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The effectiveness of e-health interventions for the treatment of overweight or obesity in children and adolescents: a systematic review and meta-analysis

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Abstract

The aim of this systematic review and meta-analysis was to examine the effectiveness of e-health interventions for the treatment of children and adolescents with overweight or obesity. Databases were searched up to November 2020. Studies were randomised controlled trials where interventions were delivered via e-health (e.g. computers, tablets, smartphones, but not phone calls). Studies should target the treatment of overweight or obesity in children or their agent of changes and report BMI or BMI-z score. A meta-analysis using a random-effects model was conducted. Nineteen studies met the inclusion criteria, and 60% were of high quality. The narrative review revealed variation in behaviour change strategies and modes of delivery. The pooled mean reduction in BMI or BMI z-score showed evidence for a non-zero effect (standardised mean difference = -0.31, 95% confidence interval -0.49 to -0.13), with moderately high heterogeneity between studies ($I^2 = 74\%$, $p < 0.001$). Subgroup analysis revealed high heterogeneity in studies with a high or unclear risk of bias. E-health interventions can be effective in treating children and adolescents with overweight and obesity and should be considered by practitioners and policymakers. However, an understanding of the most effective and acceptable intervention components, long-term benefits and sustainability should be further studied.

Introduction

Childhood obesity is a serious public health issue, with over 340 million children and adolescents between the ages of 5 and 19 years worldwide classified as living with overweight or obesity according to the World Health Organisation in 2016.¹ Obesity in children and adolescents can result in the early onset of cardio-metabolic risk,² musculoskeletal,³ respiratory,⁴ digestive⁵ and psycho-social⁶ problems. There is also evidence from a meta-analysis that childhood obesity is associated with moderately increased risks of adult obesity-related morbidity.⁷ The resulting economic consequences can be significant, contributing to the increased burden of the healthcare system, including high treatment costs for obesity-related diseases, such as diabetes, heart diseases and cancer.⁸ However, as obesity is a complex chronic relapsing condition, successful long-term treatment remains a challenge.⁹

A series of six Cochrane systematic reviews have recently examined the effectiveness of treatment interventions for the management of overweight and obesity in children: including surgery, drugs, parent-only programmes, and lifestyle interventions.¹⁰⁻¹⁵ This collective evidence demonstrated that multi-component interventions that were traditionally delivered face-to-face across different settings lead to significant but small reductions in children's body weight status. However, the cost-effectiveness of interventions was not frequently assessed, and there was insufficient evidence on the scalability, generalisability and long-term sustainability of the interventions. Equally, the effectiveness of digitally delivered interventions used for the treatment of overweight and obesity in children remains unclear.¹⁶ However, issues such as sustainability¹⁷ and

generalisability (i.e. targeting disadvantage populations and access into rural areas)¹⁸ might still remain with digitally delivered intervention.

Digitally delivered interventions, commonly called e-health, are defined as the use of information and communication technologies (ICT) to enable and/or improve health care delivery and health outcomes,¹⁹ and may provide an opportunity to enhance the quality, efficiency, and reach of primary and secondary healthcare.²⁰ However, public engagement with e-health services is variable, and there is a need to improve access,²¹ in particular to children with overweight and obese from economic and social disadvantage background which are disproportionately affected.^{22,23} However, interventions designed to improve obesogenic behaviour in socioeconomic depressed areas and ethnic minority groups are challenging and usually require a multicomponent approach.^{24,25} Recently, the COVID-19 pandemic brought many challenges to the health sector in which the worldwide health community had to quickly adapt to deliver services.²⁶ This brought e-health to the spotlight of the health system,^{27,28} not only for primary and secondary care,²⁹ but also for health promotion initiatives.^{30,31}

Systematic reviews have shown that e-health interventions could be effective for the treatment of obesity in adults.³²⁻³⁴ However, there is high heterogeneity across studies,^{32,34} and a poor understanding of the particular features that can improve the intervention effect.³² Many reviews also concluded a need for more rigorous and population-specific research,^{32,35} and a need to examine long-term sustainability.³³

A recent scoping review revealed that for adults, the majority of the e-health intervention studies focusing on treatment or prevention of overweight and obesity examined the effectiveness of these interventions (n=98, 92.5%). However, very few evaluated

intervention components associated with success (n = 7, 6.6%).³⁶ Other systematic reviews also attempted to examine intervention components, theory use and behaviour change techniques; however, they focused on young adults (over 17 years) and on weight management rather than the treatment of overweight and obesity.³⁷⁻³⁹ Therefore, systematic reviews focusing on the understanding of the effective components of e-health interventions for treatment of overweight and obesity in children are needed.

It is assumed that children and adolescents, who are ubiquitous users of digital technology,⁴⁰ will readily engage in e-health lifestyle interventions.⁴¹ There is also evidence to suggest that children, adolescents and parents would prefer to receive lifestyle behaviour change information from the computer or mobile and via the internet compared to printed materials.^{41,42} As a result, e-health interventions are becoming more commonly used in children on self-management of behaviours that have an impact on health conditions.^{43,44} However, the long-term sustainability of e-health interventions could be an issue because of the fast-moving pace of technology, when by the point of implementing, technology might be obsolete and may result in children becoming bored affecting adherence and sustainability.⁴⁵

In a survey, study parents showed interest in eHealth programs.⁴⁶ They reported that they wanted a service that was endorsed by reputable involved both themselves and their children, and was practical, engaging, and tailored to their needs. For younger children, e-health interventions would still require parental engagement. However, it will offer additional benefits that overcome traditional barriers, including the increased reach of services as the location is less of an issue, the need for parents to take time off work, and

the ability for more than one parent/caregiver to attend as there can be multiple people joining a call.⁴⁷

Systematic review evidence has demonstrated that the use of the internet by children or their parents can improve disease knowledge, health outcomes, health care utilisation, and quality of life in children aged six to 18 years.⁴³ Similarly, a meta-analysis found a positive small significant effect of paediatric e-health interventions on illness self-management (e.g. asthma, diabetes) and behaviour change (e.g. diet, physical activity, smoking).⁴⁴

Systematic reviews have examined the effectiveness of e-health interventions, combining prevention and treatment of obesity in children.⁴⁸⁻⁵³ However, just a few specifically focused on the treatment of obesity, defined as interventions which target only children with overweight and obesity rather than mixed weight.⁵⁴⁻⁵⁶ Smith et al., 2013⁵⁷ explored the use of technology for patient screening and treatment of obesity, whilst Chaplais et al., 2015⁵⁵ investigated the effect of smartphones to deliver treatment for overweight and obesity in children. Finally, Darling & Sato 2017⁵⁶ conducted a meta-analysis focused only on mobile health technologies using self-monitoring for weight management in children. These systematic reviews found small and sometimes inconsistent results regarding different e-health interventions for the treatment of obesity.

However, two meta-analyses explored the effect of both treatment and prevention of obesity using e-health interventions.^{49,52} Hammersley et al. 2016 examined the effect of e-health interventions where parents or carers were the agent of change,⁴⁹ while Fowler et al., 2021⁵² assessed e-health interventions that also included phone calls as part of the technology-based intervention. The Hammersley et al. (2016)⁴⁹ meta-analysis included five studies and found a non-significant effect on BMI or BMI-z score, while Fowler et al. (2021)

⁵² included a larger number of studies (n= 32) and found a significant effect on weight outcomes.

The meta-analyses on e-health intervention for the treatment of overweight and obesity so far published do not limit the duration of the intervention delivery. However, there is evidence that although interventions appeared to be effective in the short- term, they may not be in the long term (> 6 months),⁵⁸ in particular e-health interventions seem to have a greater effect on shorter intervention duration.⁵²

Therefore, this narrative systematic review and meta-analysis aimed to examine the effectiveness of e-health interventions for the treatment of overweight or obesity in children (0 to 17 years old). The secondary aim was to explore subgroup differences according to age, weight status, duration, behaviours targeted, income and study quality on intervention outcomes and provide a narrative synthesis to gather knowledge of the components of e-health interventions to guide future research and implementation.⁴⁸ This systematic review distinguishes it from others as it targets the child or agent of change (e.g. parent/ career, teachers, peers) and use a range of e-health intervention delivery methods (e.g. computer, tablets, SMS, digital games but not phone calls). However, interventions should be delivered for a minimum of six months.

METHODS

This systematic review was based on the methodological approaches defined in the Cochrane Handbook for Systematic Reviewers⁵⁹ and is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses criteria.⁶⁰ An *a priori* protocol was published in Prospero (registration CRD42019133807).

Study inclusion and exclusion criteria

We included randomised controlled trials (RCTs), where randomisation was implemented at individual or cluster level. Cross-over trials were also included if they were randomised and met the other inclusion criteria. However, only the first period of data from each arm in a cross-over trial was extracted and analysed to avoid contamination.

We included studies with children and adolescents with a mean age of 17 years or less with overweight or obesity at the start of the intervention, as defined by the authors using local or international growth reference or standards. Studies involving children with comorbid disorders were included as long as the study was not delivered to critically ill participants (e.g. morbid obesity), or participants with the secondary or syndromic cause of obesity (e.g. Down's syndrome or Prader-Willi syndrome). The primary aim of the intervention has to focus on the treatment of overweight or obesity or target only children with overweight and obesity rather than mixed weight. Studies were also excluded if they were delivered to pregnant participants. We included studies if they targeted parents or carers as the sole agent for change in their child or adolescent.

This review considered any behaviour change interventions, which aimed to treat paediatric overweight or obesity. Interventions had to be delivered using 'eHealth' or m-health, defined as interventions delivered via computers, tablets, mobile/smartphones, personal digital assistants (PDAs), internet, wearable tracking devices and digital games but not phone calls. E-health interventions could be delivered alone or in combination with other intervention delivery methods, for example, face to face, phone calls, printed materials or exercise training sessions. Phone calls alone as a mode of delivery were not included as this review focuses on modern-based technology that is more frequently used by the younger

generation (e.g. text messages, e-mails). Interventions could also be delivered in any settings.

We included any comparator intervention such as no intervention, wait-list control, standard or usual care or concomitant intervention (another behaviour-change intervention, which was also delivered in the intervention group). To be included, the minimum duration of the intervention had to be six months from baseline. Studies must have objectively measured (not-self-reported) weight and height and provided BMI (body mass index) or BMI z-score.

Search strategy

The following eight databases were searched: MEDLINE; Cochrane Central Register of Controlled Trials; Embase; PsycINFO; CINAHL; LILACS; ClinicalTrials.gov; World Health Organization International Clinical Trials Registry Platform (ICTRP). Databases were initially searched up to November 2020. A pilot search strategy was tested in Medline and examined if it retrieved papers that were already known by the team. An example of a search strategy (e.g. MEDLINE) is provided in Supporting information 1. Searches were restricted to articles published in the English language only. However, no publication date restriction was applied. Citations were imported into EndNote reference management software (version X7.8, Thomson Reuters), and duplicates were removed. References of included articles and relevant reviews identified in the search were hand searched for additional relevant publications.

Screening and article selection were conducted using Covidence systematic review software (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org). Title and abstract screening were undertaken by one of

the 11 reviewers (MH, LA, SAN, CO, AVG, TB, AH, LKC, EG, AD and DJ) following the pre-specified eligibility criteria. All excluded titles and abstracts were second-screened by two reviewers (CO and MH). Full texts of eligible studies were subsequently obtained and screened independently by any two reviewers (MH, LA, CC, AMG, TB, AH, LKC, EG, AD and DJ). Discrepancies were resolved by consultation with a third reviewer (LA or MH).

Data extraction

Standardised data extraction tables were created. For trials that fulfilled our inclusion criteria, two reviewers (two of MH, LA, CC, SAN, CO, LE, TB, LKC, AD and DJ) independently extracted data using a pre-piloted data extraction form and discrepancies were discussed between the two review authors until a consensus was reached. All extracted data was checked by the main author (LA).

The reviewers extracted the following information: study information (i.e. authors, year, study country); study design (i.e. aim or question, description of study design, the timing of follow-ups); population (i.e. recruitment setting, number of children in the intervention and control groups, age, gender, ethnicity and population weight category); intervention (i.e. behaviours targeted, the theoretical basis for intervention and behaviour change technique (BCT), mode and dose of delivery, description of intervention and technology used); outcome measures (i.e. baseline and follow-up BMI or BMI z-score); analysis (i.e. statistical analysis performed, whether intention-to-treat was conducted and if crude or adjusted results were presented).

Critical appraisal

Working in pairs, two review authors (two of MH, LA, CC, SAN, CO, LE, TB, LKC, AD and DJ) independently evaluated the risk of bias for included studies. Completed critical appraisals were compared, and any inconsistencies were resolved by a third reviewer (LA).

The risk of bias of included studies was assessed according to the Cochrane Handbook of Systematic Reviews of Interventions.⁵⁹ Seven domains were scored: sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting and 'other' (e.g. bias related to the study design implemented, extreme baseline imbalance). Each of these criteria was assigned to one of these three ratings: 'low risk of bias', 'high risk of bias' or 'unclear risk of bias'. The overall strength of the evidence was determined by the Grading of Recommendations Assessment, Development and Evaluation systems (GRADE pro 3.6). The assessment was rated as high, moderate, low, or very low based on the five domains of evidence: risk of bias, indirectness, imprecision, inconsistency and reporting bias.

Data analysis

The analysis was based on summary statistics (sample size, mean and standard deviation) of change from baseline and follow-up of BMI or BMI z-score. Three studies,⁶¹⁻⁶³ did not report the necessary statistics and therefore were not included in the meta-analysis but were reported in the narrative synthesis. Therefore, the meta-analysis was conducted on 16 studies (BMI or BMI-z scores); and 13 studies (BMI-z scores).

To examine the immediate effect of the intervention, we prioritised the follow-up data point closest to the end of the intervention to enter into the meta-analysis. Statistics were entered directly where reported, or calculated from reported baseline and follow-up measures, using standard methods for pooling standard deviations. In two studies,^{64,65}

including multiple intervention groups of interest, statistics were derived from combination of intervention groups.

We used Stata (version I/C 14.2, StataCorp) to calculate effect size synthesis and subgroup analyses. A random-effects model (using the DerSimonian and Laird method),⁶⁶ was used to derive pooled estimates of the effect of BMI z-scores using unstandardised mean differences (treatment minus control); and the effect of BMI or BMI z-scores using standardised mean differences (treatment minus control). Synthesised estimates and associated 95% confidence intervals were reported on forest plots alongside a Z-test for the standardised mean difference. Heterogeneity statistics were reported using Cochran's Q test and the I² statistic. Sensitivity analyses were conducted on both meta-analyses to assess the robustness of the derived estimates. For this analysis, each of the included studies were omitted in turn, and a meta-analysis was conducted based on the remaining studies. Funnel plots were generated for both meta-analyses to detect small study effect-related bias and indicate publication bias.⁶⁷ Subgroup analyses were conducted measuring standardised mean differences, with subgroups defined by: 1) duration of the study (6-12 months and 12 months or more); 2) age of the child (under 12 years and 12-17 years); 3) weight status (overweight and obesity and obesity only); 3) behaviour targeted (three behaviours and two or one behaviour); 4) socioeconomic status (low income and mixed or not reported income) 4) study quality (low risk of bias and high risk of bias or unclear bias). Within-groups and between groups effects were derived for all subgroups.

Results

Description of the included studies

The search yielded a total of 29,198 papers, of which 19 met the inclusion criteria and were included in this review (Figure 1). Table 1 summarises the main characteristics and findings of the 19 eligible studies,^{61,62,64,65,68-82} including the intervention and BMI findings. Detailed information about study aims, population setting, intervention and authors' conclusion is provided in Supporting information 2.

Across the studies, a total of 2,352 individuals were included. Included studies were published between 2006 and 2020. The majority of studies were conducted in the USA (n= 12),^{61,62,65,69-71,74,77-79,81} two in China^{64,73} and one in each of the following countries: Australia, New Zealand, Malaysia, Sweden and the Netherlands^{68,72,75,76,83}. The oldest included study was published in 2006.⁸²

Only two studies out of the 19 used a cluster randomised rather than an individually randomised design.^{71,78} Eleven studies were conducted with children younger than 12 years old (age range 3 to 11)^{68,70-73,76-81} while eight studies were conducted with adolescents (age range 12 to 16 years old).^{61,62,64,65,69,74,75,82} Four studies were conducted exclusively in children with obesity.^{64,65,78,80} In these studies, participants BMI percentile at baseline were above 95% for age. However, one study did not set BMI criteria and just reported that children were eligible if they had obesity.⁸⁰

The majority of the studies included a mixed ethnicity population, but two studies focused the intervention on a particular ethnicity (e.g. African American,^{69,82} and Chinese American⁵⁰). Only one study targeted children with co-morbidity disorder (i.e. intellectual disabilities).⁷³ Family income was not reported frequently. However, some reported a large proportion of their population with lower-income levels.^{64,69-71} The recruitment setting varied between clinical,^{61,62,64,65,69,72,76,78,79,81} or schools settings.^{68,70,71,73-75,77,80}

Nine e-health interventions targeted physical activity, sedentary behaviour and diet^{61,62,64,68-71,81,82}, seven interventions targeted physical activity and diet,^{65,73,74,76,78,79,83} while three interventions targeted physical activity only.^{72,75,77} Other behaviours or strategies included: daily self-monitoring of weight,⁷² psychosocial health,⁷⁶ and sleep.^{78,79} Overall, nine^{64,65,68,69,71,73,76,77,81} out of the 19 included studies specified that they used a behavioural theory to design or implement the intervention. The overall majority (16 out of 19) of the interventions targeted children and parents in the intervention, with only three studies^{69,72,74} targeting only children, including two studies that focused on teenagers.^{69,74}

The majority of the interventions (N= 12)^{61,62,64,68-75,77} were less than 12 months in duration.

The mode of delivery of the e-health intervention varied and had one or more of the following methods of delivery: websites,^{64,65,69,81,82} personal messaging (e.g. SMS, Whatsapp),^{62,64,65,68,69,74,76,78,79} wearable sensors for health monitoring (i.e. Fitbit),^{69,77} telehealth,^{61,70,71,77} mobile apps,^{72,73} social media,^{68,73} emails,^{65,73,78,79,82} active video game,^{75,77} and computer software.⁷⁸⁻⁸⁰ Only two studies offered an intervention solely delivered through e-health.^{69,75} One of the sole delivered e-health interventions offered an active video game for children to play at home,⁷⁵ while the other offered a combination of website, text messages and wearable sensors (Table 1).

Characteristics of the included studies which reported significant differences

Eight of the 19 included studies reported a significant reduction in BMI or BMI-z score in the intervention group compared to the control.^{61,68,69,72,75,77,78,82} Two successful interventions targeted only physical activity delivered through an active video game intervention at home.^{75,77} However, participants in Staiano et al., 2018⁷⁷ also received a wearable activity tracker and met via video chat with a fitness coach to create solutions to barriers to physical

activity, build self-efficacy and social support. Likewise, the two interventions that targeted specific ethnic communities (i.e. African- American,⁸² and Chinese- American⁶⁹) were also successful in reducing BMI.

Two interventions that reported significant differences in favour of the intervention group offered an online platform with an interface between the participants (i.e. primary school-age children), their parents or carers and the clinicians.^{72,78} Johansson et al. 2020⁷²

feasibility trial offered an interface between parents and clinicians through an app (for parents) and website (for clinicians) and included rewarding (e.g. gems and spirits displayed in the app), weight self-monitoring, goal setting, and strategies to increase in motivation for physical activity. The intervention showed a greater reduction in BMI-z compared to standard care. In the study of Taveras et al. 2015⁷⁸ computerised clinical decision support (CDS) with self-guided behaviour change resulted in significant improvement in childhood BMI compared to usual care. However, no significant difference was noted when CDS were combined with individualised health coaching.⁷⁸

Ahmad et al. 2018,⁶⁸ focused on parenting skills, self-monitoring, goal setting, self-efficacy, problem solving, relapse prevention, and stimulus control and was delivered through social media (i.e. Facebook) and face-to-face sessions within a university setting but included booster sessions through WhatsApp and was effective in reducing childhood adiposity.

Finally, Fleischman et al. 2016⁶¹ found that the addition of obesity specialist tele-visits in combination with primary care in-person visit was effective in reducing BMI-z compared to primary care in-person visit alone.

Risk of bias in included studies

Eleven studies were considered to have a low risk of bias, only two were high risk of bias, and the remaining eight were unclear. Figure 2 and Supporting Information 3 reports the aggregated risk of bias of studies using the Cochrane Effective Practice and Organization of Care risk-of-bias tool for randomised controlled trials.⁵⁹ The main source of bias was blinding of participants, with five reporting high risk and seven being unclear, while the second main reason was blinding of outcome assessors (i.e. six as high risk and five as unclear). Reasons for being an unclear risk of bias were no specification on how participants and outcome measures were blinded.

Meta-analysis

All the studies included in this review provided either BMI or BMI-z scores as an outcome measure. However, three studies did not report the necessary statistics,^{61,62,74} hence the meta-analysis was conducted on 16 studies. Figure 3 shows the forest plot of the meta-analysis of the pooled SMD of BMI or BMI-z score between intervention and control groups. The pooled effect size estimate from the random effects model showed a small but statistically significant difference favouring the e-health intervention groups compared to control (SMD -0.31, 95%CI: -0.49 to -0.13, $p < 0.001$). A Z-test further revealed strong evidence for a non-zero effect ($Z = 3.41$; $p = 0.001$).

There was evidence of moderately high heterogeneity levels ($I^2 = 74\%$, $p < 0.001$). However, a sensitivity analysis identified that no individual study exerted excessive influence on the results. All points of estimate lay within the 95% confidence interval, and no omitted meta-analytic estimate was significantly differing from the estimate associated with the combined analysis. Similarly, the funnel plot displayed no evidence for publication bias, with data points for only three out of 16 included studies lying marginally out of the 95% confidence

limits (Supporting information 4). The quality of the evidence for the pooled SMD outcome was rated as 'high' and is summarized in Table 2.

Fifteen^{61,62,65,68,70-72,74-81} of the studies included in this meta-analysis measured change in BMI-z scores as an outcome. Of these, the necessary statistics were obtainable from 13 studies^{61,65,68,70-72,75-81} for a meta-analysis. The unstandardised mean difference BMI-z scores from e-health treatment methods and traditional treatment methods were -0.063 (95% CI -0.089 to -0.036), with a Z-test revealing strong evidence for a non-zero effect (Z=4.66; p<0.001) and heterogeneity was moderate ($I^2 = 59.8\%$, p <0.05).

Table 3 reveals the subgroup analysis. E-health interventions were significant when delivered to children at both selected age ranges (under 12 years and 12-17 years) and duration ranges (6 to 12 months and 12 months or over). Similarly, it was effective independently of the study risk of bias (low risk and high/unclear risk). However, heterogeneity for studies with high or unclear risk of bias studies was high and significant ($I^2=90.6\%$, p<0.001), but lower and non-significant for low risk of bias studies ($I^2=33.3\%$, p=0.13). There was a non-significant pooled effect on e-health interventions that targeted only children with obesity (SMD -0.578 (-1.158, 0.002), N=4), however, this was significant for children with overweight and obesity (SMD -0.219 (-0.398, -0.041).

Interventions which targeted two (PA and diet) or one behaviour (PA only) were significantly associated with the outcome, but not when targeting three behaviours (PA, sedentary behaviour and diet). Similarly, interventions were not significantly associated with the outcome when intervention targeted low income population, but it was significant when the population was of mixed income or income not reported. Study heterogeneity was very high in these subgroup analysis (i.e. two/one behaviours and mixed income/not reported),

compared to the group they compared to (i.e. three behaviours and low-income). No significant between-subgroups effects were detected.

Discussion

This systematic review and meta-analysis explored effectiveness of e-health interventions to treat children and adolescents with overweight and obesity. Studies were predominantly of high quality (or low risk of bias) (60% of included studies). Results from a meta-analysis indicates that e-health interventions are effective for the treatment of obesity in children and adolescents. However, findings should be taken with caution as the pooled effect size is small and unclear whether clinically meaningful.

There is an ongoing debate around statistical versus clinical significance.⁸⁴ It has been argued that clinical significance reflects “the extent of change, whether the change makes a real difference to subject lives, how long the effects last, consumer acceptability, cost-effectiveness, and ease of implementation”.⁸⁵ These aspects were not explored in this review. However, others are more in favour of an operational meaning and use on what is defined as the minimum clinically important difference (MCID),⁸⁶ which is the smallest difference in score in which patients perceived as beneficial.⁸⁷ The MCID on BMI z-score to promote health benefits in children with overweight or obesity is difficult to define.⁸⁸⁻⁹⁰ As a reference score, previous systematic reviews⁹¹⁻⁹³ define a minimum reduction of 0.25 BMI z-score as a requirement for improvement in cardiometabolic risk factors in children with obesity.⁹⁰ In the current meta-analysis, the unstandardised mean difference BMI-z scores were SMD -0.063 (95% CI -0.089 to -0.036), which is substantially lower than the predefined MCID.⁹⁴ However, although the MCID can provide a threshold to serve as a treatment goal, the establishment of MCID can be challenging considering the variety of methods, loss of

the patient's perspective on the benefit of treatment and change in score depending on patient initial baseline status.⁹⁵

Another critical point to consider is the heterogeneity of studies included in the meta-analysis. Similar to another meta-analysis,⁹⁵ we found moderate heterogeneity levels on the standardised and unstandardised meta-analysis. Study quality has possibly been an important contributing factor to the observed heterogeneity. The subgroup analysis identified that heterogeneity was considerably lower in studies with low risk of bias ($I^2=33.3\%$) compared to high risk of bias studies ($I^2=90.6\%$). This was expected⁹⁶ and comparable to the findings observed in another meta-analysis for treatment of overweight and obesity in children.⁹⁷

We also attempted to investigate the components of e-health interventions. A range of e-health delivery modes were used, including SMS, WhatsApp, wearable sensors, telemedicine, mobile apps, social media, emails, active video game and web-based software. In parallel to the meta-analysis, we conducted a narrative synthesis, which identified that interventions that targeted active video games were successful in reducing BMI or BMI z-score.^{75,77} This is in agreement with a previous systematic review which has identified that exergaming could potentially impact obesity-related outcomes, although high-quality studies are lacking.⁹⁸ Other e-health methods such as social media (e.g. Facebook)^{68,73} and instant messaging (e.g. SMS and WhatsApp)^{62,64,65,68,69,74,76,78,79} showed mixed findings in our review. The use of social media on weight management has been systematically reviewed but only included studies in adults, and the authors concluded that the impact of social media was hard to access due to the varied implementation approaches,⁹⁹ and maybe more applicable for adolescent groups rather than children. A

systematic review investigating the effect of text messaging for the treatment or prevention of obesity could not fully determine the effect as it is usually embedded in multicomponent interventions.⁸⁹ Nevertheless, in a scientific statement, the American Heart Association recommends that clinicians, policymakers and researchers should consider using social media and text messaging to apply elements of behaviour change (such as stimulus control, self-monitoring, goal setting, and rewards).⁹⁰

Although there were no significant differences between shorter and longer duration interventions, the majority (N=12) were less than 12 months in duration. Similar to our findings, the previous meta-analyses on the treatment of childhood obesity have not found a difference in treatment effect according to intervention duration.^{97,100} However, a previous meta-analysis targeting technology-based interventions for prevention and treatment of obesity,⁵² found that shorter duration interventions were associated with significant effect, which the authors argue that could be related to the issues of engagement and long-term adherence of digital interventions.¹⁰¹ In our meta-analysis, none of the included studies recorded follow-up measurements after the end of the intervention. This is important as a previous systematic review revealed that sustainability of long-term weight loss are limited for adults.¹⁰²

Another essential point to consider is the population targeted. The majority of the studies focused on a mixed ethnic community, while two studies focused on a specific ethnic community and showed their intervention to be effective in reducing BMI.^{69,82} Previous systematic reviews have identified that interventions which target specific racial and ethnic minority groups on diabetes self-management interventions in adults are effective.¹⁰³ However, there is still weak evidence on obesity prevention interventions that targeted

middle school-age children of an ethnic minority.¹⁰⁴ We explored income status in the subgroup analysis and found that studies which targeted mixed income or not reported the income were statistically significant, however study heterogeneity was very high ($I^2 = 79.8\%$). The subgroup of the meta-analysis also revealed that studies which included a mix of children with overweight and obesity showed a significant effect. In contrast, studies that only targeted children with obesity were not effective. However, only four studies targeted children with obesity,^{64,65,78,80} and between group analysis revealed no significant differences. Therefore, further high quality and adequately powered RCTs are needed to further explore these subgroup differences.

Strengths and Limitations

This systematic review and meta-analysis included e-health interventions targeting the child or agent of change (e.g. parent/ career), and studies included a range of e-health intervention delivery methods (i.e. SMS, WhatsApp, wearable sensors, telemedicine, mobile apps, social media, emails, active video game and web-based software). We employed a rigorous methodology, including a comprehensive database search, which yields a large number of studies (n=29,198) with no year of publication restrictions applied. All screening, data extraction and quality assessments were carried out in duplicate using standardised protocols. The majority of studies (60%) were considered at low risk of bias, and there was no evidence of publication bias. Likewise, the GRADE assessment profile shows high certainty of evidence. We also conducted a rigorous analysis which included a meta-analysis with further sensitivity and subgroup analysis.

This review also contains some limitations, such as moderate heterogeneity levels, particularly for the standardised analysis (BMI and BMI z-score). Likewise, BMI-z score was

calculated using different growth reference charts across studies. We have performed a number of subgroup analyses which helped to guide on the key components of e-health interventions. However, we were unable to explore some other components such as mode of intervention (e.g. e-health alone vs e-health combined with other intervention modes), settings (e.g. school, community, clinical) or the effectiveness on different populations subgroups (e.g. gender and ethnicity) due to a small sample of studies for subgroup analysis. Finally, only studies published in English were included in the analysis. Moreover, the majority of studies were conducted in high-income countries. Therefore, findings cannot be generalized to low- and middle-income countries.

Conclusion

E-health interventions have shown to be 'an effective channel' for promoting healthy obesity-related behaviours.¹⁰⁵ This systematic review which only included RCTs and the majority of studies were rated as high-quality, found that e-health interventions for treating overweight and obesity in children and adolescents are associated significant effect on lowering BMI and BMI z-score. Therefore, practitioners, clinicians, and policymakers should consider e-health as a model for behaviour change in children.

E-health behaviour interventions have the potential to reach large populations in a time-efficient manner. Nevertheless, the 'digital divide' can also occur among children and young people with evidence that age, gender and socioeconomic status could all play a role in the quality and use of the internet.¹⁰⁶ This should be taken into consideration on implementation of e-health interventions in children.

More research is needed to explore long-term sustainability, cost-effectiveness, scalability and generalisability of e-health interventions. In particular, high-quality studies are needed

to explore the different modes of e-health interventions, different settings and targeted populations. More evidence is also needed from low and middle-income countries.

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Table 1: Summary of included studies

Author, year and country	Intervention targeted, behaviour and behaviour theory	Intervention overall description and non e-health component.	E-health component intervention	Results (BMI, BMI z-score or mean difference)
Abraham et al. 2015, China ⁶⁴	<p><i>Intervention target:</i> children and parents</p> <p><i>Behaviour:</i> Diet/ nutrition, physical activity, screen time</p> <p><i>Behaviour theory:</i> Transtheoretical Model-Stages of Change and social cognitive theory (based on ABC curriculum)</p>	<p>Participants were randomised to three intervention groups: 1) Internet (IT) intervention group; 2) Simplified Lifestyle Modification Programme (sLMP) intervention group; 3) control group received usual care visits with a physician in the obesity clinic</p> <p>The Simplified Lifestyle Modification Programme (sLMP) intervention group used a patient-centred approach and cognitive behavioural concepts to improve knowledge regarding lifestyle behaviours. The group received usual care visits at the Obesity Clinic and parent-teen pair attended four meetings with a nutritionist over three months.</p>	<p>The internet (IT) intervention group: usual care visits to obesity clinic (as control group), internet-based curriculum and cell phone follow-up over 6 months. The internet -based curriculum constituted of 12 x 15 min interactive sessions (e.g. reflective questions, quizzes and games). Information on lifestyle behaviours and relaxation mindful eating practices were provided. Participants set goal setting and received semi-personalized SMS messages weekly.</p>	<p>BMI baseline (kg/m²) Control: 30.1 (28.4–32.3) IT group: 29.3 (26.7–30.9) SLMP group: 31.5 (29.8–33.7),p value between group difference p= 0.032</p> <p>BMI 2nd visit (kg/m²) Control: 30.5 (28.7– 32.0) IT group: 28.4 (26.7–31.9) SLMP group: 31.0 (30.6– 34.1) p value between group difference p=0.065</p>
Ahmad et al. 2018, Malaysia ⁶⁸	<p><i>Intervention target:</i> children and parents</p> <p><i>Behaviour:</i> Nutrition, physical activity and screen time</p> <p><i>Behaviour theory:</i></p>	<p>Participants were randomised to intervention or wait-list control.</p> <p>The researcher established a lifestyle goal setting, but parents and children chose the one they will target.</p>	<p>Face-to-face sessions were uploaded on Facebook.</p> <p>The booster phase was delivered weekly through WhatsApp group to strengthen parents' knowledge and skills in promoting</p>	<p>BMI z-score intervention vs. control: Mean difference intervention and control: -0.14 (95%CI -0.278 to 0.003)</p>

	Social cognitive theory	<p>The REDUCE intervention constituted eight units (delivered face- to -face or via Facebook).</p> <p>The training sessions were delivered by a public health physician and a sports medicine specialist to parents only, except units 7 and 8, which were delivered to parents and children.</p>		
Chen et al. 2019, USA ⁶⁹	<p><i>Intervention target:</i> children</p> <p><i>Behaviour:</i> Diet physical activity and sedentary behaviour</p> <p><i>Behaviour theory:</i> Social cognitive theory</p>	<p>Participants were randomised to intervention and control group and received general health information.</p> <p>The intervention had three components: 1)wearable sensor; 2) online education; 3) text messages.</p> <p>The programme was culturally adapted to Chinese culture.</p>	<p>Use of wearable sensor (Fit- bit Flex) for six months to track physical activity, sedentary behaviour and diet, set goals, monitor progress and offer healthy tips.</p> <p>Eight online educational modules for three months using online educational videos covering lifestyle modification, weight and stress management, self-efficacy and problem-solving.</p> <p>Tailored biweekly text messages for three months.</p>	<p>BMI= (z=4.89, p<.001)</p> <p>BMI z-score(z=4.72, p<.001)</p>
Davis et al. 2013, USA ⁷⁰	<p><i>Intervention target:</i> children and family</p> <p><i>Behaviour:</i></p>	<p>Families were randomised to intervention delivered via telemedicine, while control group received structured physician visit condition.</p>	<p>Children and families participated in 8 weekly psychoeducational groups over telemedicine led by psychologists.</p>	<p>BMI z-score</p> <p>Telemedicine group: pre-treatment 1.88 (0.52), posttreatment: 1.76 (0.52) Change 0.12</p>

	<p>Diet, physical activity and sedentary behaviour</p> <p><i>Behaviour theory:</i> Theory not reported</p>	<p>Intervention had a telemedicine component which was followed by face to face.</p> <p>Parents and children met as a group with a group leader (psychologist) to cover the same telemedicine topics and set goals. This was followed by six monthly meetings over the phone with parents.</p>		<p>Physician visit group: pre-treatment, 1.70 (0.45), post-treatment 1.55 (0.59) Change 0.15</p> <p>BMI z-score (F=0.023, p =0.881).</p>
<p>Davis et al 2016, USA⁷¹</p>	<p><i>Intervention target:</i> children and parents</p> <p><i>Behaviour:</i> Diet, physical activity, sedentary behaviour</p> <p><i>Behaviour theory:</i> Cognitive behavioral theory</p>	<p>Participants were randomised to telemedicine or telephone arms.</p> <p>The intervention was culturally adapted to rural families and consisted of eight weekly meetings, followed by six monthly meetings.</p> <p>The intervention offered an on-site group session review of weekly goals and progress. This was led by both the offsite leader and the on-site school representative.</p> <p>The on-site school representative met with the children. Meetings lasted 1 hour and were more didactic to parents and activity-based for children.</p> <p>For the telephone intervention arm, parents and children sat around a speakerphone to</p>	<p>The offsite leader, a clinician member of the research team, met with parents via telemedicine or phone, depending on the group allocation.</p> <p>In telemedicine intervention, parents and children sat around a large TV screen to communicate in real-time with the research team.</p>	<p>BMI z-score</p> <p>Telemedicine Group Mean difference 0.00 (.22)</p> <p>Telephone Group Mean difference 0.00 (.18)</p>

		<p>communicate with the research team for the group meetings.</p>		
<p>Fleischman et al., 2016, USA ⁶¹</p>	<p><i>Intervention target:</i> children and parents</p> <p><i>Behaviour theory:</i> Diet, physical activity and sedentary behaviour.</p> <p><i>Behaviour theory:</i> Theory not reported</p>	<p>Participants were randomly allocated to two groups:</p> <ol style="list-style-type: none"> 1) Primary care providers (PCP) in-person plus obesity specialist tele-visits. 2) Primary care providers (PCP) in-person clinic visits only. <p>Interventions were delivered for 6 months. Both arms emphasized healthy diet (e.g. balanced meal, healthy snacks and low-glycaemic). The intervention also focused on increase in physical activity and decrease in sedentary behaviour. Educational materials were consistent between both arms.</p> <ol style="list-style-type: none"> 1) PCP in -person clinic utilized a booklet about healthy eating and developing plans to achieve goals. Visits were 30 min in duration. 2) The obesity specialist tele-visits consisted of 12 tele-visits over 6 months with the child and parents. Including 6 weeks intense phase (1 hour visit) plus twice monthly follow-up (30 min visit). The visits alternated between a dietitian and 	<p>In both intervention arms there were tele-consultations between primary care providers (PCPs) and obesity specialists.</p> <p>VidyoDesktop (video conferencing) were used for tele-visits and parents were provided with webcams, iPads and internet for the duration of the study.</p>	<p>BMI Group 1 (-0.11, P=0.0006) BMI Group 2 (-0.06, P=0.08); No significant differences between groups.</p>

		<p>psychologist who worked together to understand the dietary behaviour and develop a plan. They did a dietary assessment (environment, behaviour, cognitive, emotional and family) and then provided education and counselling.</p> <p>The primary care centres involved in the study met weekly to share information and experiences and to access need for supplemental services.</p>		
Jensen et al. 2019, USA ⁶²	<p><i>Intervention target:</i> children and parents</p> <p><i>Behaviour:</i> Diet, physical activity and sedentary behaviour.</p> <p><i>Behaviour theory:</i> No behavioural theory reported (used motivational interviewing)</p>	<p>Participants were randomly allocated to two groups:</p> <ol style="list-style-type: none"> 1) Motivational Interviewing (MI) plus Self- monitoring and Adaptive Text Messaging (SM/ATM). 2) Motivational Interviewing (MI) plus self-monitoring (SM) <p>Participants in both groups attended a single 50 min of MI plus six months of self-monitoring and adaptive text message.</p> <p>The MI visit was conducted by a clinical psychology doctoral student. The session was designed to access barriers and reinforce the behaviour. Both groups also</p>	<p>In addition to the intervention components of the MI+SI group, the MI+SM/ATM participants received three intervention text messages daily from the automated messaging system. The computer-tailored messages based on participants self-reported behaviours. Participants were also requested to like or dislike messages which informed the tailoring algorithm.</p> <p>Participants were instructed to report the health behaviours via text message daily. Participants were given a monetary incentive for self-reporting via text message.</p>	<p>No significant differences across groups.</p> <p>The MI + SM/ATM BMI z-score reduced 0.32 SD unit. $p < 0.01$, $d=0.54$. However, BMI z-score did not change for individuals in the control group $p= 0.63$, $d =0.11$.</p>

		<p>received information about the Stoplight Eating Plan.</p> <p>Participants were guided to do 60 min of physical activity and reduce sedentary behaviour to less than 2 hours per day.</p>		
<p>Johansson et al 2020, Sweden⁷²</p>	<p><i>Intervention target:</i> parents</p> <p><i>Behaviour:</i> Physical activity and daily self-monitoring of weight</p> <p><i>Behaviour theory:</i> No behavioural theory reported</p>	<p>Participants were randomized to mHealth support system in addition to standard care (intervention) or to standard care alone (control).</p> <p>The intervention group, was delivered in six months, using a mHealth support system. The intervention comprised daily weighing on scales with no displays. Parents received a graphic presentation of BMI SDS and individual goals for weight development. The clinicians had the same information in their interface.</p>	<p>The mHealth support system could be accessed by parents via a mobile app while clinicians used an interface via a website.</p> <p>Participants used a commercially available app to increase motivation in physical activity.</p>	<p>BMI SDS: – 0.23 (intervention) vs.0.01 (control), p = 0.002.</p> <p>BMI SDS difference between groups 0.24 units.</p>
<p>Lee et al 2017, Hong Kong, China⁷³</p>	<p><i>Intervention target:</i> children, parents and school</p> <p><i>Behaviour:</i> Diet, physical activity</p> <p><i>Behaviour theory:</i></p>	<p>Schools were randomised to intervention or control (usual school planned activities).</p> <p>The intervention was delivered over six months, and it involved experts on physical activity, diet, psychology and school nurses.</p>	<p>The intervention was delivered over 6-months school-based weight management program (SBWMP) via mHealth and involved parents.</p> <p>The intervention promoted healthy eating and regular exercise via 24 training sessions at school and involved parents via mHealth tools</p>	<p>Mean difference between groups BMI (kg/m²) = - 0.14 (95% 0.50 to 0.22), p= 0.33</p>

	<p>Bandura's Social Learning Theory</p>	<p>The intervention focused on social support from peers and parents to modify unhealthy lifestyles.</p> <p>The intervention consisted of a mix of individual, group and environmental strategies with social factor components.</p> <p>Parents were encouraged to attend seminars, parent-child health promotion activities and dietary consultation sessions.</p> <p>Parents participated in 8 sessions of parent skill training. Children attended eight sessions of face-to-face group contact in the first month.</p>	<p>After the initial 8 face-to face sessions the remaining sessions were delivered via Facebook, apps, email and phone calls for both students and parents</p>	
<p>Love-Osborne et al. 2014, USA⁷⁴</p>	<p><i>Intervention target:</i> children</p> <p><i>Behaviour:</i> Diet and physical activity</p> <p><i>Behaviour theory:</i> No behavioural theory reported (used motivational interviewing)</p>	<p>Participants were randomised to intervention or control group.</p> <p>An educator saw participants. Diet and physical activity habits were recorded, and feedback was provided to participants using the motivational interviewing framework to support change and start goal-setting discussions. This was reviewed and modified at each session. The frequency of the visits was set by the participant, who could choose two weeks, one month or two months.</p>	<p>Participants of the intervention group were randomized to receive text messages (TM) in the first semester of the intervention. However, in the second semester, both intervention and control groups received the TM. The TM contained individualized goals. The analysis of outcome measures was provided for the intervention group as a whole.</p>	<p>From baseline to the final visit, 55% of the intervention group and 72% of the control group decreased or maintained a stable BMI z-score, within 0.05 of baseline ($p = 0.025$). Forty percent of the control group versus 18% of the intervention group decreased BMI z-score by 0.1 or more ($p = 0.02$).</p>

		<p>The educator also signposts participants to health behaviour resources, local activities and memberships.</p> <p>Participants were encouraged to self-monitor their lifestyle behaviours and weight. Participants received a monetary incentive if they returned the log sheet.</p>		
<p>Maddison et al. 2011, New Zealand⁷⁵</p>	<p><i>Intervention target:</i> children</p> <p><i>Behaviour:</i> Physical activity</p> <p><i>Behaviour theory:</i> No behavioural theory reported</p>	<p>Participants were randomised to intervention (active video game) or control (no change) groups.</p> <p>Children were encouraged to meet current physical activity recommendations by supplementing periods of inactivity with active video gameplay and substituting traditional non-active video gameplay with the active version.</p>	<p>Participants received an upgrade of existing gaming technology that enabled them to play active video games at home. The Sony PlayStation Eye Toy (Sony) was used. The game had a motion capture camera that places a picture of the gamer on the screen with which the gamer interacts. The upgrade consisted of an EyeToy camera, dance mat, and a selection of active video games (e.g., Play3, Kinetic, Sport, and Dance Factory; Sony).</p> <p>Children received a new package of active video games after 12 weeks. The full intervention was delivered in 6 months.</p>	<p>Mean difference between intervention and control: BMI (kg/m²) = 20.24 (95% CI: 20.44, 20.05); p = 0.02.</p>
<p>de Niet et al. 2012, Netherlands⁷⁶</p>	<p><i>Intervention target:</i> children and parent</p> <p><i>Behaviour:</i></p>	<p>Participants were randomised to a short message service maintenance treatment (SMSMT) via mobile phones with personalized feedback or to a control group.</p>	<p>The SMS intervention focused on self-regulation and included self-monitoring (self-observation), goal setting (self-evaluation) and reinforcement. Participants in the SMS maintenance group received a</p>	<p>BMI-SDS at 12 months Control 2.34 (0.57) SMSMT 0.38 (0.59) P= 0.76</p>

	<p>Diet, physical activity and psychosocial health</p> <p><i>Behaviour theory:</i> Social learning and cognitive theories, self-regulation theories and behavioural models</p>	<p>Parent sessions focused on children's diet, physical activity and psychosocial aspects of obesity. It informed about the increased risk of physical and psychological morbidity. The sessions also focused on changing interaction patterns between parents and their children by teaching them how to support their child instead of controlling, and by applying positive feedback and reinforcement.</p> <p>The intervention lasted twelve months.</p>	<p>mobile phone for the period of the intervention. The researcher explained to participants how to use the mobile phone.</p> <p>The children were asked to send weekly self-monitoring data on physical activity, healthy eating patterns, and mood using a five-point Likert scale via SMS. A software program automatically compared each self-monitoring SMS data and detected deterioration, improvement or maintenance of behaviours.</p> <p>The programme suggested tailored feedback with a 160-character limitation out of a large pool of pre-formulated statements. A researcher checked the feedback before sending it to the child. The feedback messages were formulated according to the following principles: 1) social support; 2) motivations (iii) reinforcement; and (iv) suggestions of behaviour modification and self-management skills.</p> <p>To enhance compliance, the researcher sent an SMS reminder after one week of nonresponding.</p>	
Patrick et al. 2013, USA ⁶⁵	<i>Intervention target:</i> children and parent	Participants were randomised to one of the three arms: 1) website	The application and content of the program website were divided into	BMI z-score at 12 months: W: mean 2.1, SE 0.09

	<p><i>Behaviour:</i> Diet and physical activity</p> <p><i>Behaviour theory:</i> The intervention was informed by the theoretical concepts from the behavioral determinants model and the transtheoretical model of behavior change.</p>	<p>only (W); 2) website, monthly group sessions, and follow-up calls (WG); and 3) website and SMS (WSMS).</p> <p>The intervention content was piloted and revised after input from a diverse group of adolescents regarding reading level, understanding of concepts, ability to hold their attention, and usability of the information.</p> <p>Participants were randomized to four study arms: 1) website only (W), 2) website plus sessions (WG), 3) website and SMS (WSMS), and 4) usual care.</p> <p>Participants in the W only received weekly “check-in” emails, monthly mailed tip sheets, and access to the program website and its web tutorials. If participants did not visit the website, they received repeated reminders via email and, if necessary, a phone call from a health counsellor.</p> <p>Participants in the WG condition also participated in group counselling aimed at skill-building to support their adolescent’s behavioural goals. Participants in this condition also received brief bi-</p>	<p>three phases:1) education on healthy behaviours needed for weight loss; 2) more interactive with true/false quizzes, interactive activities/games and challenges and goals selections to master skills and behaviours introduced earlier; 3) interactive and encourage working on multiple behaviours at the same time. The parent completed an adult version of the program website (except for skills and rewards).</p> <p>The program website used the “stoplight approach,” participants were encouraged to limit red-light foods (low nutrient, high calorie/fat) and red-light activities (unproductive, low energy) and increase green-light foods (high nutrient, low calorie/fat) and green-light activities (high energy). They were also encouraged to eat yellow-light foods and do yellow-light activities in moderation. The website and tutorials provided educational topics and challenges based on weekly nutrition or physical activity goals, skill-building exercises, including a reward system to encourage success.</p> <p>Participants were also provided feedback on their progress and</p>	<p>WSMS: 2.1, SE 0.09 WG: 2.0, SE 0.09 UC: 2.2, SE 0.09</p>
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		<p>monthly phone calls from the health counsellor to review concepts presented in the web tutorial and reinforce behavioural strategies such as goal setting and problem-solving. Attendance and participation in the group sessions were rewarded with incentives and prizes.</p> <p>The WSMS arm included the website, monthly web tutorials and text messages.</p> <p>The intervention lasted 24 months.</p>	<p>received a pedometer and a bodyweight scale to report their steps daily and body weight weekly. The website also included general information on diet and several behaviour change strategies.</p> <p>The WSMS group received three text messages per week related to weekly challenges and intervention goals. Reminder text messages were sent if the participant did not log on to the website by the fourth day of the intervention. Participants could communicate via text messages with a health counsellor and be provided with cell phones and prepaid text message plans that allowed research staff to monitor SMS use.</p>	
<p>Staiano et al. 2018, USA⁷⁷</p>	<p><i>Intervention target:</i> children and parents</p> <p><i>Behaviour:</i> Physical activity</p> <p><i>Behaviour theory:</i> Social cognitive theory</p>	<p>Participants were randomised to intervention and control conditions.</p> <p>The intervention consisted of an exergame, supplemented by a telehealth component and use of activity monitor (Fitbit).</p>	<p>Fitness coaches visited the parent and child at home to set up the equipment and play the first gaming challenge together.</p> <p>The GameSquad intervention encouraged participants to meet a goal of 60 minutes/day of MVPA for the 24-weeks of the intervention. Participants were asked to play exergames three days/week with a family member or friend to help them meet this MVPA goal.</p>	<p>BMI z-score: Intervention: -0.06 [0.03] vs. Control 0.03 [0.03], p=0.016</p> <p>BMI z-score Intent-to-treat analysis Intervention -0.06 [0.03] vs. Control 0.02 [0.03], p=0.065.</p>

			<p>Participant received a booklet with information on playing three challenges each week with increasing intensity, difficulty, and duration. The maximum duration of 60 minutes per exergaming session was selected to meet the physical activity guidelines but not exceed screen-time guidelines (≤ 2 hours/day).</p> <p>A telehealth component consisted of each participant and a parent meeting with a fitness coach weekly for the first six weeks and biweekly after that. Participants in the GameSquad intervention were also provided with a Fitbit Zip (Fitbit, San Francisco, California) to wear during the 24 weeks. At the virtual meeting, the fitness coach followed a script that reviewed the child's steps/day, recorded gameplay data, helped the child and parent create solutions to barriers for physical activity, and built the child's self-efficacy and social support for physical activity.</p>	
<p>Taveras et al. 2015, USA⁷⁸</p>	<p><i>Intervention target:</i> children and parents</p> <p><i>Behaviour:</i> Diet, physical activity and sleep</p> <p><i>Behaviour theory:</i></p>	<p>Participants were randomized to clinical decision support (CDS), CDS plus coaching or usual care.</p> <p>The CDS component is the e-health component and explained in the next column.</p>	<p>The CDS was modified from an electronic health record deployed from a point-of-care CDS to alert to paediatric clinicians if a child had a BMI at the 95th percentile, or greater. The alert contained links to growth charts, evidence-based childhood obesity screening and</p>	<p>Adjusted difference: CDS= -0.51 (95% CI: -0.91 to -0.11)</p> <p>CDS+ Coaching =-0.34 (95% CI: 0.34 to 0.07)</p> <p>p = 0.04</p>

	<p>No behavioural theory reported</p>	<p>In the CDS arm clinicians used brief motivational interviewing to negotiate a follow-up weight management plan with the child and their family.</p> <p>Families randomized to the CDS + coaching intervention arm were assigned to a health coach who used motivational interviewing to support families by telephone at 1, 3, 6, and 9 months.</p>	<p>management guidelines, and a prepopulated standardized note template which included options for documenting and coding for the BMI percentile, nutrition and physical activity counselling and placing referrals for weight management programs and laboratory studies, other than printing for educational materials.</p> <p>The educational materials focused on decreases in screen time, decreases in sugar-sweetened beverages, increases in moderate and vigorous physical activity, and improving sleep duration and quality.</p> <p>In the CDS + coaching arm parents could choose to receive texts messages or email to support behaviour change twice weekly during the 1-year follow-up.</p> <p>Participants in the randomized to the control arm received the current standard of care offered by their paediatric office.</p>	
<p>Taveras et al. 2017, USA⁷⁹</p>	<p><i>Intervention target:</i> children and parents</p> <p><i>Behaviour:</i></p>	<p>Participants were randomized to Enhanced Primary Care (Control) or Enhanced Primary Care + Coaching (Intervention).</p>	<p>The Enhanced Primary Care also received monthly text messages that contained links to publicly available resources to support behaviour change and listed places</p>	<p>BMI adjusted difference: -0.02 (95%CI: -0.80 to 0.03), p=0.39</p>

	<p>diet, physical activity and sleep</p> <p><i>Behaviour theory:</i> no behavioural theory reported</p>	<p>The Enhanced Primary Care was supported by clinicians who gave parents a set of evidence-supported educational materials focusing on specified behavioural targets to support self-guided behaviour change.</p> <p>In the Enhanced Primary Care + coaching, participants received individualized health coaching tailored to their socio-environmental context. They also offered families free membership to community gyms and invited them to attend a healthy grocery shopping program.</p> <p>The intervention lasted one year.</p>	<p>that support healthy living in their community.</p> <p>In the Enhanced Primary Care + coaching following parents preference, trained health coaches contacted families every other month using telephone, videoconference, or in-person visits. Families also received twice-weekly text messages or emails and mailings following the coaching session with educational materials to support families' behaviour change goals. Health coaches used a motivational interviewing style of counselling and shared decision-making techniques. At each contact, health coaches used an online community resource map developed for the study to identify resources within each family's community that could support behaviour change.</p>	
<p>Wake et al. 2013, Australia⁸⁰</p>	<p><i>Intervention target:</i> children and parents</p> <p><i>Behaviour:</i> Diet and physical activity</p> <p><i>Behaviour theory:</i> No behavioural theory reported</p>	<p>Participants were randomised to shared care software or usual care</p> <p>In the shared care software arm, children first attended an appointment with a specialist tertiary weight management service and were seen by a paediatrician and a dietitian. They screened participants and discussed relevant dietary, physical</p>	<p>The share care software enabled data sharing and focused communication. It was designed to provide collaboration and communication between the specialists and general practitioners and structured to weight management care. The software enabled a structured consultation for each visit, comprising five standardized sequential steps:</p>	<p>BMI adjusted mean difference (Kg/m²) -0.1 (95% CI:-0.7 to 0.5; p=0.7</p>

		<p>activity, and family/child lifestyle changes. Family and clinicians agreed on an initial care plan and specific goals. This information was entered into the shared care, web-based software.</p> <p>A long appointment was set with the child's general practitioner and followed by regular four to eight weekly standard consultations to review lifestyle and body mass index progress, identify and solve problems, and set new goals using brief solution-focused techniques.</p>	<p>recording anthropometry; reviewing the change in body mass index, using an online chart to plot and track body mass index visually; assessing and tracking progress and motivation; reviewing the care plan (e.g. identifying problems and revising goals); and providing educational resources.</p> <p>Data from each appointment were entered into the shared care software. The specialist team accessed the software to review each child's progress and faxed a summary progress report to the general practitioner after six months.</p>	
Wald et al. 2018, USA ⁸¹	<p><i>Intervention target:</i> children and parents</p> <p><i>Behaviour:</i> Diet, physical activity and sedentary behaviour</p> <p><i>Behaviour theory:</i> Self-determination theory</p>	<p>Participants were randomised to family- web-based intervention or customary care.</p> <p>This was a family-based behavioural model intervention in which healthy eating and activity were encouraged, and authoritative parenting was supported. Parents in the intervention group attended six face-to-face group meetings and received group counselling from a primary care nurse. The intervention group had additional office visits at 3, 6, and 9 months.</p>	<p>Participants were also given access to O-CHESS website, populated with materials from the session for parents to review and comment.</p> <p>The website contained information services, including health topics related to nutrition and physical activity, FAQs, weblinks, local resources, personal stories that emphasized authoritative parenting, interactive discussion group, and Ask the Expert. The site was updated weekly. Discussion group entries were reviewed daily, and parents were encouraged to share their triumphs</p>	<p>Change in BMI control = 0.1 , SD = 2.26; p= 0.8026; Change in BMI intervention = 0.3; SD= 1.65, p= 0.6037</p> <p>p value comparing control and intervention = 0.8688</p>

			<p>and challenges so that all might benefit. The website was a source for reinforcement of messages provided in the face-to-face sessions.</p>	
<p>Williamson et al. 2006, USA⁸²</p>	<p><i>Intervention target:</i> children and parents</p> <p><i>Behaviour:</i> Diet, physical activity and sedentary behaviour</p> <p><i>Behaviour theory:</i> No behavioural theory reported</p>	<p>Participants were randomly assigned to an interactive behavioural internet program or an internet health education program (control condition).</p> <p>Each family was assigned a counsellor who conducted face-to-face sessions and corresponded regularly using email.</p> <p>. The family was involved in mutual problem-solving and behavioural contracting. The adolescent and their parent attended four face-to-face counselling sessions. The purpose was to encourage adherence to behavioural principles, provide additional training, and solve computer problems.</p> <p>The trial lasted two years.</p>	<p>The internet-based behavioural intervention provided nutrition education and behaviour modification for adults and adolescents using a family-oriented format.</p> <p>Counselling for behaviour modification was accomplished primarily by asynchronous email communications. Participants had an email account where they were encouraged to send emails weekly to their counsellor regarding their progress in the program. The email communication allowed counsellors to provide feedback on program components, for example, quizzes, lessons, weight graphs, goal-setting and clinic appointments.</p> <p>The intervention also contained a website with various interactive components to self-monitor weight and physical activity, and diet, which would then be viewable as a graph. Participants receive feedback on the number of servings and caloric content of the food.</p>	<p>Change in BMI control = 1.2, SD = 0.65; Change in BMI intervention = 0.73, SD = 0.34 p=0.04</p>

			Parents and adolescents were trained to use problem- solving to a web-based 52 lessons.	
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Table 2. GRADE evidence profile for the effect of e-health health interventions for the treatment of obesity in children.

Certainty assessment							No of patients		Effect	Certainty	Importance
No of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Intervention	Comparison	Effect size (95% CI)		
16	100% RCTs	not serious	serious ^a	serious ^b	not serious ^c	Reporting bias and dose response gradient ^d	904	1196	SMD: -0.31 (-0.49 to -0.13)	⊕⊕⊕⊕ HIGH	CRITICAL

- a. There was moderately high heterogeneity levels (I2 = 74%, p<0.001) in the meta-analysis
- b. There was a serious risk of indirectness as e-health interventions were combined with other delivery modes in 14 of the 16 studies included
- c. The confidence interval was relatively narrow (95% CI -0.49 to -0.13) and the sample size was sufficiently large (n= 2,100)
- d. The grey literature was not searched, and there were language restrictions. Furthermore, dose of e-health intervention varied across studies

Table 3. Subgroup analysis of effect estimates of e-health intervention on BMI and BMI z-score (presented as SMD).

Subgroup	Estimate (95% CI)	Heterogeneity	Z-test for effect
<i>Age</i>			
Under 12 years (<i>n</i> =11)	-0.183 (-0.352, -0.015)	<i>I</i> ² =62.3%	Z=2.14; <i>p</i> =0.033
12-17 years (<i>n</i> =5)	-0.633 (-1.193, -0.072)	<i>I</i> ² =83.3%	Z=2.21; <i>p</i> =0.027
Between groups effect			Z=0.95; <i>p</i> =0.343
<i>Weight status</i>			
Overweight or obesity (<i>n</i> =12)	-0.219 (-0.398, -0.041)	<i>I</i> ² =62.3%	Z=2.41; <i>p</i> =0.016
Obesity only (<i>n</i> =4)	-0.578 (-1.158, 0.002)	<i>I</i> ² =87.8%	Z=1.95; <i>p</i> =0.051
Between groups effect			Z=0.78; <i>p</i> =0.435
<i>Duration</i>			
6-12 months (<i>n</i> =9)	-0.301 (-0.550, -0.052)	<i>I</i> ² =66.9%	Z=2.37; <i>p</i> =0.018
12 months or over (<i>n</i> =7)	-0.342 (-0.632, -0.051)	<i>I</i> ² =82.1%	Z=2.30; <i>p</i> =0.021
Between groups effect			Z=0.09; <i>p</i> =0.928
<i>Risk of bias status</i>			
Low risk of bias (<i>n</i> =11)	-0.195 (-0.332, -0.058)	<i>I</i> ² =33.3%	Z=2.79; <i>p</i> =0.005
High/unclear risk of bias (<i>n</i> =5)	-0.675 (-1.27, -0.079)	<i>I</i> ² =90.6%	Z=2.22; <i>p</i> =0.026
Between groups effect			Z=0.92; <i>p</i> =0.357
<i>Behaviour targeted</i>			
PA, sedentary behaviour, diet (<i>n</i> =7)	-0.100 (-0.274, 0.075)	<i>I</i> ² =0.00%	Z=1.12; <i>p</i> =0.264
PA and diet or PA only (<i>n</i> =9)	-0.443 (-0.704, -0.183)	<i>I</i> ² =84.4%	Z=3.33; <i>p</i> =0.001

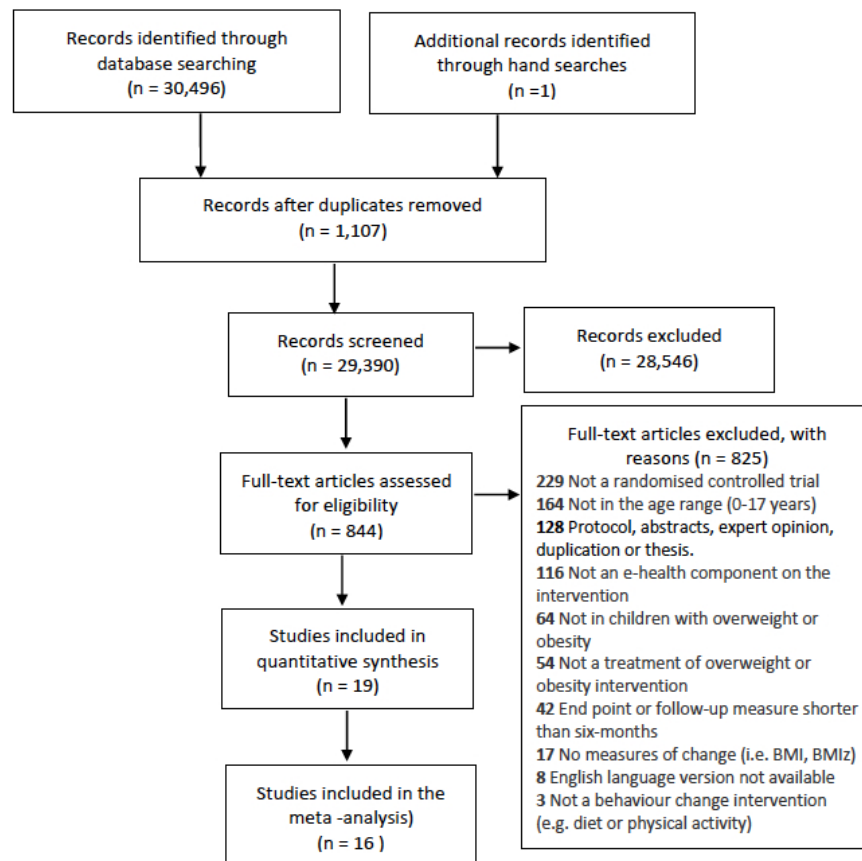
Between groups effect Z=1.20; p=0.263

Income status

Low income (n=4) -0.051 (-0.276, 0.174) I²=0.00% Z=0.44; p=0.658

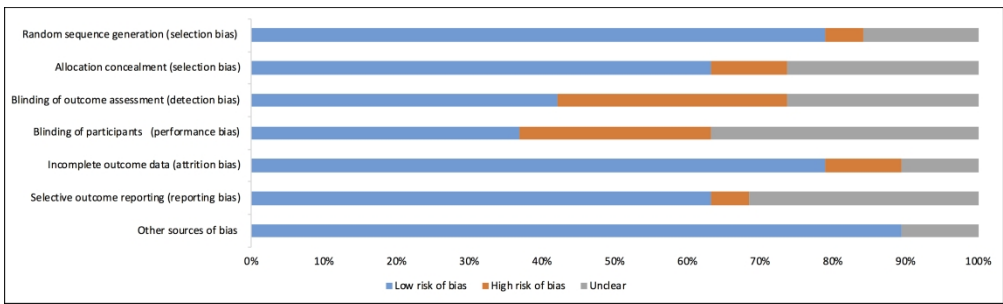
Mixed income/not reported (n=12) -0.385 (-0.605, -0.166) I²=79.8% Z=3.44; p=0.001

Between groups effect Z=1.12; p=0.261



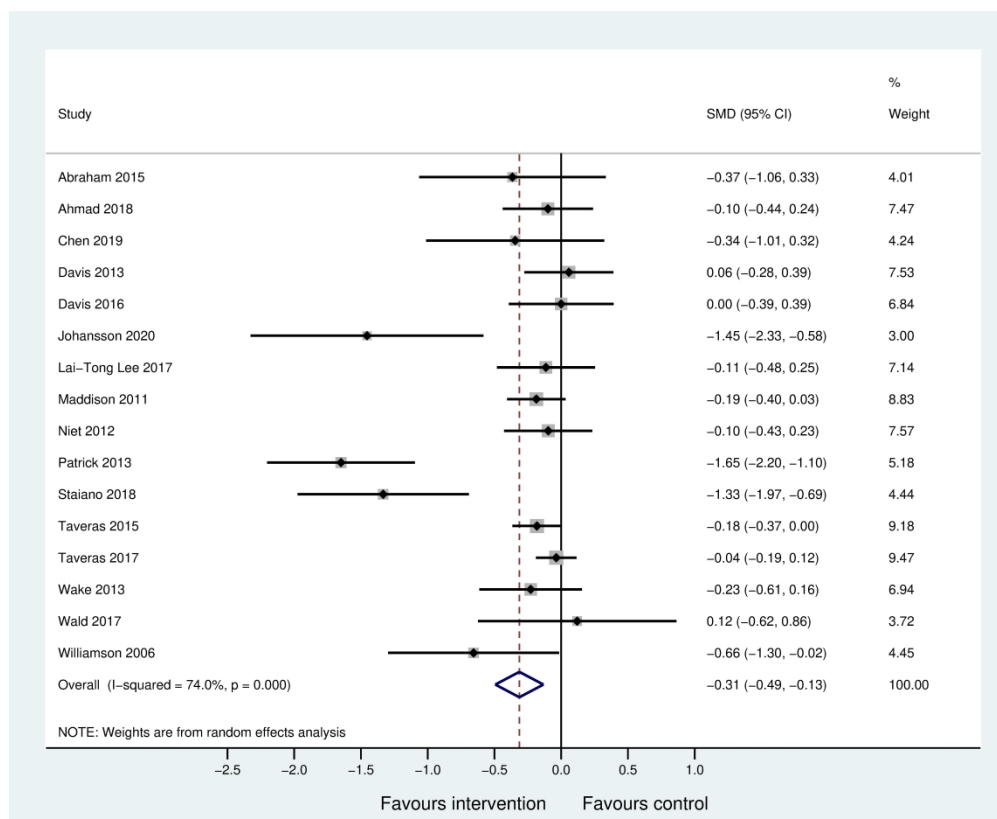
Flow diagram

262x250mm (72 x 72 DPI)



Aggregated risk of bias of included studies

333x98mm (300 x 300 DPI)



Forest plot for meta-analysis based on BMI and BMI-z outcomes (presented as SMD)

279x227mm (600 x 600 DPI)