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Technology as a Platform for Improving Healthy Behaviors and Weight Status in Children and Adolescents: A Review

Laura Lappan, Ming-Chin Yeh* and May May Leung

Nutrition Program, CUNY School of Public Health, Hunter College, City University of New York, USA

***Corresponding author:** Ming-Chin Yeh, PhD, Nutrition Program, CUNY School of Public Health, Hunter College, City University of New York, 2180 Third Ave, New York, NY 10035, USA, Tel: 212-396-7776; Fax 212-396-7644; **E-mail:** myeh@hunter.cuny.edu

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Abstract

Background: Obese children and adolescents are at an increased risk for obesity in adulthood, emphasizing the need for early intervention. Prior research shows potential benefits of using technology to promote weight loss, healthy dietary habits, and/or physical activity in adults; however, little is known about the efficacy of different modes of technology in children and adolescents. The objective of the present study was to review the use of technology-based interventions to improve nutritional behaviors and weight status in children and adolescents.

Methods: Literature searches of PubMed, PSYC INFO, Web of Science, and Science Direct were performed, using PRISMA review guidelines, to find studies published between 2008 and 2015. Articles were included if they were randomized controlled trials conducted on children or adolescents 19 years or younger, and if the intervention components included mobile applications, websites, and/or text messages.

Results: Eighteen studies met inclusion criteria and were included in the review. In nine studies, technology was the stand-alone intervention and in nine studies, technology was a supplemental intervention. Seven studies resulted in significant improvements in nutritional behaviors or weight status in favor of the technology-based intervention, eight studies showed trends toward favorable outcomes, and three studies showed no effects. Additionally, all studies employed a behavioral approach and seventeen were informed by a behavioral theory.

Conclusions: Technology seems to be an acceptable and feasible means for improving the health of children and adolescents and using behavioral theory to tailor interventions and incorporating family-based content may help improve health outcomes.

Keywords: Mobile technology; Weight; Obesity; Nutrition; Children; Adolescents; Body mass index

Abbreviations

RCT: Randomized Controlled Trial; FFQ: Food Frequency Questionnaire; avg: average; y: years; BMI: Body Mass Index; app: application; SSB: Sugar-Sweetened Beverage; PD: Paper Diary; PAM: Physical Activity Monitor

Introduction

Worldwide obesity has more than doubled since 1980, putting almost two billion people at risk for chronic health conditions such as cardiovascular disease, diabetes, and some cancers [1]. Nearly two billion adults were overweight in 2014 and the World Health Organization estimated that over 42 million children under the age of five were overweight in 2013 [1]. According to the Centers for Disease Control and Prevention, obesity has more than doubled in children and quadrupled in adolescents in the past 30 years [2]. In the United States alone, more than one third of children and adolescents aged 2 to 19 years were overweight or obese in 2012 [2]. Obesity is a preventable condition that is most often caused by increased intake of energy-dense, nutrient-poor foods and a decrease in physical activity [1]. Not surprisingly, efforts to reduce rates of obesity are a major focus of health professionals worldwide. The World Health Organization recommends limiting intake from total fats and sugars; increasing consumption of fruits and vegetables, legumes, whole grains, and nuts; and increasing physical activity [1].

The use of technology has increased in the past decade. Mobile broadband usage has nearly doubled since 2011 and mobile-cellular growth rates are reaching saturation levels, indicating that the number of mobile-cellular subscriptions worldwide is approaching the number of people on earth [3]. Researchers can use this increase in technology access and usage to their benefit by using technology to enhance interventions aimed at reducing rates of obesity. The benefits of using technology to promote weight loss and physical activity among adults are well documented in the literature [4-6]. Previous review articles found that mobile-phone applications, websites, and text messages were feasible and acceptable means of delivering health interventions. The majority of these studies resulted in reductions in participants' bodyweight, body mass index (BMI), or waist circumference and most participants reported being satisfied with the technology-based intervention [4-6]. Technology was the stand-alone intervention in some studies and a supplemental intervention in others. For example, Lee et al. [7] developed a stand-alone interactive mobile phone application for obese adults that included a Diet Planner component, where users entered their daily calorie intake and physical activity, and a Diet Game component meant to quiz users and increase knowledge around nutrition [7]. Compared to the control group, the intervention group showed significant reductions in fat mass, weight, and BMI after using the application for six weeks [7]. Contrarily, Gerber et al. [8] included technology as a supplemental intervention in a weight loss program for obese women. After completing a six-month weight loss program highlighting dietary changes and physical activity, participants received weekly, personalized text messages to encourage

weight control behaviors for four months [8]. Although Gerber et al. did not objectively measure weight loss maintenance, participants reported that text messages were a feasible and acceptable way to promote healthy weight maintenance behaviors [8]. Most interventions in recent reviews were informed by behavioral health theories and utilized constructs such as self-monitoring, goal-setting, feedback, and social support [5]. While the majority of studies utilizing technology-based interventions in adults showed promising results, little is known about the efficacy of technology-based health interventions in children and adolescents.

Rates of childhood overweight and obesity are on the rise and obese youth are at an elevated risk for obesity in adulthood, making intervening early in life imperative [1]. Obese youth and adolescents are more likely to have risk factors for cardiovascular disease, bone and joint problems, sleep apnea, social and psychological problems, and are at an increased risk for developing diabetes [2]. Establishing healthy habits at an early age may help reduce rates of obesity and related consequences. Additionally, targeting adolescents as they transition into young adulthood is important, as these years may play a critical role in shaping individuals' dietary and physical activity behaviors into adulthood [2]. A review by Wickham et al. [9] explored the use of mobile phones as an intervention component in weight loss programs for adolescents aged 12 to 18 years and found mixed results [9]. Seven of the eight included studies reported a reduction in overall BMI and/or BMI z-score, but significant results between intervention and control groups were not found in any studies [9]. All studies included mobile phones as a supplemental intervention, and therefore, favorable results could not be attributed to technology alone [9].

Because childhood BMI is associated with adult adiposity and because overweight 2 to 5 year olds are more than four times as likely to become overweight adults [10], it is necessary to target children in addition to adolescents. Additionally, although interventions utilizing text messages are becoming increasingly popular, mobile phone applications and internet access may be promising additions or alternatives to health-based interventions [10]. Finally, while weight loss is often the primary goal, improvements in diet and physical activity are necessary to achieve and sustain a healthy weight, and it is important to identify successful interventions that target these behaviors [2]. To date, to the authors' knowledge, no reviews address the efficacy of different modes of technology to improve weight status, dietary intake, and physical activity in children and adolescents. Therefore, the current review expands upon recent reviews [4-6,9] by examining the use of multiple modes of technology as a means to improve healthy behaviors in both children and adolescents. The objective of the present study was to review the use of technology as a stand-alone intervention or as a supplemental intervention to improve healthy behaviors and weight status in children and adolescents.

Methods

Databases and search terms used

A literature search was performed to find articles published between 2008 and 2015 in the following electronic databases: PubMed, PsycINFO, Web of Science, and Science Direct. Search terms included "mobile health", "mobile phone", "smartphone", "website", "text message", "weight loss", "nutrition", "physical activity", "exercise", "children", "adolescents", and "randomized".

Study inclusion and exclusion criteria

Studies were included if they were randomized controlled trials (RCTs) conducted in children or adolescents 19 years or younger and if the intervention components included mobile applications, websites, and/or text messages. Studies were excluded if: (1) weight status, physical activity, or dietary intake were not primary outcomes; (2) children or adolescents were not the primary target audience; and (3) articles were not published in English.

Review process

The first author did the initial search and review. The second author was consulted if there were questions regarding the eligibility of the studies. A final decision to either include or exclude those articles in question was discussed and reconciled between the two authors. For each included study, a full text article was obtained and reviewed. Pertinent information was then extracted and synthesized for the review. This review was conducted between March and July 2015. PRISMA guidelines were used in the preparation of the review (Figure 1) [11].

Results

The search and selection process is illustrated in Figure 1. Nearly 700 articles were identified through initial database searches and 24 additional studies were identified through the reference lists of relevant studies. After reviewing the abstracts of identified articles and excluding 665 studies for reasons cited in Figure 1, 58 full-text articles were assessed for eligibility. Of those, 40 were excluded for the following reasons: weight, diet or physical activities were not primary outcomes (n=5); the intervention did not include text messages, websites, or mobile phone applications (n=3); adults were the target population (n=4); and the studies were not RCTs (n=28). Eighteen were included in the current review. Five studies were conducted in children between the ages of 5 and 10 years (Table 1) [12-16], and thirteen studies were conducted in adolescents between the ages of 10 and 19 years (Table 2) [17-29]. Age cut-offs are consistent with the World Health Organization's definition of childhood and adolescence [30]. Fourteen studies included both male and female participants [12,13,15-20,22-26,28], two included only females [14,21], and two included only males [27,29]. Four studies included only overweight or obese participants [12,23,24,28], five studies included participants who were at risk for obesity [14,19,21,26,27], eight studies included no restrictions on weight status [13,15,16,18,20,22,25,29], and one study included only participants who were normal weight or overweight [17].

Behavior change theories

All studies employed a behavioral approach and seventeen were informed by a behavioral theory [12,13,15-29]. The most common theory used to inform the development of interventions was Social Cognitive Theory [13,15-19,21,26,27,29], followed by the Transtheoretical Model of Behavioral Change [17,22,24], the Theory of Planned Behavior [19,20,25], Self Determination Theory [27,28], Cognitive Behavioral Theory [12,23], and the Behavioral Determinants Model [24]. Behavioral techniques common to all interventions included goal-setting, self-monitoring and feedback [12-29].

Mode of intervention

Nine of the eighteen studies focused on technology as a stand-alone intervention [14,17-20,22,24-26], while nine studies incorporated technology as a supplement to another mode of intervention [12,13,15,16,21,23,27-29]. The forms of technology used were mobile applications that enabled participants to monitor and track behaviors, set goals, and receive tailored feedback; websites; and text messages. Three studies involved a combination of these technologies [24,26,27] and the others involved one mode of technology. Interventions lasted from two weeks [25] to two years [23] and primary outcomes were BMI or weight status, dietary intake, and physical activity.

Weight status

Of the eight studies that measured BMI or weight status, two were conducted in children [12,14] and six were conducted in adolescents [17,20,21,23,24,27]. None resulted in statistically significant intervention effects. Two studies found that changes in BMI or weight status favored the intervention groups but were not statistically significant [21,27]; two

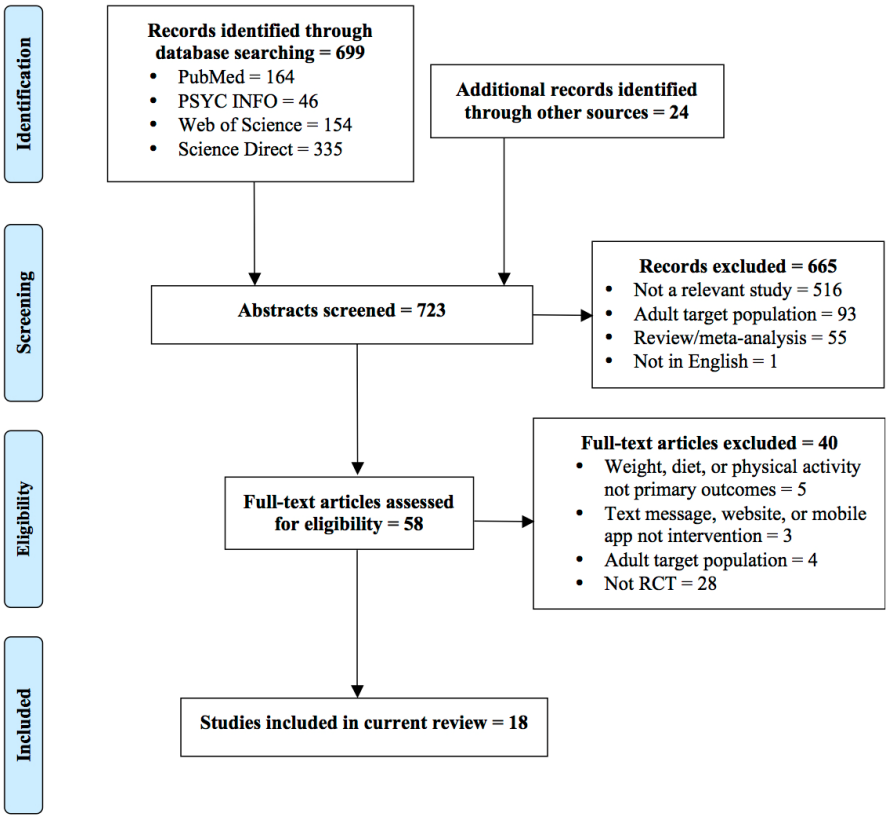

Figure 1: PRISMA flow chart of search and selection process for included studies.

studies found that participants' BMI or weight decreased over the duration of the study, but the intervention groups did not differ significantly from the control groups [12,23]; and four studies found no significant change in BMI in any group [14,17,20,24].

Dietary behaviors

Of the ten studies that measured dietary intake, four were conducted in children [13-16] and six were conducted in adolescents [17,18,20,22,28,29]. Dietary intake was self-reported via food frequency questionnaire (FFQ) or food diary and captured frequency of fruit and vegetable consumption [13,14,16-18,20,22,28,29] and frequency of sugar-sweetened beverage (SSB) consumption [14,15,20]. Improvement in dietary intake was defined as increased fruit and vegetable consumption or decreased SSB consumption. The technology-based interventions resulted in statistically significant improvements in dietary intake compared to controls in seven studies [13,16-18,22,28,29]. One study found that improvements in participants' dietary intake favored the intervention group but were not statistically significant [20], and two studies found no changes in dietary intake in any group [14,15].

Physical activity

Of the twelve studies that measured physical activity, four were conducted in children [13-16] and eight were conducted in adolescents [17-20,22,25,26,28]. Physical activity frequency was measured by self-reported questionnaires [13-16,18-20,22,25,26] and pedometers [13,15-17,20,26,28]. The technology-based intervention resulted in statistically significant increases in physical activity in five studies [17,19,22,26,28]. Two studies found that participants' physical activity levels increased over the duration of the study, but the intervention groups did not differ significantly from controls [18,25], and four studies found no changes in physical activity in any group [13,15,16,20].

Discussion

Developing healthy behaviors and weight status during childhood and adolescence is important. The current review reveals that technology-based interventions aimed at reducing weight status or improving healthy behaviors in children and adolescents show promising results. Fifteen of the eighteen studies showed trends in favor of technology-based interventions in at least one of the primary outcomes (i.e., BMI or weight status, dietary intake, physical activity) that may be clinically meaningful.

Changes in dietary intake and physical activity were more responsive to intervention than changes in BMI or weight status. This may be due, in part, to the dietary intake and physical activity outcomes often being self-reported, while BMI and weight status were measured by study personnel and thus, objectively. Self-reported outcomes may result in social desirability bias and are not as reliable as objective measures [31,32]. Furthermore, changes in dietary intake and physical activity seem more feasible in the short-term than changes in BMI or weight status, and thus, could explain the lack of significant findings related to BMI or weight status observed in this review. Similarly, a recent review of eight studies on the use of mobile phones as a component of weight loss interventions in adolescents found no significant differences in BMI between intervention and control groups [9]. Although weight loss is often the end goal, behavior changes, such as increasing physical activity and improving dietary intake, are necessary to achieve weight loss, making interventions that target behavioral change crucial to reducing the rising rates of obesity [1].

Findings from the present review are consistent with previous reviews in children and adolescents. For example, a 2011 review on electronic

Reference	Sample	Research design/ duration	Intervention/ theories used	Mode of technology	Control	Primary outcomes	Results
de Niet et al. [12]	*n*=141, age range 7-12 y, 36% male, overweight or obese	38-week, 2-armed, multi-center RCT	Family-based multidisciplinary behavioral group intervention plus weekly text messages that included self-monitoring data on physical activity, eating patterns, and mood; reminder text messages; and feedback text messages tailored to individuals' patterns of behavior change **Theory:** Cognitive behavioral theory	Supplemental text message	Family-based multidisciplinary behavioral group intervention only	BMI	Both groups significantly decreased BMI; text message group less likely to withdraw from intervention
Fassnacht et al. [13]	*n*=49, age range 8-10 y, 53.1% female, 71.4% normal weight	8-week RCT	Two educational sessions focused on physical activity and healthy diets; monitored fruit and vegetable consumption, physical activity, and screen time and received feedback via text messages **Theory:** Social cognitive theory	Supplemental text message	Received two educational sessions; did not include text message monitoring and feedback	FFQ, physical activity, screen time	Intervention group showed significant increase in fruit and vegetable consumption and a significant decrease in screen time compared to control group; both groups achieved the physical activity goal before the intervention
Nollen et al. [14]	*n*=51, age range 9-14 y, 100% female, avg BMI = 23.7	12-week 2-armed RCT	Hand-held computer program targeting fruit and vegetable consumption, sugar-sweetened beverage (SSB) consumption, and screen time **Theory:** N/A; *intervention grounded in behavioral weight control principles*	Stand-alone mobile app	Received intervention content via written manual	BMI, food intake, screen time, use of hand-held computer program	Within intervention group, significant association between increased computer program use and decreased SSB consumption; no significant changes between groups for BMI, screen time, or fruit and vegetable consumption
Shapiro et al. [15]	*n*=58, age range 5-13 y, 62% female, no weight restrictions	8-week RCT	*2 groups:* Text message group: attended educational group sessions; monitored physical activity, SSB intake, and screen time via text message; received feedback messages via text message Paper diary (PD) group: attended educational group sessions; monitored physical activity, SSB intake, and screen time via PD **Theory:** Cognitive social learning theory	Supplemental text message	Attended educational group sessions; no self-monitoring	Physical activity levels, SSB intake, screen time	Text message group showed significant reduction in screen time compared to PD and control groups; no significant differences in exercise or SSB between groups; text message group showed significantly greater adherence to self-monitoring than PD group
Silva et al. [16]	*n*=139, age 8-10 y, 47% female, 55% overweight or obese	8-week school-based RCT	Two 60-minute psycho-educational sessions targeting fruit and vegetable consumption, physical activity, and screen time; children monitored behaviors (number of steps measured by pedometer, fruit and vegetable consumption, screen time) for 8 weeks via text message once a day; tailored feedback messages were sent to children **Theory:** Social cognitive theory	Supplemental text message	Attended same two 60-minute psycho-educational sessions; did not monitor behavior or receive tailored feedback via text message	FFQ, physical activity frequency	Intervention group showed significant increase in fruit and vegetable consumption over time compared to control group; no significant difference between groups for physical activity and screen time

Table 1: Characteristics of randomized controlled trials examining technology-based interventions to improve nutritional behaviors and weight status in children between the ages of 5 and 14 years (n=5).

RCT: Randomized Controlled Trial; **FFQ:** Food Frequency Questionnaire; **avg:** average; **y:** years; **BMI:** Body Mass Index; **app:** application; **SSB:** Sugar-Sweetened Beverage; **PD:** Paper Diary

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Reference	Sample	Research design/ duration	Intervention/theories used	Mode of technology	Control	Primary outcomes	Results
Chen et al. [17]	*n*=54, age range 12-15 y, 53.7% male, normal weight or overweight	8-week RCT	Tailored, web-based behavioral program focused on promoting adequate dietary intake and improved physical activity; included a family component to provide reinforcement and social support at home **Theory:** Social cognitive theory; transtheoretical stages of change	Stand-alone website	Received non-tailored, general health information delivered via website	BMI, waist-to-hip ratio, blood pressure, actigraph, food diary, health-related knowledge	Intervention group showed significant reductions in waist-to-hip ratio and blood pressure, increased physical activity, increased vegetable and fruit intake, and increased knowledge related to physical activity and nutrition compared to control group
Cullen et al. [18]	*n*=408, age range 12-17 y, 54% female, 70% normal weight	8-week RCT	Website focused on physical activity and healthy eating that includes role model video stories addressing barriers, recipes, educational materials, access to a blog, online self-monitoring, goal review and problem-solving **Theory:** Social cognitive theory	Stand-alone website	Website developed from the basic intervention website; did not include role model stories, online self-monitoring, goal review, and problem-solving	Dietary intake, physical activity behaviors	Intervention group showed significant increase in vegetable consumption compared to control group; both groups showed significant increase in physical activity and significant decreases in TV watching
De Bourdeaudhuij et al. [19]	*n*=1053, age range 12-17 y, 51% male, 47.6% inactive	1-month school-based RCT	Computer-tailored physical activity intervention that included an introduction page, a diagnostic tool, and advice; received the tailored advice at baseline and 1 month **Theory:** Theory of planned behavior; social cognitive theory	Stand-alone website	Received generic standard advice at baseline and 1 month	Physical activity levels	Intervention group showed significantly more physical activity at 1-month and 3-months post-intervention compared to control group
Ezendam et al. [20]	*n*=883, age range 12-13 y, 45.2% female, 76.5% normal weight	10-week school-based, cluster RCT	Web-based, computer-tailored intervention to increase physical activity, decrease sedentary behavior, and promote healthy eating; included information, assessments, tailored feedback, goal-setting, and action-planning **Theory:** Theory of planned behavior	Stand-alone website	No intervention control group	BMI, FFQ, physical activity, sedentary behavior	No significant differences between groups for BMI, sedentary behavior, and physical activity; favorable effects on dietary behaviors for the intervention group in the short-term but not at 2-year follow up
Lubans et al. [21]	*n*=357, age range 12-14 y, 100% female, avg BMI = 22.64	12-month cluster RCT	Multi-component, school-based intervention plus weekly text messages encouraging physical activity and healthy eating **Theory:** Social cognitive theory	Supplemental text message	Received intervention content via printed materials	BMI, percent body fat	No significant changes between groups; changes in BMI and percent body fat favored intervention group
Mauriello et al. [22]	*n*=1800, avg age = 16.97 y, 50.8% female, 74.7% normal weight	2-month school-based stratified RCT	Multi-media intervention for physical activity, fruit and vegetable consumption, and limiting TV viewing administered via computer; included assessments and tailored feedback messages **Theory:** Transtheoretical model of behavior change	Stand-alone website	No treatment control group	Physical activity, fruit and vegetable consumption, TV viewing	Treatment group consumed significantly more fruits and vegetables 12 months post-intervention compared to control group; treatment group reported significantly more physical activity compared to control group immediately post-intervention but this was not maintained 12 months later

Nguyen et al. [23]	*n*=151, age range 13-16 y, overweight or obese, (did not report gender statistics)	24-month 2-armed RCT	Community-based behavioral lifestyle intervention plus additional therapeutic contact delivered via telephone coaching, text message, and/or email communication **Theory:** Cognitive behavioral theory	Supplemental text message	Community-based behavioral lifestyle intervention only	BMI	No significant changes between groups; both groups decreased BMI
Patrick et al. [24]	*n*=101, age range 12-16 y, 63.4% female, overweight or obese	12-month RCT	*3 groups:* Website only: content focused on education and behavioral goals related to nutrition and physical activity Website, group sessions, and follow-up calls: website plus monthly group sessions and bimonthly phone calls from health counselor Website plus text messages: website plus 3 or more text messages per week related to intervention goals **Theory:** Transtheoretical model of behavior change; behavioral determinants model	Stand-alone website and text message	Received intervention content via printed materials	BMI	No significant changes between groups
Sirriyeh et al. [25]	*n*=120, age range 16-19 y, 70% female, no weight restrictions	2-week school-based, exploratory pilot RCT	*3 groups:* Instrumental text messages: received one text message per day regarding the instrumental gains associated with physical activity Affective text messages: received one text message per day regarding the affective gains associated with physical activity Combination text messages: received an equal number of affective and instrumental text messages over 14 days **Theory:** Theory of planned behavior	Stand-alone text message	Received two neutral text messages over 14 days	Physical activity behavior	No significant differences between groups; physical activity levels increased for all groups; among inactive participants, affective text messages significantly increased physical activity compared to instrumental and combined text messages
Slootmaker et al. [26]	*n*=87, age range 13-17 y, 63% female, inactive	3-month school-based RCT	Received a physical activity monitor (PAM) and access to web-based tailored physical activity advice **Theory:** Social cognitive theory	Stand-alone mobile app and website	Received general physical activity recommendations via paper brochure	Physical activity levels	Among girls, intervention group showed significantly more physical activity at 3 months compared to controls but there were no significant differences between groups at the 8-month follow up; among boys, intervention group showed significantly less sedentary time than control group at 8-month follow up
Smith et al. [27]	*n*=361, age range 12-14 y, 100% male, avg BMI = 20.5	20-week cluster RCT	ATLAS group: school-based multi-component intervention including a supplemental smartphone app that monitors and tracks behaviors, sets goals, and sends tailored text messages **Theory:** Social cognitive theory; self-determination theory	Supplemental mobile app and text message	Usual care: regularly scheduled school sports and physical education lessons	BMI, waist circumference	No significant changes between groups; ATLAS group showed favorable body composition changes

Straker et al. [28]	*n*=69, avg age = 14.1 y, 71% female, overweight or obese	12-month within-subject, waitlist controlled trial	8-week community-based, family-centered behavioral intervention aimed to increase physical activity and healthy eating behaviors; 12-month follow up included structured telephone and text message contact focused on eating more fruits and vegetables, eating less junk food, being less sedentary, and being more active **Theory:** Self-determination theory	Supplemental text message	Waiting-list control	Physical activity levels, dietary intake	Significant increase in fruit consumption and moderate physical activity and significant decrease in sedentary time during intervention; behaviors maintained over 12-month follow up
Thompson et al. [29]	*n*=473, age range 10-14 y, 100% male, no weight restrictions	9-week group randomized trial	9-week group intervention to increase fruit and vegetable consumption; each session involved in-group instruction plus internet programming that included personal goal-setting, self-monitoring, and problem-solving **Theory:** Social cognitive theory	Supplemental website	Mirror-image intervention to increase physical activity	FFQ, self-efficacy	Intervention group showed significant increase in fruit juice consumption compared to control group immediately post-intervention; results were not maintained 6 months later

Table 2: Characteristics of randomized controlled trials examining technology-based interventions to improve nutritional behaviors and weight status in adolescents between the ages of 10 and 19 years (n=13).

RCT: Randomized Controlled Trial; **avg:** average; **y:** years; **BMI:** Body Mass Index; **app:** application; **PAM:** Physical Activity Monitor

interventions for prevention and treatment of overweight and obesity in young people included mainly website-based interventions and found that the majority of studies resulted in statistically significant favorable outcomes [33]. Similarly, four of the five stand-alone website interventions in the current review found statistically significant results in favor of the intervention group [17-19,22]. The favorable findings for physical activity in the present review are also consistent with past reviews. Lau et al. systematically evaluated the efficacy of Internet and mobile phone interventions to improve physical activity in children and adolescents [34]. Seven of the nine studies assessed in their review demonstrated positive and significant within-group differences for physical activity outcomes and three studies resulted in positive and significant between-group differences favoring the technology-based group [34]. Similarly, Fanning et al. conducted a meta-analysis of research utilizing mobile devices to improve physical activity and found that mobile devices were an effective means for influencing physical activity behavior [35]. Although both reviews supported the use of technology-based interventions, both stressed the need for theory-based behavior change interventions [34,35].

Most interventions in the present review were informed by behavioral change theories [12,13,15-29], with Social Cognitive Theory being the most common [13,15-19,21,26,27,29]. The one study that did not explicitly state the use of behavioral theory incorporated constructs of Social Cognitive Theory such as goal-setting, self-monitoring, and feedback [14]. According to Social Cognitive Theory, health behavior change is a dynamic process that is influenced by self-efficacy, goals, and outcome expectancies [36]. For example, de Niet et al. [12] incorporated goal-setting, self-monitoring, and positive reinforcement tailored to participants' patterns of behavior change via the text message component of their intervention. Similarly, Mauriello et al. [22] used the Transtheoretical Model of Behavior Change to develop a website-based intervention to increase physical activity and fruit and vegetable consumption in adolescents. The Transtheoretical Model is based upon the belief that behavior change progresses through several stages and, depending on which stage a person is in, different strategies are most effective at moving the individual from one stage to the next [37]. Behavior change is a complex process and health behavior theories present a systematic way of understanding behaviors and the context in which they occur [38]. Evidence suggests that interventions informed by health behavior theories or models are more effective than those lacking theory [38]. The use of behavioral theories seems to be instrumental in changing participants' health outcomes.

A systematic review on behavior-change techniques in physical activity and dietary mobile applications for children and adolescents found that modeling appropriate behavior, prompting practice, and social support were most effective for improving child and adolescent physical activity and dietary intake [39]. Few studies reviewed in the present paper included modeling behavior or prompting practice; however, several included social support in the form of schools, communities, and families [12,13,15-17,19-29]. Not surprisingly, nine of the ten studies in the current review that involved a family component resulted in desirable effects [12,13,15-17,21,23,27,28]. Parents participated in interventions by attending educational sessions focused on increasing parental knowledge about healthy behaviors and strategies to support their children [12,15-17,23,24,28] or by assisting their child with the technology component of the intervention [13,15]. For example, in the study by Fassnacht et al. [13], parents attended an educational session about the intervention program and were encouraged to supported their children's use of pedometers and mobile phones to monitor healthy behaviors throughout the program [13]. Similarly, parents in the study by Chen et al. [17] participated in online lessons about creating a healthy environment for their children. In two studies, parents did not directly participate in the intervention but instead received newsletters aimed at engaging parents and encouraging them to support their children's efforts to improve healthy behaviors [21,27]. Interventions targeting children and adolescents may benefit from a family-based approach by providing reinforcement and social support at home [17].

The variability in participant characteristics, length of intervention and specific components of each intervention in the present review hindered determination of which mode of technology-based intervention (i.e., mobile application, text message, or website) was most effective for improving healthy behaviors and weight status in children and adolescents. For example, De Bourdeaudhuij et al. [19] randomized inactive male and female adolescents to either a stand-alone website-based intervention or standard care control group [19], while Smith et al. [27] randomized

low-income adolescent boys to either a mobile application supplemented multi-component intervention or no-intervention control group. The variability in the sample population and intervention components of these two studies makes comparison difficult.

Additionally, the use of technology as a stand-alone intervention or as a supplemental intervention also varied. Nine studies included technology as a stand-alone intervention and nine studies included technology as a supplement to or a component of an intervention. Furthermore, within the broader categories of stand-alone versus supplemental interventions, some studies included a combination of technologies. For example, Patrick et al. used a combination of website and text message as a stand-alone intervention [24], Nollen et al. [14] used only a mobile application as a stand-alone intervention, Smith et al. [27] used a combination of mobile application and text message as a supplemental intervention, and Nguyen-Shrewsbury et al. used only text message as a supplemental intervention [23]. A recent review of mobile health technologies for cardiovascular disease prevention suggested that mobile technologies supplemented by other methods such as telephone calls, web sites, and peer groups may be more effective for weight loss or weight maintenance than stand-alone technologies [40]; however, the variability in interventions in the present review hindered direct comparisons.

Nonetheless, regardless of the type of technology-based intervention and whether it was stand-alone or supplemental, studies that conducted a process evaluation reported that participants found the technology-based interventions helpful [13,16,18,21,26,27]. Additionally, the incorporation of text messages in particular increased adherence to interventions [12,15,27]. Woolford et al. [41] conducted focus groups with obese adolescents to explore their perspectives about text message use and content in obesity interventions. Findings suggested that adolescents were enthusiastic about receiving text messages and text messages were an acceptable means to support weight loss efforts [41]. Text messages may be a useful tool for weight-loss maintenance and increased intervention adherence, especially among adolescents.

Strengths of the present review include an extensive search of the literature and the inclusion criteria of only RCTs published in the last seven years. Several aspects of each intervention were assessed to create a comprehensive summary of the current status of technology-based interventions aimed at increasing healthy behaviors in children and adolescents. However, as mentioned earlier, a major limitation of the present review is the variability in intervention types and components, participant characteristics, and outcome measures of the included studies. Because of the lack of technology-based RCTs addressing healthy behaviors and weight status in children and adolescents, inclusion criteria had to be broad. The ability to synthesize results of such diverse studies was limited. Additionally, several studies included multi-component interventions, making it difficult to determine which aspects of each intervention were most effective. Studies not referenced in PubMed, PsycINFO, Web of Science, or Science Direct and unpublished studies were not identified, and therefore, the present review is subject to publication bias. Most studies lacked large sample sizes, possibly affecting the statistical power of the studies. Finally, many studies also lacked long-term outcomes, possibly explaining the absence of weight change in some studies and making it difficult to determine if the interventions had lasting effects. Of the studies that did follow up with participants several months post-intervention, results were often not maintained over time [20,22,26,29], emphasizing the need for longer-term interventions with lasting effects.

Because of the size and growth in the smartphone market and the plethora of health-related mobile applications available to the public, it is likely that mobile application and text message interventions will become increasingly prevalent. Several review articles have studied the presence of behavior-change techniques, theory-based content, and evidence-informed practices in current weight management commercial mobile phone applications and concluded that inclusion of evidence-based strategies is lacking [42-44]. RCTs that utilize evidence-based mobile phone interventions as a means to prevent or reduce risk for obesity in children and adolescents are underway [45,46]. Results from these studies will add to the current literature and may shed light on the most effective components of technology-based interventions in children and adolescents.

Conclusion

To the authors' knowledge, this is the first review to explore the use of text messages, mobile applications, and websites as interventions to improve healthy behaviors and weight status in children and adolescents. Findings suggest that technology is an acceptable and feasible means for improving the health of children and adolescents and text messages, specifically, can increase adherence to interventions. Both children and adolescents were receptive to technology-based interventions; however, interventions that target children at an early age may be key to prevent unhealthy behaviors into adolescence and adulthood. In addition, using behavioral theories such as Social Cognitive Theory that utilize constructs including goal-setting, self-monitoring, and feedback to tailor interventions to specific populations is important. Incorporating family involvement is also crucial in eliciting desirable health behavior changes, as the family is a fundamental and influential component of childhood and adolescence.

Technology is a rapidly changing field and the fact that people pick up one technology and discard another every few years makes it difficult for a study to be developed, funded, and executed prior to the original technology becoming obsolete. Further research is needed to determine the specific characteristics and types of technology-based interventions that are most effective for children and adolescent populations.

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