention in the Schools: 1997-2008*. Centre for Reviews and Dissemination (UK); 2009. Accessed December 15, 2022. https://www.ncbi.nlm.nih.gov/books/NBK76673/

Methods

A total of 18,788 records were identified for screening (see Appendix 2 for the flow chart). Two reviewers (SM and MS) independently screened on title and the abstract.

Using EPPI-Reviewer software we employed an 'active learning approach' where prioritisation of records was periodically refreshed during screening, in order that the most relevant articles were screened first. A graphical output was used to indicate when to stop screening, i.e., when the number of relevant studies had plateaued (Appendix 3).

A model was then built using the machine learning algorithm and applied to classify unscreened items with a score that indicates likely relevance to the research question; the classifier model reduced the likelihood that relevant studies were missed. The reviewers doubly extracted data.

The risk of bias for randomised studies was assessed using the CASP Randomised Controlled Trial Checklist[20] and for non-randomised studies using the NIH Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies.[21]

Both tools comprised questions about study validity and assessment of the results. The answers to the questions can be "yes", "no" or "not applicable/not reported". If at least one question was answered with "no" the study was assessed as high in risk of bias. If the questions were answered with "yes" and "not applicable/not reported", the study was assessed as moderate in risk of bias and, in case of only "yes" answers the study was assessed as low in risk of bias.

20. CASP Checklists - Critical Appraisal Skills Programme. CASP - Critical Appraisal Skills Programme. Accessed January 27, 2023. https://casp-uk.net/casp-tools-checklists/
21. Study Quality Assessment Tools | NHLBI, NIH. Accessed January 27, 2023. https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools

Methods

Data synthesis

Meta-analysis was conducted using STATA 16.[22] Studies were eligible to be included in the meta-analysis if they reported zBMI as an outcome, the most common and reliable outcome (n=23). Means, standard deviations (SDs) or 95% confidence intervals (CIs), and sample sizes were extracted from the papers.

We only included studies where follow-up measurements were consistent for all children. When effects were given over multiple follow-up assessments, the final effect (longest follow-up) was included in the analysis.

Some studies reported the adjusted mean difference between the intervention and control group and others the unadjusted. Consequently, two meta-analyses were conducted: one for the adjusted (n=15) and one for the unadjusted (n=18) effect sizes. One study with zBMI as an outcome did not provide data for the calculation of the mean difference[23] another did not provide the timing of the follow-up measurement.[24]

A fixed effect meta-analysis was undertaken given that studies were similar in design, target population, and intervention components. Heterogeneity was assessed using the I^2 statistic (an I^2 greater than 50% indicates high heterogeneity). We also assessed publication bias by performing the Egger's and Begg's tests, and the trim-and-fill method.

22. Statistical software for data science | Stata. Accessed January 27, 2023. https://www.stata.com/

23. Lumeng JC et al. Improving Self-Regulation for Obesity Prevention in Head Start: A Randomized Controlled Trial. *Pediatrics*. 2017;139(5):e20162047. doi:10.1542/peds.2016-2047

24. Woo Baidal JA et al. Childhood obesity prevention in the Women, Infants, and Children Program: Outcomes of the MA-CORD study: Childhood Obesity Prevention in WIC. *Obesity*. 2017;25(7):1167-1174. doi:10.1002/oby.21865

What we found

Description of studies

In total, 6,779 records were screened manually on title and abstract. This resulted in exclusion of 6,217 records. An additional 12,004 records were excluded by the EPPI-Reviewer software. The remaining 567 records were screened on full text. Of these, 356 records were manually excluded (See Appendix 2 for the flowchart and reasons for exclusion), resulting in 212 relevant papers. Data from an unpublished study was provided, meaning the total number of the included studies was 213.

Of these, 37 studies were eligible for this review based on the criteria for robustness. Thirty-six studies were written in English, and one was in German.[25] One study[26] included children aged 2-9 years old, so we contacted the authors who then provided the data for children aged 2-5 years. Table S1 in Appendix 4 summarises the 37 studies included in the review, which evaluate 34 unique interventions.

Interventions took place in the United States (n=16), Sweden (n=4), Australia (n=2), Belgium (n=2), Germany (n=2), Israel (n=2), United Kingdom (n=2), Canada (n=1), Denmark (n=1), Italy (n=1), Netherlands (n=1), Spain (n=1), Switzerland (n=1) and one (n=1) cross-nationally in various European countries (Table 1).

Of the 37 studies, 15 were RCTs, 13 were cluster RCTs, five quasi experimental studies, three pilot trials (n=2 pilot cluster RCTs, n=1 pilot RCT) and one stratified randomised pragmatic trial.

25. Strauß A et al. TigerKids: Erfolgreiche Gesundheitsförderung in Kindertageseinrichtungen. *Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz*. 2011;54(3):322-329. doi:10.1007/s00103-010-1225-6

26. Mårild S et al. Impact of a community based health-promotion programme in 2- to 9-year-old children in Europe on markers of the metabolic syndrome, the IDEFICS study: Health promotion effects on the metabolic syndrome. *Obes Rev*. 2015;16:41-56. doi:10.1111/obr.12368

What we found

Description of studies

In seven studies, the upper age range of the participants at the outset was older than 5 years (Healthy Start: 2-6 years[27], POP Project[28], JolichenKids[29], Tooty Fruity Vegie[30]: 3-6 years, Ballabeina[31]: 4-6 years, Health Promotion Intervention[32]: 4-6.5 years, Health Promotion Intervention[33]: 3.8-6.8 years). Three studies provided a mean age of the participants at the onset, instead of the age range (MINISTOP:[34] 4.5(0.1), NET-Works:[35] 3.4(0.7), Improving Self-regulation for obesity prevention:[23] 4.1(0.5)). One study did not specify age but instead described participants as preschool children.[25] The study sample sizes ranged from 55 children[36] to 11,876 children.[24]

Risk of bias

Most of the randomised studies (n=29) had at least one high risk parameter and three had moderate risk parameters. All the non-randomised studies had at least one high risk parameter (See Appendix 5 for more detail).

27. Olsen NJ et al. Primary prevention of fat and weight gain among obesity susceptible healthy weight preschool children. Main results from the "Healthy Start" randomized controlled intervention. *Pediatr Obes*. 2021;16(4):e12736. doi:10.1111/ijpo.12736

28. Coen VD et al. Effects of a 2-year healthy eating and physical activity intervention for 3–6-year-olds in communities of high and low socio-economic status: the POP (Prevention of Overweight among Pre-school and school children) project. *Public Health Nutr*. 2012;15(9):1737-1745. doi:10.1017/S1368980012000687

29. Steenbock B et al. Impact of the intervention program "JolinchenKids – fit and healthy in daycare" on energy balance related-behaviors: results of a cluster controlled trial. *BMC Pediatr*. 2019;19(1):432. doi:10.1186/s12887-019-1817-8

30. Zask A et al. Tooty Fruity Vegie: an obesity prevention intervention evaluation in Australian preschools. *Health Promot J Aust Off J Aust Assoc Health Promot Prof*. 2012;23(1):10-15. doi:10.1071/he12010

31. Puder JJ et al. Effect of multidimensional lifestyle intervention on fitness and adiposity in predominantly migrant preschool children (Ballabeina): cluster randomised controlled trial. *BMJ*. 2011;343(oct13 2):d6195-d6195. doi:10.1136/bmj.d6195

32. Nemet D et al. Health promotion intervention in Arab-Israeli kindergarten children. *J Pediatr Endocrinol Metab*. 2011;24(11-12):1001-1007. doi:10.1515/JPEM.2011.387

33. Nemet D et al. Health Promotion Intervention in Low Socioeconomic Kindergarten Children. *J Pediatr*. 2011;158(5):796-801.e1. doi:10.1016/j.jpeds.2010.10.040

34. Delisle Nyström C et al. A 12-month follow-up of a mobile-based (mHealth) obesity prevention intervention in pre-school children: the MINISTOP randomized controlled trial. *BMC Public Health*. 2018;18(1):658. doi:10.1186/s12889-018-5569-4

35. French SA et al. Multicomponent Obesity Prevention Intervention in Low-Income Preschoolers: Primary and Subgroup Analyses of the NET-Works Randomized Clinical Trial, 2012–2017. *Am J Public Health*. 2018;108(12):1695-1706. doi:10.2105/AJPH.2018.304696

36. Haines J et al. Guelph Family Health Study: pilot study of a home-based obesity prevention intervention. *Can J Public Health*. 2018;109(4):549-560. doi:10.17269/s41997-018-0072-3

What we found

Intervention setting

Most of the interventions (26/37) were community based (i.e., preschools, kindergartens, nurseries, day care centres, childcare centres, health care centres, clinics) our were home based[36,37,38,39] and five were delivered in multiple settings (Be active, Eat healthy[40] in early years centres and in families, CHILE[41] in head start centres, families and community, NET-Works[35] at homes and in the community, SuperFIT[42] at preschools, families and community, Keys[43] at child care centres and families). One intervention (MINISTOP, n=2 evaluation studies) was delivered to parents via a smartphone application.[34,44] Intervention components

All interventions had both diet and physical activity components. Diet-related components included sessions, workshops or information about diet, healthy snacking, cooking, or nutrition. Physical activity-related components included lectures or brochures on physical activity, training or exercising. Some of the interventions (n=12) addressed the use of screens and media; for example, by surveying mothers on the time that their children spent watching TV45 or by teacher-delivered sessions on media use.31

Some interventions (n=6) made changes in the environment to support behaviour change; for example, alterations to playgrounds to encourage physical activity and easier access to sports equipment30 or installation of water fountains or increased availability of fruits and vegetables at preschools.28

Similar to the studies identified in our review of UK-based interventions that had parental involvement, 32 of the included studies (excluding those in the UK) had parental involvement, e.g., participation in diet- and/or physical activity-related workshops or interviews, or information sheets with recipes, or activities for parents and children.

37. Haines J et al. Healthy Habits, Happy Homes: Randomized Trial to Improve Household Routines for Obesity Prevention Among Preschool-Aged Children. *JAMA Pediatr*. 2013;167(11):1072-1079. doi:10.1001/jamapediatrics.2013.2356
38. Morshed AB et al. The Impact of a Healthy Weight Intervention Embedded in a Home-Visiting Program on Children's Weight and Mothers' Feeding Practices. *J Nutr Educ Behav*. 2019;51(2):237-244. doi:10.1016/j.jneb.2018.09.001
39. Østbye T et al. Parent-focused change to prevent obesity in preschoolers: Results from the KAN-DO study. *Prev Med*. 2012;55(3):188-195. doi:10.1016/j.ypmed.2012.06.005
40. Hodgkinson A et al. An educational intervention to prevent overweight in pre-school years: a cluster randomised trial with a focus on disadvantaged families. *BMC Public Health*. 2019;19(1):1430. doi:10.1186/s12889-019-7595-2
41. Davis SM et al. CHILE: Outcomes of a group randomized controlled trial of an intervention to prevent obesity in preschool Hispanic and American Indian children. *Prev Med*. 2016;89:162-168. doi:10.1016/j.ypmed.2016.05.018
42. van de Kolk I et al. The Effects of a Comprehensive, Integrated Obesity Prevention Intervention Approach (SuperFIT) on Children's Physical Activity, Sedentary Behavior, and BMI Z-Score. *Int J Environ Res Public Health*. 2019;16(24):5016.
43. Ward DS et al. Keys to healthy family child care homes: Results from a cluster randomized trial. *Prev Med*. 2020;132:105974. doi:10.1016/j.ypmed.2019.105974
44. Delisle Nyström C et al. Mobile-based intervention intended to stop obesity in preschool-aged children: the MINISTOP randomized controlled trial. *Am J Clin Nutr*. Published online April 26, 2017:ajcn150995. doi:10.3945/ajcn.116.150995
45. Cloutier MM et al. Outcomes from a Pediatric Primary Care Weight Management Program: Steps to Growing Up Healthy. J Pediatr. 2015;167(2):372-377.e1. doi:10.1016/j.jpeds.2015.05.028

What we found

Intervention duration and follow up

Intervention duration varied (range: 6-39 months), with most interventions (n=21) lasting between six and 11 months, 12 interventions lasted for 12-24 months,[24–28,38,41,46–50] and four interventions lasted for more than 24 months.[35,51–53] Follow-up duration also varied. Most of the studies (n=22) reported the follow up measurements at the end of the intervention and eight in the middle.[24,25,35,38,41,46,48,53]

There were three studies that obtained follow-up measurements after the end of the intervention period;[39,40,52] three measured anthropometrics immediately after the intervention and a while after the end of it (one and two years after,[50] six months after,[42] 1.5 year after[54]) and one at three timepoints, in the middle, immediately after and six months after the end of the intervention (Table 1).[55]

Intervention effects (Table 1)

The most common outcome reported was zBMI, with 23 of the studies providing data on the mean change in zBMI between intervention and control groups (Table S1). In 15 of those, zBMI decreased in the intervention compared to the control group, while in five, this difference was significant. [30,40,49,56,57] Reductions were also observed in studies that reported alternative anthropometric measures. Specifically, eight studies reported BMI percentile as an outcome: In six, BMI percentile was reduced in the intervention compared to the control group; in four of those significantly.[32,45,47,49] Out of the eight studies that reported BMI change, six showed reductions, of which two were significant.[32,37] In five out of six studies there was a reduction in body fat (percentage or index); in three of which the difference was significant.[27,31,36] Five out of six interventions resulted in a decrease in waist circumference, three of which were significant.[30,31,58]

46. Campbell KJ et al. A parent-focused intervention to reduce infant obesity risk behaviors: A randomized trial. *Pediatrics*. 2013;131(4):652-660.

47. Natale RA et al. Obesity Prevention Program in Childcare Centers: Two-Year Follow-Up. *Am J Health Promot*. 2017;31(6):502-510.

48. Sanders LM et al. A Health-Literacy Intervention for Early Childhood Obesity Prevention: A Cluster-Randomized Controlled Trial. *Pediatrics*. 2021;147(5)

49. Sharma SV et al. Impact of the Coordinated Approach to Child Health Early Childhood Program for Obesity Prevention among Preschool Children: The Texas Childhood Obesity Research Demonstration Study. *Child Obes*. 2019;15(1):1-13.

50. Stookey JD et al. Healthy apple program to support child care centers to alter nutrition and physical activity practices and improve child weight: a cluster randomized trial. *BMC Public Health*. 2017;17(1):965.

51. Döring N et al. Motivational Interviewing to Prevent Childhood Obesity: A Cluster RCT. *Pediatrics*. 2016;137(5):e20153104. doi:10.1542/peds.

52. Enö Persson J et al. Prevention of Childhood Obesity in Child Health Services: Follow-Up of the PRIMROSE Trial. *Child Obes*. 2018;14(2):99-105.

53. Peñalvo JL et al. The SI! Program for Cardiovascular Health Promotion in Early Childhood. *J Am Coll Cardiol*. 2015;66(14):1525-1534.

54. Iaia M et al. An educational intervention to promote healthy lifestyles in preschool children: a cluster-RCT. *Int J Obes*. 2017;41(4):582-590.

55.Natale RA et al. Effect of a Child Care Center-Based Obesity Prevention Program on Body Mass Index and Nutrition Practices Among Preschool-Aged Children. *Health Promot Pract*. 2014;15(5):695-705.

56. Alkon A et al. Nutrition and physical activity randomized control trial in child care centers improves knowledge, policies, and children's body mass index. BMC Public Health. 2014;14(1):215. doi:10.1186/1471-2458-14-215

57. Verbestel V et al. Prevention of overweight in children younger than 2 years old: a pilot cluster-randomized controlled trial. Public Health Nutr. 2014;17(6):1384-1392. doi:10.1017/S1368980013001353

58. Lanigan J et al. The TrimTots Healthy Lifestyle Programme for prevention of obesity in preschool children: evidence from 2 randomised controlled trials. Unpublished.

Table 1. Summary of effects

Outcome	N studies	Country	Duration range	FU duration range	Findings (vs control)	Significance (vs control)	RoB
zBMI	23	USA (n=13) Australia (n=2) Belgium (n=2) UK (n=2) Italy (n=1) cross-nationally in Europe (n=1) Denmark (n=1) Netherlands (n=1)	6 months to 3 years	3 months post baseline to 2 years post intervention end	Range: -0.74 to 0.07 (z-score BMI) - 16 studies showed reduction -6 studies showed increase -1 study showed no change	Range: -0.74 to -0.14 -5 studies showed significant reduction	High (n=20) Moderate(n=3)
BMI percentile	9	USA (n=7) Israel (n=2)	9 months to 3 years	12 months post baseline to 2 years post intervention end	Range: -6.5 to 1.42 (percentile reduction) -7 studies showed reduction -2 studies showed increase	Range: -6.5 to -0.23 -4 studies showed significant reductions	High (n=8) Moderate(n=1)
BMI	9	USA (n=4) Sweden (n=2) Israel (n=2) Switzerland (n=1)	6 months to 39 months	6 months post baseline to 1 year post intervention end	Range: -0.4 to 0.21 (kg/m2) -6 studies showed reduction -3 studies showed increase	Range: -0.4 to -0.11 -3 studies showed significant reductions	High (n=9)
Waist Circumference	6	Sweden (n=1) UK (n=1) Denmark (n=1) Spain (n=1) Switzerland (n=1) Australia (n=1)	6 months to 39 months	6 months post baseline to 39 months post baseline	Range: -2.8 to 0.31 (cms) -4 studies showed reduction -2 studies showed increase	Range -2.8 to -0.8 -3 studies showed significant reductions	High (n=6)
Body fat percentage	4	Canada (n=1) Denmark (n=1) Switzerland (n=1) Germany (n=1)	6 months to 1.3 years	6 months post baseline to 1.3 years post baseline	Range: -3.54 to 0.60 (% change) -3 studies showed reduction -1 study showed increase	Range: -3.54 to -1.1 -2 studies showed significant reductions	High (n=3) Moderate(n=1)
Z-score waist circumference	1	cross-nationally in Europe (n=1)	2 years	2 years post baseline	0.12 (z-score waist) - 1 study showed increase in z-waist	0.12 -1 study showed significant increase	High (n=1)
Fat mass index	2	Sweden (n=2)	6 months	6 months post intervention	Range: -0.03 to 0.06 (fat mass kg/m2) -1 study showed reduction -1 study showed increase	none	High (n=2)
Fat free mass index	2	Sweden (n=2)	6 months	6 months post intervention	Range: 0.14 to 0.14 (fat free mass kg/m2) - 2 studies showed increase in fat free mass index	Range: 0.14 to 0.14 - 2 studies showed significant increase in fat free mass index	High (n=2)
Fat free mass (kg)	1	Denmark (n=1)	1.3 years	1.3-year post baseline	0.37 (kg) - 1 study showed increase in fat free mass	none	High (n=1)
Waist to hip ratio (WHR)	1	Denmark (n=1)	1.3 years	1.3-year post baseline	0.01 (W:H ration) - 1 study showed increase in WHR	none	High (n=1)
Subscapular skinfold z-score	1	Spain (n=1)	3 years	3 years post baseline	-0.22 (z-score skinfold) - 1 study showed increase in subscapular skinfold z-score	-0.22 - 1 study showed significant increase in subscapular skinfold z-score	High (n=1)

What we found

Meta-analysis of the adjusted zBMI (Figure 1)

Of the 37 studies included in the review, 14 (reporting on 15 trials) were appropriate for meta-analysis. In each study, the zBMI change was adjusted for different variables, often for demographics (age, sex, ethnicity) and baseline BMI. The forest plot for the adjusted mean zBMI difference is shown in Figure 1.

Overall, interventions were effective in reducing zBMI among children aged 0-5 years, compared to control [pooled effect size: -0.03 (95% CIs: -0.06, -0.00), p=0.03]. This effect size might be small, but it can be meaningful at population level. The heterogeneity of the studies was moderate (I^2=27.0%). We conducted subgroup analyses for intervention duration and follow-up duration, but no effects were found.

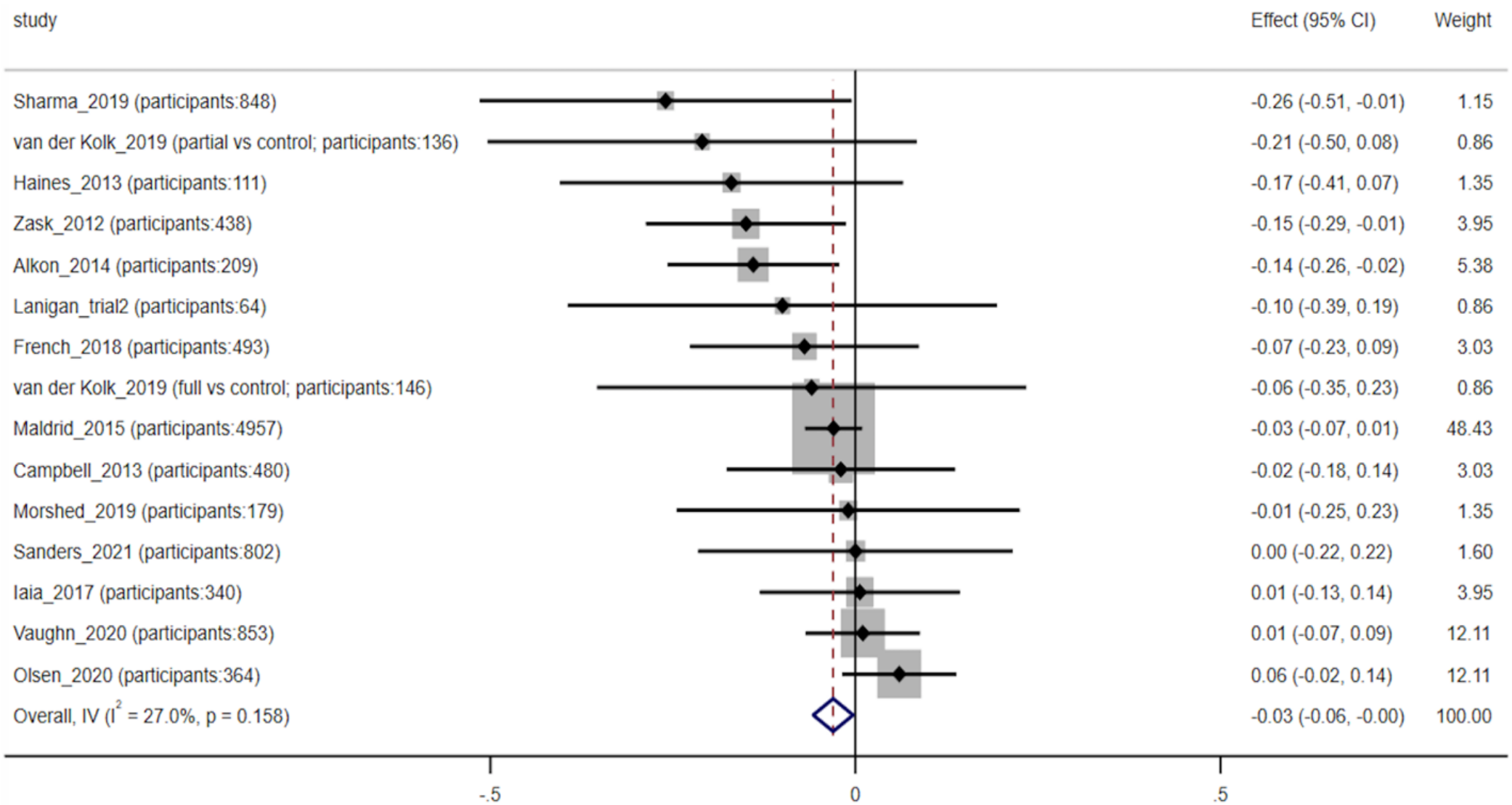
Meta-analysis of the unadjusted zBMI

- We also conducted a further meta-analysis showing the unadjusted effects (17 studies reporting 18 trials). The overall effect size was -0.28 (95% CIs: -0.32, -0.24), p<0.001, indicating a significant reduction in zBMI among children in the intervention group compared to the control group. The heterogeneity between the studies was high (I^2=99.0%).

Publication bias

- The publication bias assessment indicated no bias; however, the trim-and-fill method showed that there was bias towards published studies, with four studies reporting an increase of zBMI missing (See Appendix 7 for the funnel plot).

Figure 1: Effects of the interventions on zBMI – Intervention vs control



Case studies of good practice

PRIMROSE and **Ballabeina** trials were two case studies of robust interventions that were well-designed and delivered, were evaluated through RCTs, had large sample sizes and were effective in reducing anthropometric outcomes. Further details are provided here:

PRIMROSE trial in Sweden

A large-scale intervention delivered in child health care centres by nurses to first time parents and their children. It started when the children were nine months old and lasted for 39 months. The intervention aimed to promote healthy eating and physical activity habits. It consisted of a group session and eight individual sessions with the application of motivational interviewing and principles of cognitive behavioural therapy. It aimed to motivate the parents to obtain or maintain healthy lifestyles and subsequently become role models for their children. As the children were getting older, parents were provided with skills on how to directly influence their child's eating and physical activity habits. It was evaluated through a cluster randomised controlled trial and found reductions in BMI, waist circumference and prevalence of overweight in the intervention group, compared to the control. One year after the intervention, the reduction in BMI were sustained and children in the intervention group were found to have a lower risk of having overweight or obesity compared to children in the control group.

Ballabeina trial in Switzerland

A preschool intervention delivered at individual (children, teachers, parents) and environmental (school curriculum, built environment) levels. The intervention aimed to change the education, attitude and behaviour and provide social support. It lasted 10 months. Children participated in a physical activity program consisting of four 45 min sessions of PA per week. The PA lessons aimed to increase aerobic fitness and coordination skills; they were designed to be playful and organised into themes (e.g., "Clown, Spiderman"). Additionally, there were 22 lessons on healthy nutrition, media use, and sleep. Positive and culturally independent nutritional messages were based on the five recommendations of the Swiss Society of Nutrition ("drink water," "eat fruit and vegetables," "eat regularly," "make clever choices," "turn your screen off when you eat"). Every other week children received a new funny physical activity or nutrition activity card to take home. In addition, healthy snacks during recess and healthy treats for anniversaries were promoted and preschool classes exclusively offered their children water and healthy food. Parents participated in discussions about promoting PA, healthy eating, limitation of TV and importance of sleep. There were made changes in the preschool environment such as installation of climbing walls, hammocks, balls and cords, that aimed to promote physical activity during breaks. It was evaluated through a cluster randomised controlled trial and found reductions in body fat percentage, waist circumference and prevalence of overweight right after the intervention end.

Discussion

We reviewed the international evidence of robust universal obesity interventions for young children (0-5 years old) of any weight status. Compared to control, we found decreases in anthropometric outcomes in 28 studies (i.e., reductions in zBMI, BMI, BMI percentile, fat mass, waist circumference, skinfold z-score, overweight, and obesity rates), 12 of which were significant. Meta-analysis of 15 studies that reported zBMI-adjusted effects, showed that interventions were effective in reducing the zBMI in intervention groups compared to control.

We found a small but significant effect size, which is important for children of any weight status, meaning that universal obesity interventions can enable healthy growth. Scale-up of these interventions in the UK context has the potential to encourage healthier lifestyles. Our meta-analysis found a smaller effect size than existing evidence; a recent review of universal multicomponent interventions among children aged 0-5 years showed an effect size of -0.07.[59]

However, that meta-analysis included 16 studies in total; six of which reported unadjusted effects, which may have resulted in a higher overall effect size.

The sustainability of intervention effects would likely require ongoing management. In this review, only four interventions had follow-up measurements of more than a year after the intervention ended. Of these interventions, only the Be Active, Eat Healthy intervention showed a significant reduction in zBMI at follow-up, which was 18 months after the intervention ended.

Time and financial constrains often hinder intervention providers from carrying out longer-term follow-ups. Participants often regain lost weight due to changes homoeostasis, metabolic adaptations, and inflammatory responses.[60–62] Evaluations of interventions with longer follow-up durations would allow assessment of long-term benefits.

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62. van Baak MA et al. Mechanisms of weight regain after weight loss — the role of adipose tissue. *Nat Rev Endocrinol*. 2019;15(5):274-287. doi:10.1038/s41574-018-0148-4

Discussion

Most of the studies (34/37) included in this review featured parental involvement, which has been suggested to be an important component in the effectiveness of obesity interventions in the early years.[63] Young children spend many hours of the day with their parents or caregivers and are influenced by their behaviours and attitudes. Parental dietary and physical activity behaviours[64,65] are significantly related to the child's, meaning that involving parents in the process of behaviour change would be likely to increase the success of an intervention.

Effective interventions are likely to account for the obesogenic environment and the structural determinants that contribute to excess weight gain. Intensive marketing of unhealthy foods, and their high availability often lead children and families to overeat or consume foods of low nutritional value. [66,67] We found interventions that attempted to improve environments (e.g., buying or making sports equipment more available and increasing the visibility of healthy foods) were effective and may be more likely to have lasting impacts,[68] while workshops or home visits conducted for short periods may be less likely to have sustained effects.

There are inequalities in engagement with interventions and healthcare services generally.[69] There is a need for interventions that target individual and structural determinants to reach across the socioeconomic spectrum;[69] for example, interventions that enhance the affordability of healthy food and accessibility of health services for disadvantaged families, or interventions that improve the provisioning or availability of facilities and green space.[69]

An example of an early years programme that could reduce inequalities in obesity is the Head Start Service in the US. This service supports children and their families from birth to 5 years, focusing on the child's development and health by engaging children in physical activity, educating them about healthy nutrition, and monitoring their weight. There is no cost for this programme, with enhanced accessibility for disadvantaged and low-income families.[70]

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Discussion

This systematic review and meta-analysis of universal obesity interventions from high-income countries found evidence that multicomponent interventions can be effective at reducing zBMI in children aged 0-5 years. The large number of studies included in this review indicates a broad evidence base. Effective multicomponent interventions often had parental involvement and induced behaviour change.

The international evidence, which includes interventions that adhere to NICE guidance (such as NET-Works, Guelph Family Health Study, Steps to Growing up Healthy[35,36,45]) may present useful case studies for policymakers, local authorities, and public health practitioners in the UK. Consistent and systematic implementation of effective studies in the UK can be meaningful and can lead to a considerable reduction of obesity and improvement of healthy growth in the population.

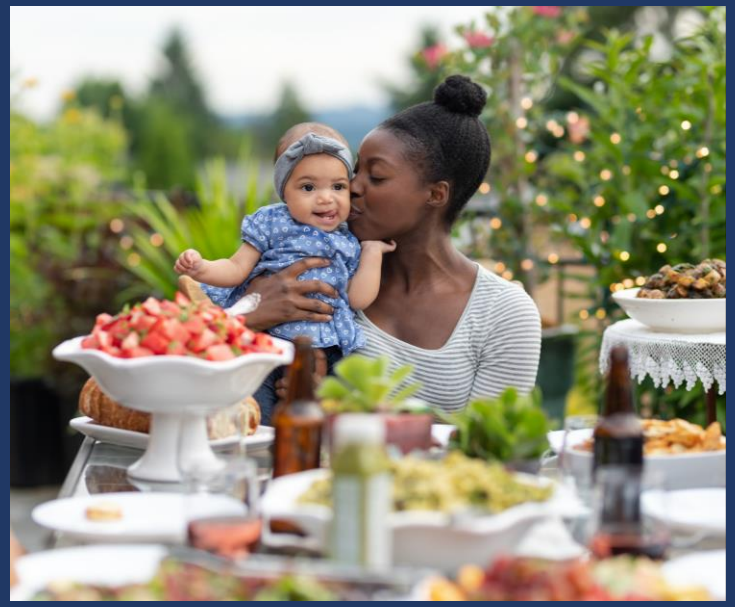
Promoting a healthy diet and a physically active lifestyle have numerous health benefits beyond the promotion of healthy weight.

Limitations

Our search strategy yielded a high number of records and we used EPPI-Reviewer software to apply an active learning approach, which reduced screening time but resulted in 12,004 records being excluded without being screened. We chose to include only studies that reported anthropometric outcomes, as these would be the most powerful in assessing effectiveness. Objectively recorded anthropometric outcomes are less prone to measurement bias than assessing energy balance behaviours such as dietary intake or sedentary time. However, we acknowledge there may be interventions that are effective in changing energy balance behaviours that are not included in this review. We also excluded studies published before 2011; however, previous reviews of obesity interventions among young children indicate very few relevant studies published before 2011.[59]

Policy Relevance

The international evidence shows that universal interventions can support in the prevention of obesity. Effectiveness was irrespective of the intervention duration or the follow-up duration, meaning the intervention components are likely to be the most important factor in determining effectiveness. We provided some case studies of interventions that appeared to be successful and well-designed; however, the settings and contexts in which interventions are delivered are also likely to be important. Scaling-up interventions from trials to broader populations also presents challenges but the PIET-T model (P: population, I: intervention, E: environment, T: transfer, -T: transferability) is a useful tool that assesses the contexts of interventions and the likelihood of intervention transferability.[71] Intervention development requires careful consideration of the evidence base, likely intended and unintended outcomes, the theoretical underpinning of an intervention, and its effect on the wider system in order to support real-world decision-making.[72]



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