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E- & mhealth interventions targeting nutrition, physical activity, sedentary behavior and/or obesity amongst children: A scoping review of systematic reviews and meta-analyses

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ABSTRACT

Childhood obesity is a public health concern. Electronic and mobile health (e-&mHealth) approaches can facilitate the delivery of interventions for obesity prevention and treatment. Synthesizing reviews of e-&mHealth interventions to improve weight and weight-related behaviors (physical activity, sedentary behavior, and diet) is useful to characterize the current scope of the literature and identify opportunities for future reviews and studies. Using a scoping review methodology, we aimed to evaluate the breadth and methodological quality of systematic reviews and meta-analyses of e-&mHealth interventions targeting weight and weight-related behaviors in children and adolescents aged <19 years. A systematic search of seven databases was conducted, including reviews published between 2000-2019. Review characteristics were extracted, and methodological quality was assessed using the AMSTAR2 tool. Forty-five systematic reviews and meta-analyses were included. All reviews evaluated intervention efficacy (100%), but few assessed other aspects (20% in total) such as cost-effectiveness. Smartphone applications (47%), text messages (44%), and websites (35%) were the main modalities. Weight (60%), physical activity (51%), and diet (44%) were frequently assessed, unlike sedentary behavior (8%). Most reviews were rated as having critically low or low methodological quality (97%). Reviews that identify the effective active ingredients of interventions and explore metrics beyond efficacy are recommended.

INTRODUCTION

Childhood obesity continues to be a significant public health issue, despite emerging as a concern a few decades ago.^{1,2} Globally an estimated 38 million young children under the age of 5 years and over 340 million children and adolescents aged 5–19 years have overweight or obesity.³ Overweight or obesity during childhood increases the likelihood of developing metabolic and cardiovascular risk factors, such as elevated blood pressure and lipid levels, as well as musculoskeletal pain, liver complications,⁴ and psychological comorbidities such as depression, anxiety, and other emotional and behavioural disorders.⁵ In the long term, childhood obesity increases the risk of developing cardiovascular diseases, type 2 diabetes, some cancers, and musculoskeletal disorders into adulthood.^{6,7} Given the health risks posed by excess weight in childhood and adolescence, the World Health Organization (WHO) has identified childhood overweight as a priority area for action to catalyse global change.⁸

The food environment, built environments, socioeconomic-cultural conditions promoting consumption of unhealthy foods, sedentary forms of leisure and transport, insufficient physical activity, and passive screen time are the main interconnected sources contributing to obesity development.⁹ Interventions at the individual (e.g., those that involved oneself) and family level (e.g., those directed at parents and family environment) have shown moderate success to curb the obesity problem.¹⁰⁻¹² Accordingly, the proliferation of the Internet, smartphones, and wireless devices (e.g., wrist worn activity tracker) have provided a powerful channel for eHealth and mHealth (herein: e-&mHealth) intervention approaches to widen the reach of behavioural

interventions to prevent and treat obesity in children and adolescents.¹³ e-&mHealth intervention technologies include modalities such as the internet (web), text messages with Short Message Service (SMS), smartphone applications (apps), and social media to monitor and improve health behavior.¹⁴ eHealth is “the use of information and communications technology, especially the internet, to improve or enable health and health care,”¹⁵ while mHealth is a subdivision of eHealth and can be defined as “medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices (e.g., heart rate monitor), personal digital assistants (PDAs), and other wireless devices.”¹⁶

e-&mHealth interventions are unlike traditional methods as they can deliver materials in various forms (i.e., text, sound, video, gamification, and animation) to sustain children’s and adolescents’ attention in accordance with their preferences.^{17,18} e-&mHealth interventions are also preferred by children and adolescents over traditional behavioral approaches involving in-person interactions¹⁹⁻²¹ and promote a healthy lifestyle amongst cultural, literacy and numeracy barriers^{22,23} and across a spectrum of sociodemographic strata.²⁴ For these reasons, e-&mHealth approaches can be successful in improving health behaviors, such as increasing physical activity and fruit and vegetable consumption in children and adolescents.^{11,25,26} Given the wide availability and increase in the use of technology, it is not surprising that there has been an exponential increase in research in this area since the early 2000s. A bibliometric analysis examining the entirety of e-&mHealth literature related to physical activity, sedentary behavior and diet found a considerable increase in papers published in 2016 ($n=363$) compared to 2000

($n=9$).²⁷ Of the 1,712 publications included in the analysis, 47% targeted children and adolescents (24% on adolescents and 23% on children) compared to 32% on adults.²⁷

Consequently, systematic reviews evaluating the efficacy of e-&mHealth interventions have grown and most have a specific focus on types of e-&mHealth technology or behaviours. For example, systematic reviews examining e-&mHealth interventions in children and adolescents have focused on one or a combination of approaches such as wearables,²⁸ the use of online social networks,²⁹ gamification,^{18,30} computer-tailoring,³¹ smartphone applications,³² web-based interventions,^{33,34} exergames,³⁵ virtual reality,³⁶ and other forms of technology. Additionally, these reviews focused on one or a combination of behavior changes that target sedentary behavior, physical activity, diet, and weight management, among others. Without a methodical examination of systematic reviews on e-&mHealth interventions related to physical activity, sedentary behavior, diet and obesity, the current landscape of evidence on obesity prevention and treatment is unclear, and it is challenging to assess potential gaps in the literature to date. A scoping review is an approach to synthesizing evidence by highlighting strengths and limitations (i.e., methodological quality), identifying knowledge gaps of existing systematic reviews, and establishing the potential for a systematic review and future research directions.³⁷ Therefore, the objective of this scoping review was to examine the breadth of scope and methodological quality of systematic reviews and meta-analyses conducted to evaluate e-&mHealth interventions targeting nutrition, physical activity, sedentary behavior, and/or obesity

in children and adolescents aged <19 years. This review will aid in designing future systematic reviews and identifying research directions to address gaps in existing knowledge.

METHODS

Search Strategy

This scoping review is part of a larger scoping review protocol that included systematic reviews of e-&mhealth interventions targeting nutrition, physical activity, sedentary behavior and/or obesity in adults and children. The present review reports on the findings specifically for children, and the adult review is published elsewhere.³⁸ The scoping review followed the framework of Arksey and O-Malley³⁹ and adhered to the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist.⁴⁰ A search for studies published between 2000 to October 2019 was conducted using seven separate databases MEDLINE, Medline in process, EMBASE, PsychINFO, Scopus, CINAHL, and Cochrane Library. The year 2000 was chosen based on a bibliometric analysis that showed almost no e-&mHealth research was published prior to this year.²⁷ The comprehensive search strategy is presented in Supplementary Table 1. In addition, reference lists of all included studies were hand-searched for additional reviews.

Eligibility Criteria

Only systematic reviews and meta-analyses of (quasi-) experimental studies (i.e. randomized control trials [RCTs], quasi-experimental studies, and single group pre-post design)

were included. The current scoping review focuses on systematic reviews and meta-analyses of children/adolescents (<19 years). To be eligible, reviews must include more than one child study in their review and present outcomes separately for child-based studies. Manuscripts were excluded if not published in English. Additional selection criteria included having a focus on behavioral interventions with the aim of improving at least one obesity-related behavior (diet, physical activity, or sedentary behavior) and/or treating or preventing overweight and obesity. e-&mHealth was defined as interventions that used websites, computers, email, smartphones (for using applications or text messages), digital games, telehealth and/or behavioral monitoring devices as a component of the behavioral intervention. Reviews were included that either 1) required interventions to be delivered by e-&mHealth (e.g., applications) or 2) reviewed e-&mHealth intervention components (e.g., focus is on SMS text messaging) as a part of the main behavioral change strategy. There were no specific comparators or outcomes required to be included.

Study Selection

Title, abstract, and keywords of identified papers were screened in duplicate by a pair of independent reviewers, with multiple pairs of independent reviewers participating in the process. Full text screening was also conducted by multiple pairs of independent reviewers (authors: CLK, MA, AES, CAM, LMA, CEM, CV, AD, HB, MW, MH), and reasons for exclusions were recorded. A third reviewer was consulted to resolve conflicts at both phases of study selection. An initial pilot test of the screening process with all reviewers was undertaken for

abstracts and full text articles. Study selection was completed using Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia).

Data Extraction and Critical Appraisal

Data were independently extracted by one reviewer and checked by a second reviewer using a predetermined form for each included review. Data were extracted specific to the review characteristics (e.g., type of e-&mHealth device or delivery mode included, health behavior included); inclusion criteria related to participants, intervention, comparators, and outcomes (PICO); and findings (e.g., bias assessment, and main findings of the included studies). Two reviewers conducted critical appraisal independently. Discrepancies were resolved by discussion or by a third reviewer. A critical appraisal of all included reviews was conducted using AMSTAR 2, a tool for assessing reviews that include randomized or nonrandomized studies of healthcare interventions.⁴⁶ The AMSTAR 2 tool is used to assess review quality by critical and non-critical domains, rather than a total score. Critical domains include protocol registration, adequacy of literature search, reason for exclusions, risk of bias from included studies, appropriateness of meta-analytical methods (when applicable), risk of bias interpretation, and assessment of publication bias. Based on AMSTAR 2 guidance, reviews that met all (7/7) or all but one (6/7) critical domain were deemed “high” or “moderate” quality, respectively.⁴¹ Further, reviews that met all but one critical domain and missed few non-critical domains were deemed “low” quality, and all others that did not meet multiple critical domains were deemed “critically low.”

Synthesis of Results

A numerical analysis was undertaken to report the number of studies per data extraction category. These categories included: systematic review and meta-analysis characteristics (e.g., search date range), participant inclusion criteria (e.g., age), intervention/comparator inclusion criteria, outcome inclusion criteria (e.g., diet, weight), and review findings. Further results are presented by methodological quality based on the AMSTAR 2 rating (critically low, low, moderate, and high). Quality of studies included in reviews was also obtained after initial data extraction.

RESULTS

In total, 1040 abstracts were screened, 306 full-text articles were assessed for eligibility, and 172 reviews were deemed eligible for full-text review (see Figure 1). During full-text review of articles that included child and adolescent interventions (57 articles), 10 articles were excluded for the following reasons: only one child study included in the article ($n=5$)⁴²⁻⁴⁶ and did not present outcomes separately for children ($n=5$).⁴⁷⁻⁵¹ Two protocols of retrieved studies ($n=2$) were identified,^{52,53} thus this scoping review includes forty-seven papers of forty-five reviews for the scoping analysis.

Only three reviews exclusively conducted a meta-analysis, and eleven reviews performed a meta-analysis together with a systematic review to determine the effect of these interventions on outcomes. The median number of databases searched was five databases (16/45), with a range

of 2-15 databases searched. Several reviews searched for studies published in the last 5 or 10 years prior to the search (12/45) or chose a date range between 1995 to 2000 to publication year (11/45). Five reviews were conducted from inception of databases.⁵⁴⁻⁵⁸

Population, Interventions, Comparators, and Outcomes of Included Reviews

A summary of population, intervention, and comparator components of included reviews are shown in Table 1, individual characteristics of included reviews are presented in Table 2, and outcomes assessed are shown in Figure 2. The median number of included studies in the review was 13.5, with a range of 2-43 studies (mean±SD:15.0±9.0). As shown in Table 1, one third of included reviews ($n=12$) had no age restriction but included multiple child studies and presented results by age group. The age range of included reviews varied, with the most frequent inclusion being all ages below 19 years (9/45)^{54,59-66} and adolescents (10-18 years of age, 10/45).^{56,57,67-74} Only one review examined e-&mHealth interventions below the age of six years.⁷⁵ Four reviews did not specify an age range for inclusion criteria, only “children and adolescents,”⁷⁶⁻⁷⁹ or in one instance “students attending school or university” which included mean ages of included studies ranging from 12-21 years.⁷⁷ About a third of reviews detailed whether the intervention was parent-focused for behavior change (3/45) or directly delivered to the child (10/45). Only one review included e-&mHealth modalities targeting only the parent,⁶⁵ while seven reviews included those targeting only the child.^{54,59,67,73,77,80-82} Reviews did not exclude children based on socioeconomic status, ethnicity, region, or within countries of a specific socioeconomic status (e.g., lower or middle income countries). Four reviews focused on children with overweight or

obesity^{59,64,69,83} with all others had no restrictions on child weight status or any other health condition.

The most frequently included types of e-&mHealth interventions were those delivered by a smartphone application (21/45), mobile text messages (20/45) or website (17/45, Table 1). Most reviews had a wide inclusion criterion for e-&mHealth, with reviews allowing between one and six different types of devices or delivery modes, but only two reviews explicitly stated they allowed all types of e-&mHealth modalities.^{68,84} Fifteen systematic reviews focused on only one device or delivery mode, including five reviews only on exergames,^{58,60-62,64} three reviews on smartphone applications,^{32,76,85} three reviews on mobile/SMS text messaging,^{73,86,87} two reviews on social media,^{71,88} one review on self-monitoring devices,⁸⁹ and one review on website-based interventions.⁵⁶

All reviews assessed intervention efficacy, whereas few assessed reach, engagement, acceptability, or cost-effectiveness of the interventions ($\leq 5/45$ per category, 9/45 overall).^{57,68,81,82,86,89-92} One review focused on the reach, effectiveness, adoption, implementation, and maintenance (RE-AIM) framework for website interventions.⁹⁰ Another review examined the effectiveness along with feasibility of wearable devices (e.g. FitBit or Sensewear armband) in youth (ages 5-19 years) for increasing physical activity.⁸⁹

Though all reviews assessed efficacy, about half (21/45) reported either behavior change techniques (BCTs, 4/45) or theoretical frameworks in included studies (17/45). The integration of these constructs into the review varied widely, from counting the number included within each

study to subgroup analyses by BCT or theoretical framework used within studies. Villinger et al. examined the effectiveness of smartphone applications on diet and diet-related outcomes, such as obesity, including three studies in adolescents.⁸⁵ Villinger et al. did not see a difference in outcomes by age group but did perform subgroup analyses across the 41 studies (including both adults and adolescents) by each type of BCT as defined by the Michie taxonomy.⁹³ In those analyses, which included 2-37 studies per BCT, they found no significant differences in change in nutrition behaviors by BCT ($ps>0.05$).⁸⁵

The included reviews comprised a range of study designs including single group pre-post studies (7/45), quasi experiment studies (25/45), and RCTs (42/45); with twelve reviews including only RCTs.^{17,54-56,63,65,75,79,82-84,88} Three studies did not provide a clear inclusion criteria for study designs.^{76,81,94} Eight reviews required interventions to have a particular control group,^{54-56,58,60,73,75,95} with all of these reviews allowing usual care, wait-list, or no intervention controls. Three reviews allowed another type of e-&mHealth intervention or a non- e-&mHealth intervention as a comparator.^{55,56,95}

As shown in Figure 2, the most frequently assessed outcomes in reviews were weight-related (e.g., Body Mass Index (BMI) z-score, or BMI) (27/45), followed closely by physical activity (23/45), and diet (20/45). Many reviews required included studies to contain either a weight or weight-related outcome (i.e. diet or physical activity). Sedentary behavior was included as a part of four reviews^{32,55,73,76} but was not a part of reviews published before 2013. Sedentary behavior was estimated by device-based measures (i.e. accelerometer) and self-report

of screen-time or sitting time^{32,55,76} but was also defined as physical inactivity, as in not meeting the physical activity guidelines.⁷³ Few reviews focused on only diet (6/45) or physical activity outcomes (9/45). Most allowed any measure of diet or physical activity, with some focusing on very specific behavior-related measures such as food literacy,⁶⁸ fruit and vegetable intake,⁹⁵ and physical activity self-efficacy.⁶¹ Accordingly, slightly more reviews included studies focusing on treatment of obesity (18/45) rather than obesity prevention (15/45). Various operational definitions of weight status were included in reviews, including BMI, BMI z-score, waist circumference, and body fat.

Attributes of Included Reviews

Various study quality tools were used, and reviews reported a range of study quality from weak to high. Three reviews only included studies above a certain quality threshold based on their quality measure, though no studies failed to be included based on the authors predetermined thresholds.^{62,70,96} Of the seven reviews rated their included studies collectively as high or moderate quality,^{17,69,77,83,85,87,94} these reviews included multiple intervention study designs (e.g., RCTs, pseudo randomized trials), reviewed a moderate number of studies (range 2-9), and conducted their search within the last 10 years. Six reviews examined the overall quality of the evidence of the included studies, of which four reviews found the body of evidence to be low or “critically low” in quality.^{56,61,67,71} One review rated the quality of the evidence by weight outcomes and physical activity outcomes and found high or moderate quality evidence for both.⁵⁸

Quality of Included Reviews

The quality of the systematic reviews and meta-analyses as determined by AMSTAR 2 is presented in Supplementary Table 2. Reviews were of low (3/45) or critically low quality (41/45), with only one review rated as moderate quality.⁵⁸ Oliveira had “partially adequate” review methods and search strategy but met all other critical domains.⁵⁸ On average, reviews met 3.9/7 critical domains (e.g., search strategy characteristics) and 4.6/9 non-critical domains (e.g., performing study selection in duplicate). As for critical domains, most reviews had a somewhat adequate (35/45) or adequate search strategy (2/45). Five reviews indicated that their review was registered with PROSPERO.^{56,58,65,71,72} Four reviews reported the list of excluded articles with individual reasons for exclusion.^{58,80,82,85} Some reviews used a tool that partially (8/45) or completely (21/45) addressed all the risk of bias components.

For non-critical domains, around one quarter of reviews included all PICO components (participant, intervention, comparison, and outcome, 12/45) or provided justification for the criteria for study design (11/45). Half of the reviews performed study selection in duplicate (23/45), while one third conducted data extraction in duplicate (17/45). Many partially (9/45) or adequately (30/45) described the included studies, but only three reviews extracted funding information.^{54,56,71} About half of reviews reported low risk of bias for included studies or discussed the role of bias in results (20/45), and half found no heterogeneity in results or examined moderators of heterogeneity in their results (27/45). For the included meta-analyses, most had adequate statistical measures (9/14), assessed risk of bias (6/14), and assessed publication bias (9/14).

DISCUSSION

In this scoping review, many systematic reviews of e-&mHealth interventions included a wide range of modalities and study designs, and primarily assessed efficacy. Most systematic reviews included broad age ranges and few focused on younger children or subgroups. The methodological quality of most systematic reviews was critically low, with a limited number of systematic reviews scored as low or moderate quality. Overall, the scope and inclusion of these systematic reviews were broad, and there are many opportunities to improve the rigor for future research studies and systematic reviews.

Many systematic reviews sought a broad definition of e-&mHealth and allowed a wide range of child ages to be included. e-&mHealth modalities have evolved to target school age and younger children (<12 years) and their parents,⁹⁷ though only one systematic review was confined to a younger age range (<6 years)⁷⁵ and one systematic review included only e-&mHealth modalities targeting the parent.⁶⁵ Along with targeting a specific age range, there were few studies that focused on subgroups, including those with overweight or obesity.^{59,64,69,83} e-&mHealth can bridge population level challenges, but the implementation, opportunities, and barriers to using the technology may differ by subgroups.⁹⁸ A recent systematic review on digital behavior change interventions for children (5-12 years) with chronic conditions found that interventions in these populations were effective for treating overweight and obesity,⁹⁹ though replication of these subgroup analyses specific to weight and weight-related outcomes is warranted.

Smartphone interventions were most common, which aligns with the smartphone being the most common device used to access the internet.¹⁰⁰ Yet, only three systematic reviews were confined to only smartphone applications^{32,76,85} and three were confined to SMS/mobile text messaging.^{73,86,87} These findings may be based on the time frame of the review, as smartphone applications and SMS/mobile text messages to deliver behavioral interventions have become more common recently, allowing only modern reviews to focus solely on these modalities. Further, these modalities may have been included in a multi-component intervention and difficult to isolate and assess within a systematic review format. It is likely authors of other systematic reviews chose a wide range of modalities to increase the amount of studies retrieved, but this may hinder modality specific conclusions.

All reviews assessed intervention efficacy, but fewer than a quarter assessed a component such as reach, engagement, acceptability, or cost-effectiveness.^{57,68,81,82,86,89-92} Adherence and engagement are assessed multiple ways in e-&mHealth literature¹⁰¹ but adherence metrics within a controlled trial do not necessarily address the external validity of results. Reach, engagement, acceptability, implementation, and maintenance may help translate one-time RCTs into real-world settings.¹⁰² Further, e-&mHealth modalities are the opportune research tool to assess engagement, reach, and usability. Accordingly, the RE-AIM framework incorporates both evidence-based components and implementation strategies to address these gaps.¹⁰³ Cost-effectiveness is another key component to address in e-&mHealth interventions to demonstrate the return on investment, including financial cost of technology and behavior change or

improvement of quality of life for lasting effects.^{82,104} Expanding to other components beyond effectiveness is important due to the ability of e-&mHealth modalities to improve health behavior and integrate into real-world settings.

BCTs and theoretical frameworks are the active ingredients of an intervention, though only half of systematic reviews reported these components. Since all reviews evaluated intervention effectiveness, it may be expected more reviews would investigate these components. The commonly used standardized taxonomy of BCTs was only published in 2013⁹³ and may not have been available in older primary studies and reviews. The interest in focusing on active components for e-&mHealth intervention was called to action five years ago¹⁰⁵ and will be more valuable than ever as e-&mHealth modalities continue to grow in popularity.

There were various definitions of weight status and weight-related behavior outcomes, both within and between included reviews. The inclusion of a wide age range and varying standards to reflect age and growth (e.g., BMI z-score for young children and BMI for older children) may explain the use of different weight outcomes. Similarly, many of the systematic reviews used a variety of definitions for diet-related behaviors, such as fruit and vegetable intake.⁹⁵ Using uniform definitions of weight and weight-related behavior may provide more comparable outcomes and point to specific behaviors that e-&mHealth modalities can effectively target to support the development of healthy habits. More recent systematic reviews (2013-2019) included sedentary behavior interventions, which are distinct from physical activity interventions, commonly seeking to disrupt prolonged bouts of sedentary time and replace

sedentary time with light physical activity. Importantly, sedentary behavior has been defined in multiple ways (e.g., screen-time and physical inactivity), making it difficult to summarize findings across multiple studies.

The rigor of studies in the included systematic reviews of e-&mHealth interventions also varied widely. This finding may be due to only half of systematic reviews using an adequate risk of bias tool or the limitations in the design and methodology of the included studies. Around one-third of included reviews were exclusive to RCTs, and few required a specific comparison group. The risk of bias and rigor of studies may relate to the constraints and considerations of behavioral research.¹⁰⁶ For example, blinding of participants is difficult in behavioral interventions.¹⁰⁶ Some included reviews updated their risk of bias tool to not include blinding, such as Ludwig et al. which omitted this portion of their risk of bias tool.⁷³ Areas for improvement were found in the planning, execution, and presentation of the review, as less than one-quarter of included reviews defined PICO in their research questions, used adequate review methods, reported excluded studies with reasons, or reported funding of included studies. It is possible reviews were conducted to the AMSTAR 2 standard but did not report these components within their manuscript. For example, two articles reported using an adequate risk of bias tool in their published protocols for the review^{52,53} but did not report this information within the actual systematic review or supplementary files.^{80,82} In addition, it is likely that systematic reviews will have recorded excluded studies and reasons for exclusion during the conduct of their review but may not have reported these details in the publication.

Strengths of this scoping review include methodology based on an accepted framework for scoping reviews,³⁹ assessment of articles and results in duplicate, a rigorous assessment of the included reviews using AMSTAR 2, and inclusion of multiple behaviors related to obesity (e.g., sedentary behavior). Including all types of e-&mHealth, along with multiple behaviors and definitions of weight status, allows this review to encompass the breadth of e-&mHealth. This scoping review focused mainly on the major documented behaviors in relation to weight (e.g. diet), thus one limitation of this scoping review is that other behaviors that may also contribute to excess weight gain (e.g. sleep) were not included. Another limitation is that included reviews varied in their participants, interventions, comparators, and outcomes, making it difficult to conduct subgroup examinations by e-&mHealth modality or health behavior outcome or deduce that enough systematic reviews were available to conduct systematic review on a specific modality or health behavior outcome. All reviews did assess effectiveness, which may be due to the review selection criteria (e.g., quasi experimental studies), thus another limitation is this selection criteria may have caused some topics to be missed such as engagement, description of intervention, and cost-effectiveness. Examination of other systematic reviews, including those assessing qualitative studies, may better address other components of interventions such as engagement and acceptability, though few were identified in our search. This scoping review also searched literature during a critical time for e-&mHealth development (2000-2019). Appraisal tools such as the AMSTAR 2 recognize the time and effort needed to complete a

review and as such deem reviews conducted within 24-months from the search as higher methodological quality.

From this scoping review of reviews, there are clear recommendations for future e-&mHealth based studies and systematic reviews.

Population:

1. Examine use and application of e-&mHealth modalities for specific populations, such as to improve the behaviors and weight of young children (<6 years), focus on parent-only and/or child-only interventions, and explore subgroups (e.g., those with chronic conditions, by sex, socioeconomic status, etc.).

Intervention Components:

1. Use consistent definitions of e-&mHealth modalities, for standardized comparison across modalities. An up-to-date taxonomy of e-&mHealth may be difficult with the rapid advances of technology, but thorough description of use and capabilities may enable future comparisons.
2. Studies should explore metrics beyond efficacy, including cost effectiveness, reach, engagement, and other metrics (e.g., RE-AIM framework), which could translate interventions to the real-world and allow for an examination of the broader impact of interventions. We suggest collecting cost, adherence, and engagement data within protocols, providing additional detail on these components in methods, and reporting these data and interpretation within the manuscript or supplementary material. Active collaboration

between implementation scientists and e-&mHealth researchers throughout the research process may also help address this concern.

3. Identify active ingredients in interventions (e.g. BCTs and theoretical frameworks) using innovative and replicable designs. The multiphase optimization strategy (MOST) and the sequential multiple assignment randomized trial (SMART) can allow for identifying critical components in interventions and behavior change.¹⁰⁷ Describing BCTs and frameworks included in a universal language, such as using BCT taxonomies,⁹³ can help identify which components are most effective.

Conduct of Systematic Reviews

1. Future reviews should strongly consider complying with current systematic review assessment tools (e.g., AMSTAR 2) in the design stage and incorporate these standards within the planning, executing, and presentation of their research. These standards may be more comprehensive and thorough compared to other reporting guidelines (e.g. PRISMA). Academic journals could support the conduct of high quality systematic reviews by requiring specific reporting guidelines, use of current quality assessment tools, and allowing for supplementary material to display excluded articles and funding information of articles.

This scoping review revealed that systematic reviews and meta-analyses of e-&mHealth interventions targeting weight and weight-related behaviors of children and adolescents were broad and varied across participants, interventions, comparators, and outcomes. The quality of

included reviews was low, with many opportunities for improvement across planning, execution, and presentation of the reviews. Enhancing future e-&mHealth research studies and systematic reviews may help advance our understanding of e-&mHealth interventions and their ability to improve weight-related behaviors and weight of children and adolescents.

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Figure 1. PRISMA 2020 flow diagram for updated systematic reviews which included searches of databases, registers and other sources

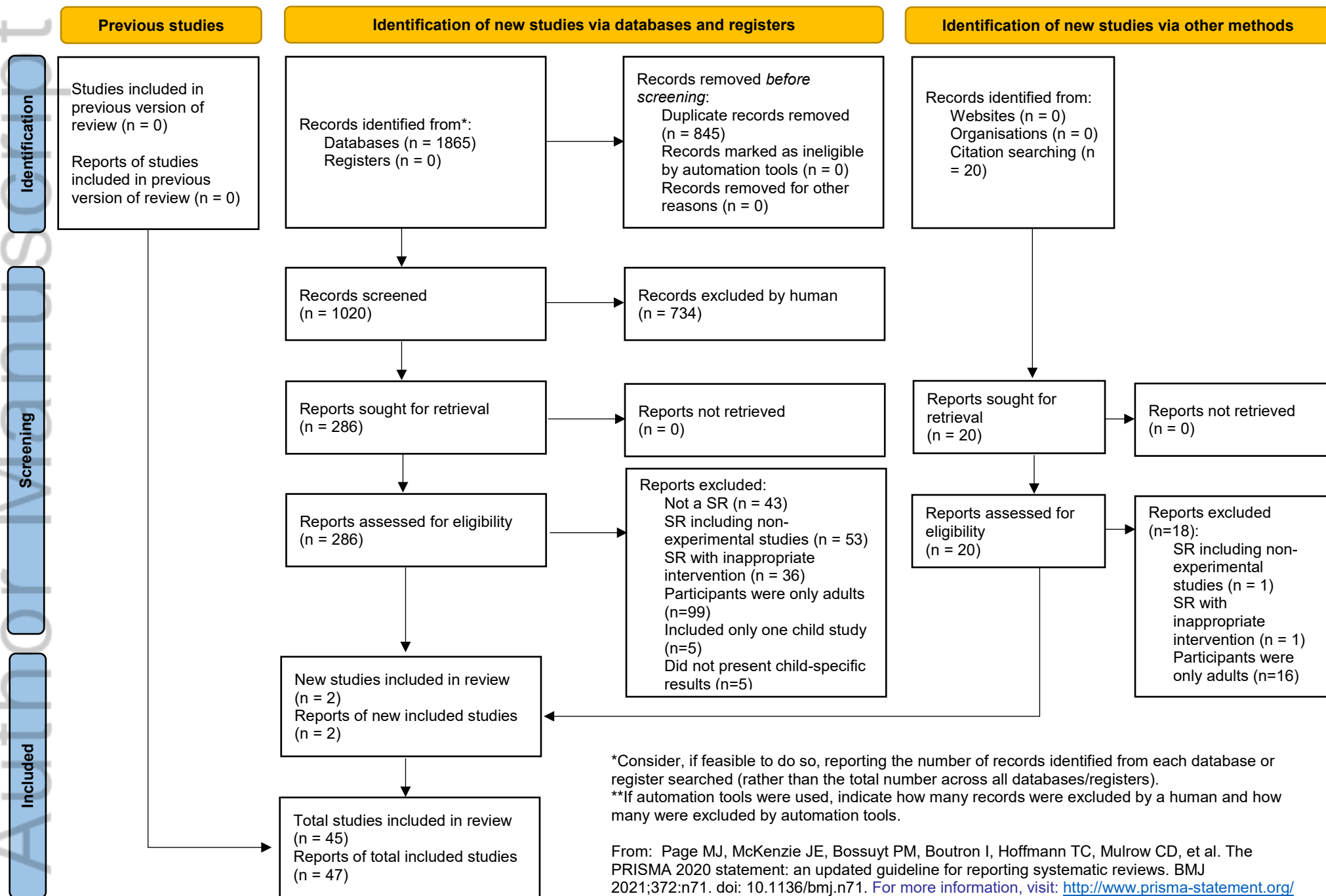
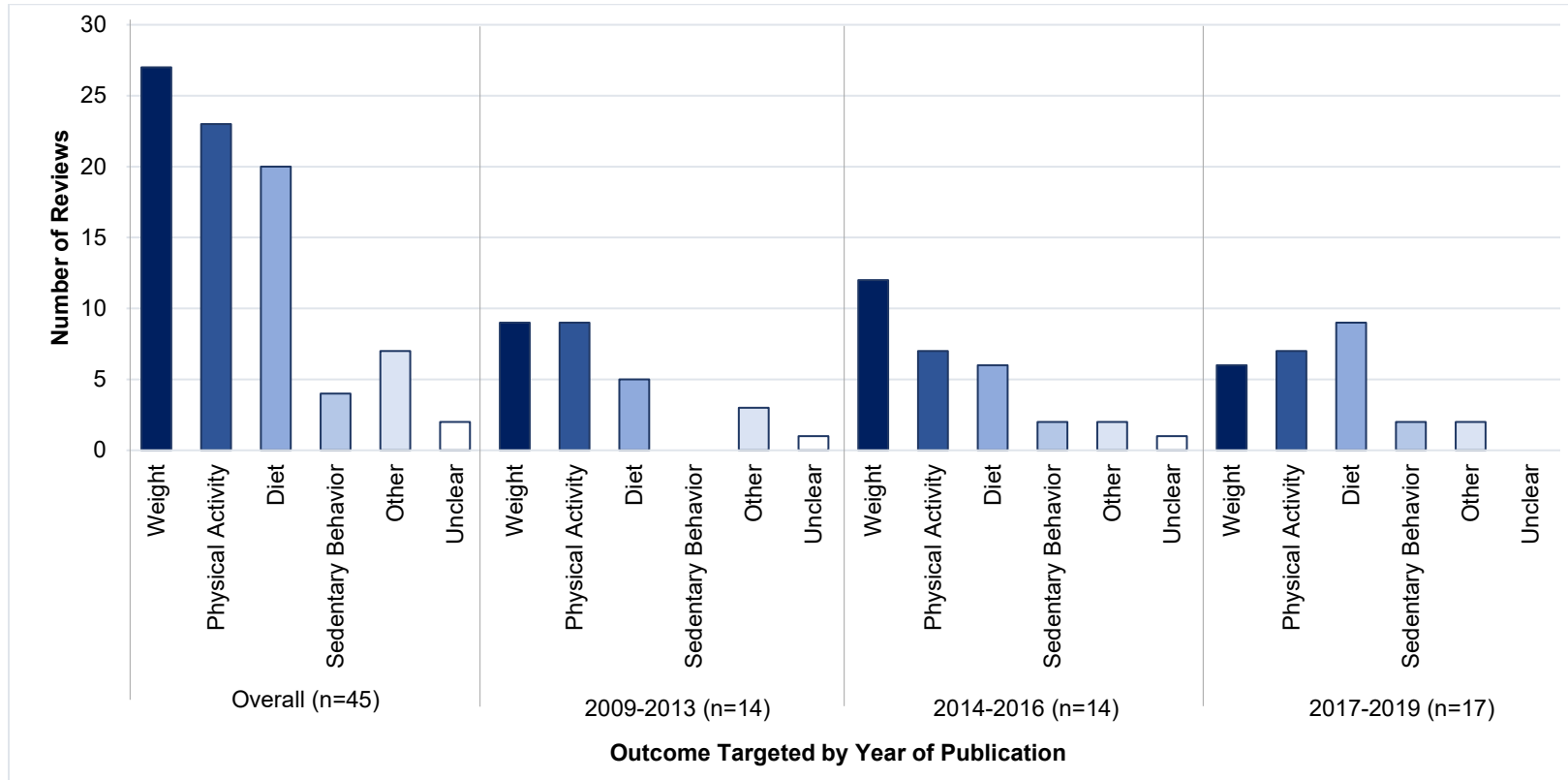


Figure 2. Behavioral or weight-related outcome by review's year of publication ($n=45$)*



*Reviews could indicate multiple outcomes as inclusion criteria

Table 1. Summary of characteristics of included studies (n=45)

	n	%
<i>Population</i>		
<i>Age range</i>		
Preschool (<6 y)	1	2%
Child and Adolescent (6-18y)	6	13%
Adolescent (10-18 y)	10	22%
Adolescent or older (>12 y)	2	4%
All children (<19 y)	10	22%
Other	4	9%
No age restriction	12	27%
Includes adult studies (in addition to child studies)	15	33%
<i>Interventions</i>		
<i>e-&mHealth modalities[^]</i>		
Smartphone applications	21	47%
Mobile text messages	20	44%
Website	17	37%
Digital Games	9	20%
Chatbots	8	18%
Email	8	18%
Social media	8	18%
Exergames	7	15%
Telehealth	4	9%
Monitoring device	3	7%
All eHealth- or mHealth	2	4%
<i>Component assessed within reviews[^]</i>		
Efficacy	45	100%
Reach	1	2%
Engagement	4	9%
Acceptability	5	11%
Cost-effectiveness	2	4%
<i>Study designs[^]</i>		
Randomized control trials	42	93%
Pseudo randomized control trials	18	40%
Comparator with concurrent control	25	55%
Comparator without concurrent control	7	15%
Case studies	13	29%
Unclear	5	11%
<i>Comparator</i>		
e or mHealth comparator only	5	11%
Control (no intervention)	8	18%

[^]Reviews could be included in multiple categories

Last Name, Year	SR and/or MA	Special Population	Age Group	e- &mHealth Assessed	Intervention Components	RCTs Only	Number of studies	Quality of Included Studies	Outcomes	Main Results
Aije, 2014 [67]	SR	None	12-18 y	Website <u>Other:</u> computer, web based, internet based, online, laptop	Efficacy	No	15	<u>Positive (high quality):</u> 10/15 studies <u>Neutral:</u> 3/15 studies <u>Negative (low quality):</u> 2/15 studies <u>Body of Evidence:</u> Limited	Diet Weight	<u>Diet:</u> 5/6 reported differences <u>Weight:</u> 2/2 studies reported significant results, 2/2 mixed results <u>Other:</u> 3/4 quasi experimental studies found improvements in dietary intake
An, 2009 [79]	SR	None	Children and adolescents	<u>Other:</u> Internet	Efficacy	Yes	8	Not assessed	Diet PA Weight	<u>Diet:</u> 3/8 studies reported improvements <u>PA:</u> 2/8 studies reported improvements <u>Weight:</u> 5/8 studies reported improvements
Antwi, 2013 [80]	SR	None	4-18 y	Website Email Smartphone Mobile text Social media <u>Other:</u> Web-based programs	Efficacy	No	8 (12 articles)	All studies determined to be adequate quality; 10/12 studies met minimum 6/10 JBL level 2 limited evidence: Promising	Weight	<u>Weight:</u> 4/8 studies reported improvements, 2/8 studies reported no difference, and 2/8 studies reported an increase in weight related outcomes
Blackman, 2013 [90]	SR	None	No age restriction	Smartphone Mobile text <u>Other:</u> Mobile technologies	Reach Efficacy Engagement Acceptability <u>Other:</u> RE-AIM (reach, effectiveness, adoption, implementation, and	No	15 (5 child)	<u>REAIM framework</u> <u>Moderate quality:</u> 3/5 studies <u>Low quality:</u> 2/5 studies	PA	No child specific results presented

					maintenance) Framework					
Bochner, 2015 [54]	SR, MA	None	<19 y	Active video games	Efficacy	Yes	7	High bias due to design (selection, poor compliance, blinding) <u>Low quality</u> : 7/7 studies	Weight	<u>Weight (SR)</u> : 4/7 studies reported an effect <u>Weight (MA)</u> : No effect of intervention on body weight (kg) using 7 studies
Chaplais, 2015 [83]	SR	Children with overweight and obesity	7-17 y	Email Smartphone Mobile text	Efficacy	Yes	2	<u>Good quality</u> : 2/2 studies	Unclear	<u>Weight</u> : 1 study reported moderate decreases, and 1 study reported significant decreases in BMI-z score
Chau, 2018 [81]	SR	None	10-19 y; 18-25 y	Website Smartphone Social Media <u>Other</u> : Social Media by website, app, homegrown technology	Efficacy Engagement	No	16 (7 child)	<i>Child specific results</i> : <u>Good quality</u> : 5/7 studies <u>Fair quality</u> : 2/7 studies	Diet	<i>Child specific results</i> : <u>Diet</u> : 6/7 studies reported improvements
Chen, 2014 [74]	SR	None	12-18 y	Website Smartphone Mobile text Social media	Efficacy	No	14	<u>Good quality</u> : 7/14 studies <u>Less than adequate quality</u> : 7/14 studies	Diet PA Weight	<u>Diet</u> : 5/7 studies indicated improvement <u>PA</u> : 6/11 studies reported improvements <u>Weight</u> : 6/14 studies found improvements <u>Other</u> : 5/7 studies suggested an improvement in psychosocial function
Darling, 2017 [59]	SR, MA	Children with overweight and obesity for	<18 y	Monitoring devices <u>Other</u> : used mHealth technology to self-monitor	Efficacy	No	16	Overall quality of studies was low (BMI, 7 studies), or moderate in diet (7 studies) and PA (4 studies).	Diet PA Weight	<u>Diet (SR + MA)</u> : Statistically significant effect (7 studies, 8 effect sizes), and quality of

		primary aim		PA, diet, or weight status (i.e. internet-delivered)						studies was moderate PA (SR + MA): No significant effect (4 studies, 4 effect sizes), and quality of studies was moderate Weight (SR + MA): Self-monitoring had a significant effect (7 studies, 9 effect sizes), and quality of studies was low
Direito, 2016 [55]	SR, MA	None	No age restriction, young people ≤ 18 y, adults: >18 y	Smartphone Mobile text Monitoring devices	Efficacy	Yes	21	Did not provide overall quality rating of studies, discussed individual components of study quality	PA SB	MA not reported for child studies
do Amaral e Melo, 2017 [72]	SR	None	10-19 y	Website Email Smartphone Mobile text Digital games Other: information and communication technologies	Efficacy	No	11	Strong: 3/11 studies Moderate: 5/11 studies Weak: 3/11 studies	Diet	Diet: 5/11 studies reported improvements
Enwald, 2010 [108]	SR	None	No age restriction	Other: Second generation health communication (email, CD-ROMs, etc.)	Efficacy	No	23 (2 child)	Not assessed	Unclear	Child specific results: Diet: 2/2 reported improvements PA: 1/1 reported improvements
Fanning, 2012 [94]	MA	None	No age restriction	Mobile text Other: Mobile devices, i.e. mobile phone, PDA, SMS	Efficacy	No	11 (2 child)	Child specific results: Good quality: 1/2 studies	PA	Child specific results: PA (MA): Both studies reported

									Fair quality: 1/2 studies		non-significant effect sizes
Hamel, 2013 [70]	SR	None	12-18 y	Website Other: Computer based	Efficacy	No	15	Not described Authors note that studies needed to achieve a "certain level of research quality" to be included	Diet Weight	<u>Diet</u> : 8/12 studies reported improvement <u>Weight</u> : 3/4 studies reported improvement	
Hamel, 2011 [96]	SR	None	8-18 y	Website Other: Computer based	Efficacy	No	14	Not described Authors note that studies needed to achieve a "certain level of research quality" to be included	PA Weight	<u>PA</u> : 8/14 reported improvement <u>Weight</u> : 2/4 studies reported improvement	
Hammersley, 2016 [65]	SR, MA	None	≤18 y	Website Email Smartphone Mobile text Telehealth Social media	Efficacy	Yes	7 (8 articles)	No overall risk of bias score per study described Overall description of studies as "not high"; studies met between 3-6 of 8 criteria	Weight Other behavior metrics	<u>Diet (SR)</u> : 4/7 studies reported significant changes <u>PA (SR)</u> : 1/6 studies reported significant outcomes <u>Weight (SR)</u> : 0/7 studies reported significant outcomes <u>Other (SR)</u> : 0/2 studies reported significant outcomes for <u>Screen-time (MA)</u> : no significant difference in weight outcomes (8 studies, 9 study arms)	
Harris, 2011 [82]	SR, MA	None	≥13 y	Website Telehealth Other: computer-	Efficacy Cost Effectiveness	Yes	43 (3 child)	<i>Child specific results:</i> <u>Moderate quality</u> : 1/3 studies	Diet Weight Use Cost	<u>Diet (SR)</u> : 0/2 reported improvements in fat intake, 1/1 reported	

				based (e.g. CD ROM, PDAs, computer kiosks)				<u>Weak quality:</u> 2/3 studies		improvements in intake of fruits and vegetables <u>Weight (SR):</u> no child-specific outcomes reported <u>MA:</u> No child specific results reported in meta-analysis, heterogeneity precluded many subgroup analyses <u>Cost Effectiveness:</u> No individual results reported, overall model estimated effects were unlikely to be cost effective at conventional levels, probably of cost effective was >25% of threshold levels
Hernández-Jiménez, 2019 [64]	MA	None	≤18 y	Active video games	Efficacy	No	16	<u>Strong quality:</u> 1/16 studies <u>Strong/moderate quality:</u> 1/16 studies <u>Moderate quality:</u> 2/16 studies <u>Weak quality:</u> 12/16 studies	Weight	<u>Weight (MA):</u> Significant improvements in fixed effect model for BMI, but non-significant in random effects model (16 studies, 19 outcomes), high heterogeneity in studies.
Ho, 2018 [56]	SR, MA	Children with overweight and obesity	12-18 y	Website	Efficacy	Yes	6	<u>GRADE:</u> Low quality of evidence	Weight	<u>Weight (SR):</u> Certainty of evidence was low (6 studies) <u>Weight (MA):</u> Small effect on BMI favoring internet based self-monitoring (6

										studies, 8 subgroups/ studies)
Hsu, 2018 [71]	SR	None	13-18 y	Social media	Efficacy	No	7 (14 articles)	Overall: quality of evidence was poor Authors reported risk of bias ranged from low to high with no individual metrics shown	Diet	Diet: 6/7 studies reported improvement in at least one diet outcome
LaPlante, 2011 [84]	SR	None	No age restriction	All e or mhealth Other: internet, computers, email, PDAs, mobile phones, or digital games	Efficacy	Yes	31 (9 child)	Child specific results: scores ranged from 44.4-88.9 (averages 65.4%) No specific discussion on ratings of individual studies	PA	Child specific results: PA: 4/9 studies reported improvements
Lappan, 2015 [63]	SR	None	0-18.9 y	Website Smartphone Mobile text	Efficacy	Yes	18	Not Assessed	Diet PA Weight	Diet: 7/10 studies reported improvements PA: 5/12 studies reported improvements Weight status: 0/8 studies resulted in significant changes
Lau, 2011 [17]	SR	None	6-12 y, 13-18 y	Website Email Mobile text Other: Internet, information and communication technologies	Efficacy	Yes	9	Good quality: 7/9 studies Overall quality not reported on remaining 2 studies	PA Other: Cognitive Outcomes	PA: 7/9 studies reported significant within group changes, 4/9 reported significant differences between groups
Lee, 2016 [78]	MA	None	Elementary students	Smartphone Mobile text	Efficacy	No	4	Not Assessed	Weight	Weight (MA): no significant effect on BMI (3 studies) Other (MA): no significant effect on behavior change

										(diet or PA, 2 studies)
Lu, 2013 [62]	SR	None	<18 y	Active video games	Efficacy	No	14	All studies met quality standard of the created framework	Weight	<u>Weight</u> : 4/14 reported significant change, all studies were with children with overweight or obesity, 2/14 studies reported partially significant changes, and 8/14 studies reported no significant changes
Ludwig, 2018 [73]	SR	None	10-19 y	Mobile text	Efficacy	No	11 (13 articles)	<u>Low Risk of Bias</u> : 3/13 articles <u>High Risk of Bias</u> : 3/13 articles <u>Unclear Risk of Bias</u> : 7/13 articles	PA SB	<u>PA</u> : 8/10 articles reported improvement of at least one PA outcome <u>SB</u> : 5/8 articles reported improvements
McIntosh, 2017 [77]	SR	None	Students attending school, college, or university	Website Email Smartphone Mobile text <u>Other</u> : Web or eHealth	Efficacy	No	10 (5 child)	<i>Child specific results</i> : <u>Moderate quality</u> : 3/5 studies <u>Low quality</u> : 2/5 studies	PA	<i>Child specific results</i> : <u>PA</u> : 3/5 studies reported improvements
Meidani, 2018 [75]	SR	None	0-6 y	Smartphone Mobile text <u>Other</u> : Telephone	Efficacy	Yes	5	<u>High quality</u> : 2/5 studies <u>Moderate quality</u> : 2/5 studies <u>Low quality</u> : 1/5 studies	Weight	<u>Weight</u> : 2/5 reported improvements in outcomes, 1/2 for weight improvements and 2/5 for BMI improvements
Murimi, 2019 [91]	SR	None	No age restriction	Website Smartphone Mobile Text	Efficacy Engagement	No	27 (6 child)	<i>Child specific results</i> : <u>Low Risk of Bias</u> : 2/6 studies <u>Moderate Risk of Bias</u> : 4/6 studies	Diet	<i>Child specific results</i> : <u>Diet</u> : 3/4 studies reported improvements, <u>Other</u> : Diet Related outcomes: 2/2 reported improvements (e.g.

										body image and self-efficacy)
Nguyen, 2011 [66]	SR	None	<18 y	Website Email Smartphone Mobile text Telehealth Social Media <u>Other:</u> interactive electronic media	Efficacy	No	21 (24 articles)	<u>High quality:</u> 2/21 studies On average, studies met 4/9 quality assessment components No other description of overall risk of bias for studies	Diet PA Weight	<u>Diet:</u> 5/11 studies reported improvements <u>PA:</u> 6/11 studies reported improvements <u>Weight:</u> 10/15 studies reported improvements
Norris, 2016 [60]	SR	None	<18 y, within a school	Active video games	Efficacy	No	22	<u>Moderate quality:</u> 6/22 studies <u>Low quality:</u> 16/22 studies	PA Weight	<u>PA:</u> 12/22 studies reported improved PA outcomes, 1/22 studies reported no change, and 5/22 studies reported decreased (worse) PA outcomes <u>Weight:</u> 3/6 studies reported improvements
Oliveira, 2020 [58]	SR, MA	None	2-19 y	Active video games	Efficacy	No	12	<u>High Risk of Bias:</u> 8/12 studies Risk of bias of other studies not described (i.e. moderate or low)	PA Weight	<u>PA (SR + MA):</u> no effect on PA (6 studies, moderate/high quality of evidence) <u>Weight (SR + MA):</u> reduced BMI (6 studies, high quality evidence) and waist circumference (3 studies, high quality evidence), and no effect on body fat (2 studies, high quality evidence) or body weight (5 studies, moderate to high)

Pakarinen, 2017 [61]	SR	None	<18 y	Active video games	Efficacy	No	5	<u>Low Risk of Bias:</u> 1/5 studies <u>Medium Risk of Bias:</u> 3/5 studies <u>High Risk of Bias:</u> 1/5 studies <u>Quality of Evidence:</u> Low	PA <u>Other:</u> PA Self Efficacy	<u>PA:</u> 3/5 studies reported improved PA self-efficacy, 1/5 studies reported marginal changes, and 1/5 studies reported no changes in PA self-efficacy
Quelly, 2016 [76]	SR	None	Children and adolescents	Smartphone	Efficacy	No	9	<u>Level of evidence:</u> 4 studies were Level 2 (RCT), 1 study was Level 3 (control without randomization), and 4 studies were Level 4 (case control of cohort). Overall study quality not described	Diet PA SB Weight	<u>Diet:</u> 4/5 studies reported improvements <u>PA:</u> 3/4 studies reported improvements <u>Weight:</u> 0/9 studies reported improvements
Ridgers, 2016 [89]	SR	None	5-19 y	Monitoring Devices <u>Other:</u> Wearables	Efficacy Engagement Acceptability <u>Other:</u> Feasibility	No	5	<u>Included Interventions (3 studies):</u> met 5-6/8 criteria, <u>Included feasibility studies (2 studies):</u> met 1/3 criteria Overall risk of bias not described	PA	<u>PA:</u> 1/3 studies reported improvements, <u>Other:</u> 4/5 studies reported wearables were feasible in this age range
Rodriguez Rocha, 2019 [95]	SR, MA	None	No age restriction	Website Smartphone Mobile text Digital games <u>Other:</u> web or internet-based programs, computer-based programs	Efficacy	No	19 (7 child)	<u>Child specific results:</u> <u>High quality:</u> 4/8 studies <u>Fair quality:</u> 3/8 studies <u>Low quality:</u> 1/8 studies	Diet	<u>Child specific results:</u> <u>Diet (MA):</u> Adolescents: significant improvement in outcomes (4 studies); Child: no significant effect (4 studies)

Rose, 2017 [57]	SR	None	10-19 y	Website Email Smartphone Digital games Telehealth Social media	Efficacy Cost Effectiveness	No	26 (27 articles)	<u>Low Risk of Bias:</u> 3/27 studies <u>Medium Risk of Bias:</u> 16/27 studies <u>High Risk of Bias:</u> 8/27 studies	Diet PA	<u>Efficacy:</u> <u>Diet:</u> 3/10 studies reported improvements <u>PA:</u> 5/14 studies reported improvements <u>Other:</u> 2/2 studies reported significant improvements in SB <u>Cost Effectiveness:</u> No study reported information on cost effectiveness.
Schoeppe, 2016 [32]	SR	None	Children or adults	Smartphone	Efficacy	No	27 (4 child)	<i>Child specific results:</i> <u>High Quality:</u> 2/4 studies <u>Fair Quality:</u> 2/4 studies	Diet PA SB Weight	<i>Child specific results:</i> <u>Diet:</u> 1/2 studies reported improvements <u>PA:</u> 1/3 studies reported significant changes <u>Weight:</u> 0/2 studies reported improvement <u>Other:</u> 1/3 studies reported improvement in SB <u>Other:</u> 1/2 studies reported improvement in physical fitness
Shaw, 2012 [86]	SR	None	No age restriction	Mobile Text <u>Other:</u> SMS must be primary mode, but included those with email, phone calls, and video conferencing as other means of	Efficacy Acceptability	No	14 (4 child)	Quality scores ranged from 44-78% (met 4-7/9 components) No overall quality described	Diet PA Weight	<i>Child specific</i> <u>Diet:</u> 1/1 studies reported improvements <u>PA:</u> 2/3 studies reported improvements <u>Weight:</u> 0/2 studies reported improvements <u>Other:</u> 1/1 study reported

				communication						improvements in screen-time
Siopis, 2015 [87]	SR, MA	None	No age restriction	Mobile text	Efficacy	No	13 (4 child)	<i>Child specific results:</i> <u>Positive (high quality):</u> 3/4 studies <u>Neutral:</u> 1/4 studies	Weight	<i>Child specific results:</i> <u>Weight (SR):</u> 2/4 studies reported improvements <u>MA:</u> No child specific meta-analysis results reported
Stephens, 2013 [28]	SR	None	No age restriction	Smartphone Mobile Text	Efficacy Acceptability	No	7 (2 child)	Not assessed	PA Weight	<i>Child specific results:</i> <u>PA:</u> 0/2 studies reported improvements <u>Other:</u> 1/1 reported less Screen-time No child studies reported weight outcomes
Villinger, 2019 [85]	SR, MA	None	>12 y	Smart phone	Efficacy	No	41 (3 child)	<i>Child specific results:</i> <u>High Quality:</u> 2/3 studies <u>Fair Quality:</u> 1/3 studies	Diet Weight	<i>Child specific results:</i> <u>Diet (SR):</u> no child study assessed diet outcomes <u>Weight (SR):</u> 1/3 studies reported improvements <u>MA:</u> age group was not a moderator of diet outcomes (adolescents vs. adults); no child specific results reported
Wickham, 2018 [68]	SR	None	12-19 y	All e or mhealth	Efficacy Acceptability	No	8	<u>High Quality:</u> 1/8 studies <u>Intermediate Quality:</u> 6/8 studies <u>Low Quality:</u> 1/8 studies	Diet	<u>Diet:</u> 8/8 studies reported improvements, variability in definition of dietary outcomes including food intake (5 studies), ability to

										select healthy foods (2 studies), and intention to consume foods (2 studies)
Wickham, 2015 [69]	SR	Children with overweight or obesity	12-18 y	Smartphone <u>Other:</u> cell phones delivered the intervention	Efficacy	No	6 (8 articles)	<u>High quality:</u> 5/8 studies <u>Intermediate Quality:</u> 3/8 studies	Weight	<u>Weight:</u> 0/6 RCTs reported improvements, 2/2 cohort studies reported improvements
Williams, 2014 [88]	SR, MA	None	No age restriction	Social Media <u>Other:</u> discussion boards	Efficacy	Yes	22 (4 child)	<u>Child specific results:</u> <u>Unclear Risk of Bias:</u> 1/4 studies <u>High Risk of Bias:</u> 3/4 studies	Diet PA Weight	<u>Child specific results:</u> <u>Other (SR):</u> 2/4 studies reported in positive results in either diet, PA, or weight, 2/4 studies reported no significant outcomes <u>MA:</u> No child specific meta-analysis results
<i>BMI = Body Mass Index; GRADE = Grading of Recommendations Assessment, Development and Evaluations; MA= meta-analysis; PA= Physical Activity; SB= sedentary behavior; SR = systematic Review</i>										