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Prevention and treatment of pediatric obesity using mobile and wireless technologies: a systematic review

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Abstract

Mobile health (mHealth) is a relatively nascent field, with a variety of technologies being explored and developed. Because of the explosive growth in this field, it is of interest to examine the design, development, and efficacy of various interventions as research becomes available. This systematic review examines current use of mobile health technologies in the prevention or treatment of pediatric obesity to catalogue the types of technologies utilized and the impact of mHealth to improve obesity-related outcomes in youth. Of the 4021 articles that were identified, 41 articles met inclusion criteria. Seventeen intervention studies incorporated mHealth as the primary or supplementary treatment. The remaining articles were in the beginning stages of research development and most often described moderate to high usability, feasibility, and acceptability. Although few effects were observed on outcomes such as body mass index, increases in physical activity, self-reported breakfast and fruit and vegetable consumption, adherence to treatment, and self-monitoring were observed. Findings from this review suggest that mHealth approaches are feasible and acceptable tools in the prevention and treatment of pediatric obesity. The large heterogeneity in research designs highlights the need for more agile scientific processes that can keep up with the speed of technology development.

Keywords

mobile health; mHealth; obesity; pediatric obesity; wireless technologies

Introduction

Pediatric obesity remains a significant public health problem. Advances in mobile and wireless technologies provide novel tools to engage a large proportion of the population with information, strategies, and resources to reduce obesity risk. The ubiquitous and preferred technology is the mobile phone, providing the user with mobile communication, wearable

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sensors, on-board or remote real-time data analytics, and internet/cloud connectivity (1). This combination of sensors and connectivity allow capture of real-time physiological, behavioral, and health-related data, provide an access to influence behaviors (e.g. physical activity, diet), or alert health care providers or interventionists when changes occur (e.g. weight, glucose).

Mobile health (mHealth) technologies are wireless devices and sensors (including mobile phones) intended to be carried and accessed during normal daily activities for the purpose of monitoring health status, changes in health outcomes, or for wireless diagnoses and clinical decision support (2). Potential advantages of mHealth for the prevention and treatment of obesity include significant reach, real-time data collection, and ability to deliver personalized, interactive, and adaptive interventions to participants in their natural environment. Significant work remains to develop mHealth approaches that are robust enough to serve as stand-alone interventions, and to determine if these approaches can improve outcomes and reduce healthcare delivery costs. While several reviews have explored the use of electronic media (e.g. web-based programs) for the prevention or treatment of obesity and related behaviors in pediatric populations (3, 4), none have exclusively focused upon the use of mobile technologies for this objective. Therefore, the purpose of this systematic review was to examine pediatric obesity prevention and treatment studies that used mobile technologies to intervene on weight-related behaviors and weight status.

Methods

Literature search and selection

A research librarian provided assistance in the literature search strategy. We used keywords from the MeSH database and synonyms for the following terms: obesity, overweight, mobile health, and pediatric. (Full search is provided in Supplement 1). A systematic search of the literature was conducted between January 3 and February 12, 2014 using PubMed, Web of Science, EBSCOhost, The Cochrane Library, and Google Scholar databases. Results were confined to English language publications.

Articles were included if the research aim was to advance the prevention or treatment of obesity in pediatric populations (0 – 19 years) and used mobile technologies to assess and/or impact diet, physical activity (PA), or weight-related behaviors such as self-monitoring. This review also included articles if they evaluated the usability (features/function of the device/approach), feasibility (of the method), or acceptability (to participants) of mobile technology-based approaches. Interventions had to directly engage children or their immediate caregivers using mobile technologies. Furthermore, articles were included only if outcomes related to the use mHealth were reported (e.g. separately evaluated as part of a multicomponent intervention).

Studies were excluded if participants were > 19 years old, enrolled in college, hospitalized, reported conditions known to influence dietary intake, PA behavior, or weight status (e.g. anorexia nervosa) or diagnosed with type 1 or 2 diabetes mellitus. Articles were excluded if the technology was not explicitly “mobile” (e.g. web- or email-based), or did not evaluate mobile and wireless aspects of assessment or intervention delivery. Articles were also excluded if the main technology components were not mobile as with stationary game consoles (e.g. Wii) or there were no indications of mobile platform compatibility. Articles describing software, hardware, or computing/engineering proof of concepts were excluded if they did not evaluate participant outcomes related to the use, acceptability, or impact of mobile technologies on the prevention or treatment of obesity and related conditions and behaviors.

Articles were screened according to study inclusion criteria. Final articles included were read and confirmed independently by two researchers and any discrepancies resolved by a senior researcher. The same research members abstracted relevant data from each eligible study including outcomes such as changes in weight status and behaviors and attitudes/ beliefs associated with energy balance (e.g. diet, PA, readiness to change). Formative and process outcomes such as usability, feasibility, acceptability, adherence and attrition were also captured.

The quality of intervention studies was assessed using the Quality Assessment Tool for Quantitative Studies (5) where applicable. Two researchers independently rated the studies; discrepancies of ratings were resolved by a senior researcher. Studies were rated based on selection bias, study design, consideration of confounders, blinding, reliability and validity of data collection tools, study attrition, percentage of treatment exposure received, and appropriateness of statistical analysis.

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) checklist was used to guide how the findings from this review were reported (6).

Results

The search of databases and other sources (e.g. review articles) resulted in a total of 4021 articles. After removing duplicate articles and studies that did not meet inclusion criteria, a total of 41 articles were included. The study selection is shown in Figure S1.

The 41 articles corresponded to 32 studies conducted at various stages of research (e.g. design, pilot, and intervention) are presented in Tables S1a and S1b. Multiple articles describing the same study (e.g. study protocols) were grouped together. Participants were 5 to 19 years old, although most frequently they were 12 to 15 years of age (95% of included studies). Most studies were conducted with diverse participant populations (i.e. diverse gender, race/ethnicity).

Randomized controlled trials

Seven articles representing three randomized controlled intervention trials (RCT) (7–13) are summarized in Table S1a. The quality of these studies rated highly.

All three RCTs used short messaging service (SMS) to help overweight and obese adolescents meet intervention goals such as improving weight-related behaviors (e.g. PA, diet, mediators of these behaviors) in order to reduce body mass index (BMI) and other indices of body fat. SMS was used as a weight maintenance treatment in addition to occasional group sessions (7, 8), in addition to other treatments such as in-person visits, emails, calls and occasional group sessions as a weight maintenance treatment (9–12), or as a weight loss treatment with other electronic communications (e.g. website) (13). SMS was used to promote self-monitoring (7, 8), goal setting (9–13), provide tips, strategies, and encouragement (9–13), reduce study attrition (7–13), and promote adherence to treatment (7–13) (e.g. reminders to attend classes (9–12) or to log on to a website (13)). Two of the three trials provided tailored feedback using SMS such as semi-personalized replies to the self-monitoring messages sent from participants (7–12).

In all three RCTs, results suggested the combination of SMS in addition to other treatments or other electronic contact (e.g. website, email) had no additional effect on BMI, weight-height ratio, adiposity, PA, diet, or psychosocial outcomes. In one of the trials, reduction in study attrition was attributed to the use of SMS (8). Adherence to SMS (defined as percent of expected SMS responses) was moderate to low in these studies (47% and 22%) (8, 11); also, overall treatment adherence was often very low over the study duration (e.g. 31% quarterly group session attendance at two years (9, 10), and 7 – 21% website login rate at one year) (13).

Pilot intervention and technology use and design studies

Table S1b summarizes all pilot intervention and user studies. Thirty-four articles representing 30 studies either evaluated mHealth as a primary (standalone) or adjunct obesity intervention (e.g. support for a weight management program) or as a technology design and use investigation. They are categorized as “Pilot intervention studies” and “Technology use and design studies,” respectively.

Pilot intervention studies—Eleven articles representing nine pilot intervention studies assessed the effects of mHealth on changes in BMI, BMI-Standard Deviation Scores (BMI-SDS), diet, PA, physiological measures, treatment adherence, and/or attitudes, perceptions, and beliefs (14–24). Six articles investigated mHealth as a support for interventions focused on weight management and obesity prevention in free-living youth (25–30).

To promote increased PA, studies used mobile applications (apps) and games with (15, 16, 20–22) or without (17, 18) wireless sensors or pedometers, or with the addition to handheld game consoles (Nintendo DS Lite) (15). The mobile apps and games were particularly successful in promoting increased PA when feedback, self-monitoring, and social networking were involved (17, 20, 21). While not statistically significant, decreased BMI (-0.51 kg/m^2 in overweight/obese group, $p= 0.13$) (18) and improvement in readiness to change PA behaviors (15) were reported. These technologies were frequently described as being more fun (16) and motivational (21) compared to traditional exercise. Participants also reported a lowered perceived effort when performing PA while using mobile apps and games even though no physiological differences (e.g. heart rate) were observed between virtual reality-integrated exercise and traditional PA (16). In a pilot study, participants used SMS to self-report behaviors (diet, PA, emotions) and receive automated feedback (via computer algorithm based upon incoming messages) during a weight maintenance study; although non-significant decreases in BMI-SDS (0.07 ± 0.26 kg/m^2-SDS, $p< 0.1$) were reported, 51.4% maintained their BMI-SDS after nine months and less than 80% of participants had no increase to a slight increase in BMI-SDS (0.1 kg/m^2-SDS) (24). SMS was used in another study to promote PA using different message tones (e.g. affect messages focused on feelings and potentially immediate benefits of PA such as "PA will make you feel enthusiastic" compared to instrumental messages that were informative and focused more on long-term benefits such as "PA will help you maintain your weight") (23). Affect messages sent via SMS were effective in increasing PA in inactive individuals only; instrumental messages had no effect (23).

Studies focused on improving dietary intake employed a personal digital assistant (PDA) app (19) and a virtual pet mobile phone game (14). PDA app with nutrition information, goal setting, goal reminders, diet strategies, feedback, rewards, and a diet diary to encourage fruit and vegetable (FV) consumption was associated with increased self-reported FV intake and increased behavior change skills (self-monitoring, goal setting) in 8- to 15-year-old girls (19). A mobile phone game with virtual pets that expressed the full range of emotions (i.e. ability to be visually sad and happy) increased frequency of breakfast consumption and child attachment to pets in 12- to 14-year-olds, whereas participants with pets that expressed neutral to positive emotions reported less interest in healthy eating and lower engagement with pet (14). There were no differences in quality of breakfast consumed or reported self-efficacy to eat healthier in either group, however, the game was played for only nine days.

To support weight management and obesity prevention programs, studies described the use of mHealth to promote self-monitoring of diet, PA, and/or other behaviors (e.g. sleep) (25–28, 30), provide support and encouragement (25–27, 30), and/or reduce study attrition (25–27, 30). Studies were structured as case reports (25), pilot studies (26, 28–30), and a feasibility trial (27). Techniques included cell phone calls and an Actigraph sensor (sleep monitor/pedometer) (26), cell phone cameras (30) with (27) or without (25) the addition of a wireless motion sensor, and SMS (28, 29). High ratings of acceptability and feasibility (e.g. ease of use, compliance to treatment, responses to prompts to self-monitor, mHealth relevance of supporting treatment and delivery characteristics) (26, 29, 30), increased self-monitoring (25, 28) and increased perceived support (30) were described.

Technology use and design studies—Approximately half of the studies in Table S1b (15 studies) were usability, feasibility, and acceptability studies designed to evaluate various mHealth approaches. Most evaluations were conducted in a laboratory or classroom setting.

To address diet, PA, sleep, or screen media usage, SMS content was developed and evaluated in controlled settings (e.g. classroom) or in free-living conditions (31–33). SMS-ready content designed with participation from youth (31, 33) and parents (32) was regarded as acceptable and feasible (e.g. enjoyment, satisfaction, preferences of message type, format, delivery and frequency). Participant preferences and suggestions included designing SMS messages with variety of relevant content (31, 32). The most popular content of SMS were factoids (e.g. a brief or trivial item of information) (31), quizzes (31), and recipes (31, 33). Participants suggested that messages should be positive (33), include action-oriented (32) or peer-endorsed strategies (33), and focus on specific, achievable goals (31). Tailored messages, especially to participant age (31, 32), gender and environment (e.g.

neighborhood) (32) and personalized feedback (33) were preferred. Due to character constraints of SMS, youth and parents suggested links (31, 32) or live support (32) as methods to access more information if desired. Preferred frequency of SMS delivery ranged from one (29) to two times a day (31) for youth and twice a week (from pediatricians) for parents (32).

Mobile apps and games were designed and evaluated to measure and/or promote PA with (34, 35) or without (36–38) wireless sensors. These apps and games were generally rated as enjoyable by youth (34, 37). Youth reported the desire to use these apps to motivate PA, and more than half were willing to use the app for up to 60 minutes a day (34). Participant preferences for PA games included a variety of tasks with increased difficulty by level (36), social-networking or sharing capabilities (34, 36, 37), audio guidance on how to use the app (36), brief motivational phrases (36), and novel exercise prompts (e.g. push-ups performed by touching nose to phone to score points) (36). Participant preferences varied by game theme, gender, weight status, and personality type (36, 37). Surveys of participant perception and technology use also varied with age: 14- to 15-year-olds perceived several exercises as more difficult than other age groups, and older teens (14- to 17-year-olds) used mobile music, video, and Global Positioning System (GPS) technologies more often than 11- to 13-year-olds (39). One study compared accelerometer data to a mobile phone survey app for PA self-reporting (40) and found that self-reports from the app agreed well with sensor-measured PA and did not appear to bias the participant's engagement in PA. High acceptability (e.g. ease of use, adherence to prompts) was also reported.

Studies evaluating dietary data collection techniques included PDA use with or without a camera (comparing it to other techniques such as 24-hour dietary recall) (41), mobile phone apps with wireless barcode readers to capture manufacture-provided nutrient data (42), and a novel app that integrated photos taken by the participant with a food database (43–45). A mobile phone game was evaluated for acceptability to promote healthy food choices while shopping (46). Articles focused on diet data collection or promoting healthy choices reported participant usability, perceptions, and preferences including the ability to enter food records using text instead of voice methods (43, 44), the availability a food search menu in lieu of a hierarchal menu (43, 44), and the use of electronic media (e.g. PDA, camera) as a substitute for paper diaries (41). There were no differences in camera use proficiencies by age or gender to record meals; however youth were less likely to remember to include fiducial markers (an object used as a measurement reference in photographs) and to photograph all meals and snacks (43, 44). The accuracy of a dietary app with the Food and Nutrient Database for Dietary Studies, was also reported (45).

Discussion

In this review, studies included mobile health technologies such as mobile apps, games, and SMS in efforts to prevent or treat pediatric obesity. SMS was used in RCTs (in addition to other forms of contact as email, calls, websites) (7, 9, 10, 13), in pilot intervention studies (23, 28–30), and was formatively evaluated in design studies (31–33). Mobile apps and games with or without sensors were the most commonly employed technology in pilot intervention and user studies and often focused on accurately measuring or promoting increased PA and behaviors (15–18, 20–22, 34–38, 47) and accurately recording and/or improving dietary intake (14, 19, 42–46). Several apps and games increased PA (20–22), readiness to change PA behaviors (15), decreased perceived barriers and perceived efforts to exercise (15, 16), and increased breakfast (14) and FV consumption (19). Furthermore, the use of apps improved self-monitoring of diet and PA goals (25) adherence of dietary data collection (41), and provided novel ways to record dietary intake (43–45).

Many of the intervention studies combined mHealth with other treatments, thus making the efficacy of mHealth-only approaches to impact outcomes such as BMI difficult to ascertain. However, the majority of the studies support the use of mHealth approaches for intervening on weight and weight-related behaviors. While no significant improvements in adiposity measures such as BMI were observed with the use of mHealth, increases in PA, changes in diet, and increases in self-monitoring (important preconditions for improvement in adiposity indices) were reported. mHealth appears to be a useful and feasible way to interact with youth as it was generally rated as a supportive medium, often lessened study attrition, and improved behaviors as goal-setting. mHealth technologies were also perceived as enjoyable and fun in most studies.

Usability

The articles in this review provided suggestions for the development and implementation of mHealth interventions. Studies described the best placement and accuracy of mobile device(s) to record PA and dietary intake (22, 34, 35, 37, 47), ways to lessen user burden (43) and which non-intrusive and practical devices (34, 37, 47) will actually be carried and used by participants (15, 22). Suggestions included considering reward-type incentives (15), providing social connections and multiplayer capabilities (15, 20, 21, 34, 38) with options to modify privacy and amount of sharing (15, 47), promoting fairness when including competition (47), and using intuitive, user-friendly formats with a variety of content and levels (29, 34, 38). Considerations when developing apps/games with social networking included the possibility of unhealthy competition, reduced interest when group members fail to participate, and the preference of close friends as social group members (in girls 13- to 17-years-old) (21). Furthermore, recommendations included providing a variety of short- and long-term motivational techniques (47), personalizing and providing feedback (32, 33, 37), using language to promote freedom of choice (i.e. no authoritarian tone) (15, 31), using only positive feedback (15, 33) to prevent demotivation unless it is an avatar or virtual entity (which should be realistic) (14, 37), and using reminders (e.g. emails, texts) when promoting self-monitoring of diet and PA (43). Practical considerations include costs, power consumption (especially when using wireless sensors where a cell phone is the main processing hub) (22, 44), availability of offsite servers to connect with (44), availability of technologies including proprietary software (47), and software and hardware compatibilities (42). Clearly, user-centered designs are needed to forge the link between the technology and the intended audience while effectively addressing determinants of behavior change to take full advantage of the technology being employed.

Discussion of SMS

The majority of mHealth studies included in this review have not reached large-scale implementation for prevention or treatment of pediatric obesity, reflecting the nascent field. Of the 41 included articles, 16 articles representing 11 studies measured important outcomes as changes in BMI, diet, or PA. Taken together, the intervention studies did not achieve significant improvements in anthropometric outcomes as BMI. However, it must be noted that these studies represent early efforts in the field, which rely largely on SMS. The full potential of mHealth lies in the capacity of wearable and deployable sensors that capture diverse health-related personal and environmental signals ubiquitously as well as on demand, combined with provider communication capabilities, and the use of just-in-time, adaptive interventions (48). mHealth interventions are still ‘catching up’ with technology, and a great deal of technological development remains to be achieved.

In the RCTs included in this review, the lack of effects of SMS messages on outcomes may be due to limitations in the overall treatment design or implementation, the SMS theme, tone, or content, or waning participant interest in treatments over time (regardless of in-person or mobile technology delivery). While all three of the RCTs included theoretically-based approaches (7–13) (e.g. Social Cognitive Theory-based group therapy (7, 11, 12) and concepts from Behavioral Determinants and the Transtheoretical Model of behavior change (13)), adherence to the mHealth component was low to moderate (22% (11) and 47% (7)). Also, limited longitudinal program participation and low program ratings were reported (9, 10, 13). This is not surprising as long-term study adherence is a common problem. However, lower drop-out rates and higher adherence to treatment was observed in several pilot studies (25–28) and one RCT (7, 8) indicating there is potential for mobile technologies to improve long-term participant interest. Effective dose and frequency of mHealth communications has not been established, but it may be that SMS contact alone is not sufficient to affect BMI, particularly if it is automated and there is no human in the loop. In this review, participatory research on SMS indicated youth may find two text messages per day acceptable (31), and obese adolescents receiving SMS as part of a weight management program requested SMS to be sent more than once a day (29). In the RCTs, SMS was used three times a week (13), weekly (7, 8) or approximately every two weeks (9–12). It is unknown whether increasing the dose or frequency would have improved measures of adiposity, PA, or diet in pediatric populations. However, in a pilot study by Sirriyeh et al. (23), inactive adolescents receiving affect-based SMS messages once a day for two weeks reported an increase of 120 total minutes of moderate PA over two weeks, suggesting that the tone and frequency of SMS may effect interest in and response to the intervention outcomes. Furthermore, in RCTs with adult participants in which reductions in weight, waist circumference, and increased PA were observed, SMS was delivered twice a day and up to three to five times a week (In (49)). Mixed findings on outcomes highlight the need for research that examines factors specific to mHealth that are likely to influence intervention success.

Conclusion

Studies reported herein describe functional and acceptable mobile technologies to promote healthy diet and PA behaviors in pediatric populations. There are limited data available to discern the overall efficacy of mHealth as a stand-alone treatment to prevent or treat obesity since few studies were designed as interventions conducted over a long period of time. Furthermore, the field is advancing so quickly that the technology used in the full trials is often no longer state-of-the-art, and interventions that employ the full range of capabilities of mobile technologies (i.e. ubiquitous sensing and real-time feedback) are only now being developed. The large heterogeneity in study designs, settings, intervention components, and outcomes also prevented a quantitative analysis of the impact of mHealth to prevent or treat obesity. Agile research designs that allow for the efficient identification, refinement, and evaluation of intervention components for inclusion should be employed, as well as innovative designs for building time-varying adaptive interventions (50). These can lead to long-term trials to examine the efficacy of well-developed, state-of-the-art mHealth interventions to prevent and treat pediatric obesity.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

mHealth	mobile health
SMS	short message service (text messaging)
RCT	randomized controlled trial
PA	physical activity
BMI	body mass index
apps	applications
PDA	personal digital assistant
FV	fruit and vegetable
GPS	global positioning satellite system

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