EFFECT OF A SHORT MESSAGE SERVICE INTERVENTION ON EXCESSIVE GESTATIONAL WEIGHT GAIN IN A LOW-INCOME POPULATION

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DEDICATION

I dedicate this thesis to my loved ones. To my parents, Tim and Therese, who have instilled in me some of the qualities I admire most about myself and have supported me in every way possible throughout my academic career. To my brother, Timothy, who has inspired me to put living a healthy lifestyle above all else. And to my partner, Lukas, who is the ultimate student and growing scientist. I am struck each and every day by your unwavering commitment to research and enthusiasm about uncovering the truths of the universe.

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ABSTRACT

Socioeconomic disparities exist in many health conditions. Behavioral interventions may promote healthy behaviors and lead to decreased risk of diseases, both communicable and noncommunicable. These interventions may be unable to reach low-income individuals, who may be lacking in time and resources. This thesis consists of two chapters investigating the use of technology for lifestyle interventions in low-income populations. The first chapter, a literature review to be submitted for publication, is entitled "Novel technologies for nutrition interventions in low-income populations" and systematically reviews the literature to characterize such interventions. The second chapter, "Effect of a short message service intervention on gestational weight gain in a low-income population: a randomized, controlled trial", reports the results an eighteen-week nutrition and physical activity intervention, delivered via short message service (SMS, or text message), on gestational weight gain (GWG) in a sample of participants of the Special Supplemental Program for Women, Infants, and Children (WIC) in Hawai‘i. The author of this thesis was responsible for drafting the manuscript included as Chapter 2. The author was also responsible for background research, synthesis of the developmental methods of the intervention, organization of results, creation of tables and figures, analysis of study strengths and limitations, and suggestions for future research to fill gaps in the literature. The appendix includes accompanying tables and figures for both chapters. The results reported in this thesis support the need for additional research in nutrition interventions using novel technology methods to reach low-income populations.

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CHAPTER 1: LITERATURE REVIEW

Novel technologies for nutrition interventions in low-income populations: a systematic review

This is a systematic review that will be submitted for publication and is included here as chapter one.

Holmes, H., Banna, J. (2020). Novel technologies for nutrition interventions in low-income populations: a systematic review.

Abstract

Background

Low-income populations experience health disparities due to many different factors, including lack of resources and knowledge about or support for living a healthy lifestyle. Nutrition interventions seek to improve nutritional status and overall health. Traditional face-to-face interventions may not be appropriate for low-income groups due to barriers to participation. Technology is a viable resource for conducting interventions to support individuals with low socioeconomic status.

Objective

The objective of this systematic review is to identify and characterize studies involving nutrition interventions with a technology component in low-income populations.

Methods

Three databases (PubMed, Cochrane Trials, and CINAHL) were searched for relevant peer-reviewed articles. The searches returned 951 entries, which were screened based on the PRISMA statement and inclusion criteria. The 21 articles included reported on 18 interventions with technology and nutrition components in low-income populations, according to search criteria. Data were extracted and a narrative synthesis is included.

Results

Many studies were feasibility, pilot, or proof-of-concept trials and had small sample sizes. A majority (90%) of the programs measured self-reported diet-related behaviors, while the other 10% considered either planned behaviors or beliefs about nutrition behaviors. Interventions focused on a range of health topics: infant or child health, adult health, breastfeeding, weight loss, maternal and child health, and oral health. Most programs attempted to improve multiple health behaviors in addition to nutrition, such as physical activity and screen time. Almost all participants surveyed found the interventions acceptable, easy-to-use, and helpful.

Conclusions

The included studies show promise for the use of novel technologies for nutrition interventions in low-income populations. Future studies should focus on larger, longer interventions tested in randomized controlled trials. Technology innovation is also important to increase participant engagement and program efficacy.

Introduction

Low-income populations experience greater rates of both communicable diseases and non-communicable diseases due to various factors, including lack of access to healthy food or adequate healthcare, knowledge, or support for healthy behaviors. Obesity is one such condition that disproportionately affects low-income groups. NHANES data from 2011-2012 and 2013-2014 show that the age-adjusted prevalence of obesity is significantly higher in individuals with household incomes of $\leq$350% of the federal poverty level than in those with household incomes above this threshold [1]. Overweight and obesity are associated with greater risks of other chronic conditions, including coronary artery disease, diabetes, and cancer [2].

Traditional nutrition interventions may be effective at achieving expected outcomes but pose barriers unique to low-income populations. Low-income individuals may live in a geographic region where these programs are unavailable, e.g. rural areas. If the programs are available, they may require a substantial time commitment that is not realistic for low-income individuals, many of whom work shift jobs, multiple jobs, or have substantial family or childcare responsibilities. These individuals might also face barriers related to transportation, including lack of access to a vehicle or inconvenience of public transportation [3].

Electronic health (eHealth) is, broadly, the use of the Internet and information technologies to manage and provide health services [4]. The use of eHealth, including mobile health (mHealth) technologies and telehealth, is becoming more prominent in the digital age. eHealth methods have been shown to be useful for supporting interdisciplinary chronic disease care, and improving knowledge, health literacy, and disease self-management [5-7]. Studies have also been successful in using technology-based interventions for improvement of other factors related to disease risks, such as weight status and health behaviors [8-10].

Use of technology is widespread. A 2019 survey found that 96% of Americans in the US own a cell phone and 90% use the Internet [11] Among individuals with an income less than $30,000 per year, 95% own a cell phone [12]. Most technology-based interventions are administered remotely, and, since there is less or no need for participants to commute, interventions utilizing technology place low resource and time burdens on participants.

The objective of this review is to identify and characterize nutrition interventions that utilize technology in low-income populations in the US. The authors systematically searched for peer-reviewed journal articles and summarized the findings here.

Methods

Refereed journal articles were identified using the PubMed, CINAHL, and Cochrane databases. References of the included papers were also reviewed for potential articles.

Inclusion and exclusion criteria

Articles included were peer-reviewed and published between 2009 and 2020. Included articles met the following criteria: (1) reported on nutrition interventions that included a technology component (defined as an intervention utilizing the Internet or mobile technology, excluding phone calls); (2) included outcome data; (3) study sample consisting of low-income individuals or individuals from low-income areas (defined as the study authors stating that the intervention is aimed at low-income or underserved populations); and (4) intervention carried out in the US. Excluded articles included those that examined only development of intervention or study methods; did not include a technology component; or did not focus on low-income individuals in the US.

Search and screening strategies

Articles related to the objective were informally reviewed to identify appropriate search terms. The agreed-upon search terms focused on three components: nutrition (“nutrition”, “diet”, “eating”), technology (“short mobile message”, “technology”, “application”, “text message”), and low-income (“low socioeconomic status”, “low-income”, “poverty”). Search terms were also used to narrow search to include only papers reporting results of an intervention (“randomized controlled trial”, “controlled trial”, “clinical trial”, “intervention”). These terms were combined with Boolean operators “AND” and “OR” to create a search string that was used across all three

databases. The wildcard feature was used to search for different iterations of "text message" (e.g., "text", "text messaging") and "application" (e.g., "app"). The complete search string is as follows: ((nutrition OR diet OR eating) AND ("short mobile message" OR "technology" OR application* OR text message*) AND ("low socioeconomic status" OR "low-income" OR "poverty") AND ("randomized controlled trial" OR "controlled trial" OR "clinical trial" OR "intervention")). Titles and abstracts were screened for relevance according to the PRISMA guidelines, and remaining full-length texts and references were reviewed. The eligible articles are included. The last search was done in March 2020.

Data extraction and synthesis

Two researchers agreed on a standardized electronic tool for data extraction. One researcher used the tool to review articles and extract the following data: first author name, publication, year published, study objectives, types of technology, health topics, program activities, psychological theories referenced for intervention development, target population(s), low-income qualifiers, program language, location, study setting, outcomes, study size, and length of intervention. Selected extracted data were compiled into a table (Table 2).

Results

Search results

The search yielded 951 results, from which 113 duplicates were excluded. Titles and abstracts of the remaining 838 entries were reviewed according to the PRSIMA statement and 805 were excluded, leaving 34 full-length articles to be reviewed for inclusion. After review of full-length articles, 13 entries were excluded based on the exclusion criteria, one article was

added from references of an included paper, and a total of 21 articles were included in the review, representing eighteen distinct programs. The studies are summarized in Table 2.

Study objectives

Most programs had multiple objectives. Ten of the eighteen programs (56%) aimed to determine the feasibility of intervention implementation in addition to the impact of the intervention on participant outcomes. Eight programs (44%) considered the acceptability of the intervention to participants. All programs aimed to measure the impact or efficacy of the intervention on their respective health outcomes.

Type of technology

Eleven programs (61%) included an SMS component, eight of which used SMS as the sole technology for the intervention, while the other three using SMS also used e-mail, social media, or a website as avenues for disseminating information. Four programs utilized only a website or computer program for the intervention. The remaining three programs each used one type of technology: social media, video, or interactive voice recognition (IVR).

Intensity of the technology portion of the intervention varied with intervention length and program objectives. Studies using SMS (n=11) ranged from sending three messages per day to one per week. Total text messages sent throughout interventions ranged from 18 messages (1 per week for an 18-week intervention) [13] to 208 messages in the longest intervention (4 per week for 12-month intervention) [14]. The shortest intervention sent 63 messages over 3 weeks [Arora].

Health topics

Programs were sorted into categories based on the main health topic addressed in the intervention. One study focused on pediatric oral health. Four programs focused on maternal and child health. Six studies each focused on child or infant health. Three studies investigated nutrition interventions with the goal of weight loss in adults. Four studies focused on improving adult health.

Program activities (intervention methods)

According to the inclusion criteria, all studies had a nutrition component and aimed to improve some aspect of nutrition in the target population.

Some studies included intervention components focusing on other aspects of health, in addition to nutrition. One program included educational material about improving oral health behaviors [15]. Five programs, including the three programs designed to promote weight loss, aimed to improve physical activity behaviors. Three of the programs looking at infant/child health attempted to reduce screen time. Two programs sought to improve infant or child sleep habits. Two of the four programs focused on improving adult health also investigated factors relating to management of chronic diseases (cardiovascular disease [16] and diabetes mellitus [17]), including self-management and medication adherence.

Seven programs (39%) included activity methods in addition to the technology component, including face-to-face meetings, standard WIC care, the WIC Breastfeeding Peer Counselor Program, phone calls and/or home visits with health coach or health educator, and mailed educational materials.

Of the eighteen studies implementing longitudinal interventions, the shortest intervention took place over 3 weeks [17] and the longest intervention was 12 months long [14]. The other two interventions took place in a single day: a 25-minute educational breastfeeding video [18] and a set of educational modules with an estimated time to view of 25 minutes [19].

Psychological theories referenced for intervention development

Many of the included programs (61%) developed interventions based on psychological theories of behavior or learning. Five programs stated that intervention materials were developed based on social cognitive theory. Six other programs each referenced one behavioral theory in development of the intervention: the social learning theory [20], the health belief model [19], the information-motivation-behavior model [21], the theory of planned behavior [22], Kolb's Experiential Learning Model [23], and the trans-theoretical model [13].

Target populations (participant characteristics)

Almost all (94%) programs were designed for adults, either directed at improving the participants' health or the health of their children. One intervention was designed for young girls [24].

Low-income qualifiers

All studies were directed at low-income participants; however, income classification was not uniform across programs. Nine programs recruited participants only from clinics or hospitals with a patient base of primarily low-income and or publicly insured, including one program in which individuals were eligible to participate if they were receiving Medicaid [20]. Five

programs recruited participants who were receiving or eligible for SNAP or WIC benefits Four programs selected participants from economically disadvantaged neighborhoods or community sites serving primarily low-income families (e.g. Head Start programs, public libraries).

Program language

The majority of programs (67%) reported on English-language interventions. Five programs were offered to participants in both English and Spanish. One program offered its intervention exclusively in Spanish [19].

Geographic region

Almost half of the reviewed programs (44%) took place in the northeastern U.S. (MA, PA, CT, MD). Two programs took place in the southeastern U.S. (VA, AL). Three programs took place in the midwestern U.S. (IN, KS, IL). Three programs took place in the western U.S. (CA). Two programs took place in locations outside of the continental U.S. (HI/PR, AK).

Study setting

Six programs recruited participants from WIC offices/sites, SNAP offices, or other governmental assistance offices. Six programs recruited participants from outpatient medical clinics. Two programs recruited participants from community health centers. One study recruited participants from patients hospitalized in a cardiac unit. One program recruited participants through afterschool programs. Two studies recruited participants from Head Start programs, with one of these studies also recruiting from other venues in the surrounding community that serve mostly low-income families.

Outcomes

Bodyweight and BMI

Eight programs collected data on participant bodyweight and/or body mass index (BMI). One weight loss intervention, *My Quest*, resulted in a significant decrease in mean bodyweight and mean BMI from baseline [25]. Three of the other programs looking at bodyweight or BMI (*Healthy Habits, Happy Homes*; *Healthy4Baby*; and *Fit Moms/Mamás Activas*) found significant differences in weight loss or BMI at the end of the study when compared to control [26, 27, 14]. Two programs found no differences in weight status or BMI between groups [13, 24]. The other two programs both focused on changing BMI in both parent and child. In the first, while the investigators found no significant difference in mean child BMI between baseline and study completion, a significantly greater proportion of mothers in the intervention experienced a decrease in BMI, compared to the control [21]. In the last program, the *HEAT* trial, the intervention allowed participants to choose how often and for how long to use it. There were no differences between the child intervention and control groups; however, children who were considered "higher users" of the intervention had significantly greater changes of weight and BMI measures than children who were "lower users" [28].

Acceptability

Half of the programs investigated satisfaction with or acceptability of the intervention. Of those interventions that asked participants whether they would recommend the program to family or friends (44%), 82% or more of participants agreed that they would. In all three interventions that asked participants if the intervention (IVR, a website, and SMS, respectively) was easy to

use, a majority of participants (66-79%) agreed that it was. In the intervention with IVR, about half of the participants agreed when asked if they would rather complete the intervention on a website [28].

Attitudes

Both of the interventions that examined attitudes were aimed at changing caregiver attitudes. Borrelli et al found that an eight-week SMS trial had a modest effect on parental attitudes towards pediatric oral health behaviors [Borrelli]. In the other intervention, Power et al found that an eleven-week SMS trial had no effect on parental attitudes related to fruit and vegetable intake [29].

Self-efficacy

Five programs measured changes in self-efficacy using various survey questions. Three of these programs (*TExT-Med*, *Txt4HappyKids*, *My Quest*) did not include a comparison group and only one, *My Quest*, found a significant improvement in at least one measure of self-efficacy from baseline to follow-up [17, 29, 25]. The two programs that did include a comparison group investigated self-efficacy of parents in improving or promoting healthy behaviors in their children [21, 15]. Both programs found at least a modest effect of the intervention on self-efficacy compared to the control, but the difference was only significant in one of the programs.

Behaviors

All but two of the programs (89%) measured self-reported changes in behaviors. Of these, all but one explored diet-related behaviors. A summary of the effects of the interventions on nutrition-related behaviors can be found in Table 2.

The two programs that did not measure nutrition-related behaviors were Borelli et al. and Thompson et al. [15,19]. Borelli et al. measured only behaviors relating to oral health and the effect of the nutrition component was measured by questions on beliefs about drinking tap water and consuming sweets on oral health [15]. The trial by Thompson et al. was not a longitudinal study and only measured participants' planned behaviors based on a short educational video. The program found that 71% of participants in the intervention planned to change a behavior based on their new knowledge [19].

Engagement

The *TExT-MED* program found that 90% of participants agreed that SMS is an effective method of communicating, but less than half of the participants responded to any SMS prompting a participant response [17].

Nundy et al. reported that, of the eight participants finishing the SMS intervention for heart disease management, only three sent any messages in response to SMS they received [16].

Borrelli et al. found that the percentage of participants responding to SMS prompts was similar in the intervention and control groups (about 70%). Other measures of engagement, such as opting-in to weekly challenges, were also similar between groups [15].

Phelan et al. found that 162 out of 174 (93%) intervention participants logged in to the study's weight loss website at least once over the twelve-month intervention. The results of this study show that frequency of logging in to the website and attendance at group meetings were both significantly associated with amount of weight lost after 12 months [14].

Retention

Only four programs had retention rates below 80%. In two programs, which used SMS as their main or only intervention method, participants who did not complete the intervention were significantly younger than completers [25, 15].

Knowledge

TExT-MED, a 3-week SMS-based trial in a small sample of adults with diabetes, tested knowledge using the Diabetes Knowledge Test (DKT), which includes questions on diet [30]. Post-intervention DKT scores were not different from baseline, but the intervention did improve certain diabetes-related health behaviors [15].

Thompson et al. found that an interactive, Spanish language, touchscreen computer-based intervention was effective in significantly improving nutrition knowledge scores of participants, compared to a control [19].

Three other programs did not test knowledge, but participants of all three reported that the intervention improved their knowledge on oral health, breastfeeding, and maternal and infant health practices, respectively [15, 22, 20].

Discussion

The literature review revealed various applications for technology in nutrition interventions. There was extensive heterogeneity among studies, especially with relation to target population, type of technology, and outcome measures. In addition, many studies were pilot or feasibility trials, and as such, a meta-analysis was not appropriate.

Incorporating theories of behavior change when designing interventions is important for encouraging individuals to perform behaviors, including those that are health related. Poorman et

al. found that the most successful SMS interventions for maternal and infant health used well-established behavior change theories in in intervention development [30]. Over half (61%) of the included programs employed components of behavioral theories in program development. The results of these programs were varied.

Potential lack of appropriate technology is a major concern for ensuring target populations are reached. In some cases, potential participants may have the technology, but lack the skills required to use it. Some of the included articles show that a significant number of potential or eligible participants did not own or know how to use the technology used in the intervention. In the study by Nundy et al., 23.5% (12/51) of otherwise eligible participants were unable to join the study because they did not own a cell phone [16]. In the study by Arora et al., 68.9% (51/74) of otherwise eligible participants were excluded because they either did not have a cell phone with SMS capabilities or if they did, they did not know how to use those capabilities [17]. These studies were published in 2013 and 2012, respectively. Cell phone ownership in individuals earning less than $30,000 per year has increased from 86% in 2013 to 95% in 2019 [12]. In one of the more recent studies included, published in 2017, 36.2% of participants had to be provided with Internet access [14].

Long-term engagement is important for maintenance of health behaviors and achievement of health goals, such as weight loss. According to the transtheoretical model, individuals are at different stages of behavior change, from pre-contemplation to maintenance of changed behaviors [30]. Many of the included studies had short follow-ups: of those studies reporting on longitudinal interventions, the longest was 12 months [14]. Twelve months may not be a sufficient time for participants to move into different stages of change and reach the maintenance stage, which is important for lifelong behavior change.

Nearly half of the studies took place in the northeastern region of the U.S. Most of the programs recruited participants who lived in urban areas. Only one program was aimed at individuals living in rural areas. Future studies should investigate how novel technologies can improve access to nutrition interventions for those living in rural areas.

All programs focused on low-income populations, typically in one geographic location, and are not necessarily generalizable to other populations. Other study limitations include lack of a control group, reliance on participant self-reporting for outcomes, and lack of objective outcome measures.

The results of the included programs should be considered with caution since many of the studies were limited by small sample size and lack of statistical power. This is justified by the objective of many of the studies as investigating feasibility and acceptability of interventions.

Conclusions

Low-income populations experience disparities with regards to many health conditions, including chronic diseases related to lifestyle. Many of the included studies found either modest or significant effects of the intervention on nutrition-related behaviors. Novel technologies for nutrition interventions may be feasible and effective in low-income populations, who use the Internet and mobile technology at rates comparable to the general population, though availability and understanding of usage remains a concern.

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CHAPTER 2: EFFECT OF AN EIGHTEEN-WEEK, SHORT MESSAGE SERVICE INTERVENTION ON EXCESSIVE GESTATIONAL WEIGHT GAIN IN A LOW-INCOME POPULATION: A RANDOMIZED, CONTROLLED TRIAL

This is a copy of a manuscript that has been published in the special issue "Evaluation of Nutrition Interventions in Mothers and Children: Pre-pregnancy, Pregnancy, and Early Childhood" of the journal *Nutrients* (*Nutr*) and is included here as chapter two.

Holmes, H.; Palacios, C.; Wu, Y.; Banna, J. Effect of a short message service intervention on excessive gestational weight gain in a low-income population: a randomized controlled trial. *Nutrients* **2020**, *12*, 1428, doi:10.3390/nu12051428.

Abstract

Objective The objective of this trial was to investigate the effect of educational short message service (SMS), or text messages, on gestational weight gain (GWG) in a low-income population.

Methods Participants (n=83) were recruited at WIC clinics on the island of O'ahu, Hawai'i at 15-20 weeks gestational age. The intervention group received SMS on nutrition and physical activity during pregnancy per the Institute of Medicine (IOM) and American College of Obstetricians and Gynecologists guidelines, respectively. The control group received SMS about general health topics during pregnancy. Both groups received one text message per week for eighteen weeks. GWG was defined as the difference between the last weight taken before delivery and participants' self-reported weight before pregnancy. Differences between study groups were examined using t-tests and Chi-square tests. Linear regression models were used to examine association of GWG with study group and other factors.

Results GWG was similar in the control group (14.1±11.4 kg) and intervention group (15.5±11.6 kg; p=0.58). The percentage of participants exceeding IOM guidelines for GWG was similar in the control group (50.0%, n=17) and intervention group (60.5%, n=23; p=0.51).

Conclusions GWG was not significantly different between intervention and control groups. Trials that begin earlier in pregnancy or before pregnancy with longer interventions and more frequent messages may be needed to detect significant improvements.

Introduction

Excessive gestational weight gain (GWG) in overweight or obese women is associated with adverse pregnancy outcomes [32]. These outcomes include gestational diabetes mellitus, birth complications, postpartum weight retention, and childhood overweight or obesity [32,33]. About 60% of overweight or obese women in the US experience excessive GWG [34]. Healthy eating and physical activity are important modalities for managing GWG [35,36]. Previous interventions for GWG have yielded inconsistent findings, with interventions failing to improve GWG across all weight groups or at all [37]. The systematic review by Skouteris et al. found that interventions focusing on either nutrition or physical activity were less successful in reducing GWG than those that combined the two approaches [37]. Focus groups of low-income women reveal a lack of knowledge on these topics as barriers for maintaining a healthy weight throughout pregnancy [38].

Low-income women in the US are more like to be overweight or obese and to enter pregnancy in this condition [39]. Women of low-income groups are also more likely to have greater and excessive GWG [40]. In addition to higher likelihoods of overweight or obesity and excessive GWG, low-income populations are hard to reach with traditional, face-to-face interventions [41]. These programs may not be available in certain geographic areas or the individual may not be close enough to participate. Even when available, these programs may place burdens on low-income individuals due to transportation, cost, and time requirements.

Much of the literature evaluates face-to-face interventions, which do not address the barriers mentioned above. Technology may be a solution for the barriers and lack of results in interventions to control GWG. Clinically significant weight loss has been achieved at a lower cost using technology-based interventions [41]. One study revealed that overweight and obese women reported positive experiences using mobile and technology-based tools for health during pregnancy [42]. In another study conducted through the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), a greater proportion of participants using a weight loss website returned to pre-pregnancy weight than those receiving only standard WIC care [14]. Of the technology-based methods suitable for mobile health interventions, the short message service (SMS), or text messages, is a valuable approach for low-income populations. SMS is low cost to both the sender and recipient, carries a low participant burden, and allows for easy participant response. Mobile phone ownership is widespread, with about 96% of adults in the United States using or owning a cellular phone [11]. A systematic review on the efficacy of SMS for maternal/infant health showed that this approach can be successful when established theories of behavior change are used, and when message content is aligned well with outcomes [31]. There are few studies investigating the effectiveness of SMS messages in nutrition interventions during pregnancy. The objective of this study was to assess the effectiveness of an 18-week SMS intervention promoting nutrition and physical activity, delivered to a low-income population of predominantly overweight/obese women in Hawai‘i, on reducing excessive GWG.

Materials and Methods

Study design

This was a parallel, randomized, controlled trial in WIC clinics using educational text messages to prevent excessive GWG in a low-income, predominantly overweight/obese population. The trial is registered on clinicaltrials.gov (NCT04330976).

Setting and participants

The study took place in four WIC clinics across the island of O‘ahu, Hawai‘i. Eligible women participating in WIC were made aware of the study and, if interested, screened for eligibility. Eligibility criteria were: (1) 10-20 weeks gestational age and 18 years of age or older at time of recruitment (2) body mass index (BMI) of 20-45 kg/m^2 in the first trimester; and (3) possession of a cellular phone with the ability to receive text messages without a charge. Exclusion criteria included: (1) conditions requiring a special diet; (2) multiparous pregnancies; (3) unable to consent to participate; (4) unwilling to be randomized.

A sample size of 80 participants (40 per group) achieves 80% power at a 0.05 significance level to detect the effect size of 0.65 in the difference of continuous outcome variables between two experimental arms. Research assistants enrolled participants and equal numbers of participants were randomized to the control arm or to the intervention arm using random block sizes (2, 4, or 6) with 26 total blocks. A list of randomization numbers and corresponding IDs was computer-generated. Research assistants were provided with the allocation scheme at the start of the recruitment period and referred to this at the time participants eligible to be enrolled were identified. Participants and WIC staff were not aware of the allocation scheme at the time of selection and enrollment. Participants were allocated an ID sequentially as they were recruited, and this ID was matched with the randomized group. The trial ended after all participants with follow-up had received the full 18-week

intervention/control message program and had given birth. WIC staff were blinded to the treatment assignments. The University of Hawai‘i Institutional Review Board approved study procedures.

Development/delivery of intervention

Eighteen messages were developed in line with WIC recommendations for pregnant women and were written at a fifth-grade reading level, as determined using the Flesch-Kincaid formula, to ensure readability. Messages were reviewed by a pediatrician with experience in working with low-income groups in Hawai‘i. Cognitive testing was conducted via interviews with pregnant participants of WIC (n=5). Cognitive interviews focused on determining whether message text was appropriate for the target population to further ensure cultural relevance. Participants were asked to state the meaning of messages in their own words to improve clarity. The method of cognitive testing has been previously described [43]. Participants in cognitive testing desired messages to include more specific recommendations and examples of food to eat to meet nutrition recommendations. These changes were made prior to intervention implementation.

Intervention messages were developed based on social cognitive theory and focused on energy intake and physical activity for healthy weight gain during pregnancy. Social cognitive theory explains the reciprocal interactions between people, environments, and behaviors [44]. The main constructs of social cognitive theory are self-efficacy, knowledge, goals, expected results, and perceived facilitators and impediments to behavior [45]. The nutrition messages were designed to promote adequate diet quality and quantity to meet the Institute of Medicine guidelines for weight gain during pregnancy [46]. The physical activity messages focused on

recommendations from the American College of Obstetricians and Gynecologists, which encourage women to engage in moderate-intensity activity for 20-30 minutes per day [36]. Messages for the control group focused on general health during pregnancy, with topics such as the importance of visiting a physician regularly and achieving adequate sleep.

Examples of intervention SMS

Nutrition and energy intake messages

- "Make half your plate fruits and vegetables. Choose a variety, like spinach, carrots, tomatoes, beans, and peas."
- "Eating healthy foods is more important now than ever! You need more protein and iron from meat and beans, and calcium and folic acid from vegetables."
- "'Eating for two' doesn't mean eating twice as much. You only need about 300 calories more during the last 6 months of pregnancy."
- "Omega-3 fats in seafood are important for you and your unborn child. Salmon, sardines, and trout are high in omega-3 fats."

Physical activity messages

- "To walk more: park far from where you are going, take the stairs instead of the elevator, take your pet for a walk, or talk on the phone while walking."
- "Include 2 ½ hours each week of physical activity such as walking fast, dancing, gardening, or swimming."
- "Tips to move more: dance while you cook, get up in a waiting room and walk up and down the aisles."

Delivery of messages was automated through the SMS platform EZ Texting [47]. Both groups received one message per week for eighteen weeks. Timing of messages varied. The researchers were able to view whether messages were successfully sent to participants.

Measures/outcomes

The main outcome of the study was GWG, which was calculated by subtracting the participant's self-reported weight before pregnancy from the last weight taken before birth. Pre-pregnancy weight and last weight before birth were reported by the participant via questionnaires at the first and second study visits, respectively. Height was also self-reported at the first study visit for calculation of BMI. The Institute of Medicine provides healthy GWG guidelines for healthy, overweight, and obese BMIs (Table 1) [46].

Statistical plan

Summary statistics were used to describe the sample characteristics by study group, and t-tests and Chi-square tests were performed to examine differences between groups or to determine if IOM guidelines were met. Linear regression models were utilized to determine if GWG was associated with study group, demographics, and other covariates. Variables that were statistically significant at the 5% level in the bivariate analysis were examined in the multivariable linear models. The multivariate model adjusted for height, age group, weight before pregnancy, and number of previous children. Since the intervention was randomly assigned, the covariates in the multivariable model were included as precision variables to include statistical precision instead of confounders for the intervention effect. Stepwise regression and backward elimination methods were applied to find factors that were associated

with GWG while adjusting for participant's height. Statistical software R was used for the analysis (version 3.5.1, R Foundation for Statistical Computing, Vienna, Austria).

Results

Recruitment began in October 2017 and the last follow-up took place in October 2018. After screening for eligibility, participants (n=83) were randomized into intervention (n=42) and control (n=41) groups. By follow-up at the last weight taken before pregnancy, 11 participants had been lost: 4 from the intervention group (n=38) and 7 from the control group (n=34). Reasons for loss to follow-up included moving out of state, miscarriage, and discontinuation of intervention.

At baseline, participants were 27.7±5.3 years old on average, 65.5% were Native Hawaiian, Pacific Islander or American Indian, 54.8% had some college education or more, and 37.8% were employed. Almost all participants used prenatal vitamins (97.6%). The average weight before pregnancy was higher in the intervention group (80.6 kg) than that in the control group (76.2 kg) but this difference (4.4 kg) was not significant (p=0.238). Mean pre-pregnancy BMI was also higher in the intervention group (30.4 kg/m^2, corresponding to an obese BMI) than in the control (29.8 kg/m^2, overweight BMI) but this difference was not significant (p=0.618). Other baseline characteristics were comparable between groups (Table 2).

There were no differences in attrition rates between groups, with 17.1% of control participants and 9.5% of intervention group participants not completing the study (p=0.490). There were no significant differences between those who completed the study and those who did not. Mean GWG was similar (p=0.580) in the control group (14.1$\pm$11.4 kg) and intervention group (15.5$\pm$11.6 kg). Of all 72 participants with pre-pregnancy BMI and follow-up data, 55.6% (n=40) exceeded the IOM guidelines for gestational weight gain for their BMI. In the control

group, 50.0% (n=17) of participants exceeded the guidelines for their BMI, while 60.5% (n=23) of the intervention group exceeded the guidelines for their BMI. The difference in number of participants exceeding guidelines for their pre-pregnancy BMI between the two groups was not significant (p=0.509). Of healthy weight, overweight, and obese women, 77.8%, 51.9%, and 52.8% exceeded the guidelines, respectively. The differences in percent of participants exceeding guidelines between these groups was not statistically significant (p=0.357) (Table 3).

The final multivariate model was adjusted for pre-pregnancy weight, height, age, and number of previous children, and was similar to a model which adjusted for BMI instead of height and weight. The multivariable linear regression model showed women aged 35 years or older gained an average of 11.5 kg (95%CI: 1.4, 21.2, p=0.021) more than those aged 18-24 and an average of 12.8 kg (95%CI: 3.9, 21.6, p=0.005) more than those aged 25-34. Older age groups were highly correlated with a greater number of previous children (p<0.001). There were no other significant differences between age groups. Women who already had 3-5 children gained more weight than those who had no children (7.03 kg; 95%CI: -15.0, 1, p=0.086) or 1-2 children (6.7 kg; 95%CI: -13.5, 0.05, p=0.051). A greater weight before pregnancy was negatively associated with weight gain during pregnancy: 4.5 kg greater pre-pregnancy weight corresponded with 0.91 kg less of GWG (p=0.016). These results are summarized in Table 4.

Discussion

In this eighteen-week, randomized, controlled trial, GWG did not differ between the intervention SMS and control SMS groups. Differences in the number of participants exceeding GWG guidelines were not significant across treatment groups or pre-pregnancy BMI categories.

Clinical trials have shown that technology-based interventions are able to produce levels of weight loss comparable to face-to-face interventions, with the additional benefit of a lower

cost per unit of weight lost [41]. A review and meta-analysis of weight management programs including a text messaging component found that these programs were successful in promoting weight loss [48]. Preconception weight loss has been investigated for the purpose of improving fertility, with interventions incorporating exercise and reduced energy intake associated with improved markers of fertility [49,50]. Preconception weight loss, whether due to lifestyle changes or medical weight-loss treatment (e.g., bariatric surgery), is shown to reduce the risk of some pregnancy complications, such as pre-eclampsia and gestational diabetes [51]. One study in obese women found that interpregnancy weight loss beyond returning to pre-pregnancy weight was associated with a decreased risk of gestational diabetes in a second pregnancy [52]. Preconception/periconception weight loss may be beneficial for decreasing risk of preterm birth, however, the impacts of preconception weight loss on other birth outcomes and offspring health have yet to be fully elucidated [53,54]. Depending on preconception diet quality, preconception weight loss may affect mothers' nutritional status and, therefore, birth outcomes [55].

Strengths

First, this was a randomized, controlled trial that investigated a novel intervention technique for the problem of excessive GWG in a low-income population. The results of this study add to the small but growing body of literature on technology-based interventions for improving maternal and or infant health. In addition, intervention messages were developed with recognized guidelines, social cognitive theory, and cultural considerations in mind.

Limitations

First, the pre-pregnancy weight and height measurements used to determine pre-pregnancy BMI and GWG were self-reported. Multiple studies have found self-reported measures of pre-pregnancy weight to be inaccurate, with participants often underestimating their weights [56,57]. Women of reproductive age also tend to overestimate their height [58,59]. Together, these differences may cause participants' calculated BMIs to be lower than their actual BMIs, resulting in misclassification of participants into BMI groups, e.g. a participant might be classified in the healthy BMI range when they are actually overweight. In this case, the participant's GWG would not be considered excessive if within the guidelines for healthy weight, but their GWG may actually exceed what is considered to be normal for their true pre-pregnancy BMI category.

Second, the sample size of the study may not have been adequate to detect between-group differences. The sample achieved 80% power at the 0.05 significance level to detect an effect size of 0.65 in the difference of the continuous variables. A more intensive recruitment period across more recruitment locations could allow for enrollment of additional participants. Trials with the ability to accommodate larger sample sizes are needed to gain adequate statistical power to determine differences between control and intervention groups.

Third, this trial included a population of low-income, primarily obese or overweight women in Hawai‘i. The findings of this study may not be generalizable to healthy or underweight women, or women of varying socioeconomic status. It is worth noting that low-income cellphone owners send/receive more SMS than those of higher incomes, and therefore, SMS interventions may be more effective and appropriate for this population than a middle- or higher-income population [60].

Fourth, the current study did not measure dietary intake, physical activity, or behavior change over the course of the intervention. Studies that collect information on dietary intake or diet quality may help researchers and clinicians determine problem areas that should be addressed or emphasized in future trials or care. It would also help to determine specifically which food choices were most significantly affected by the corresponding messages (e.g., whether the messages about fish and omega-3s were motivational enough to increase fish consumption). Although the intervention aimed to change dietary and physical activity-related behaviors, the study did not investigate changes in food or physical activity choices.

Lastly, perceptions of weight as they relate to health and readiness for change were not incorporated into message development or delivery. According to the health belief and health promotion models of behavior change, perceptions of the relationships between behaviors and health risks are necessary for health-related behavior change [61,44]. A study of 585 pregnant women found that perceived risk of health issues caused by high pre-pregnancy BMI and excessive GWG was low in both healthy and overweight women [62]. Even if individuals perceive a health-related risk, the transtheoretical model of behavior change explains that individuals are in different stages of changes with regard to particular behaviors [63]. Interventions including components based on these theories, along with the social cognitive theory, may be beneficial for supporting behavior change. The study did not target participants' perceptions of the consequences of excessive GWG, their stage(s) of behavior change, or willingness to change. Participants may have been in different stages of behavior change so that some messages may not have been effective for them.

Implications for future research

This is one of the first studies of its kind in a low-income, diverse, pregnant population. Future research can build on the current study. One potential method of improving the effectiveness of the intervention may be to include additional time periods surrounding and during pregnancy: preconception, early pregnancy, and postpartum. Since excessive GWG is associated with a greater risk of adverse health outcomes in overweight or obese women, interventions beginning before pregnancy may be beneficial for reducing the proportion of women entering pregnancy with overweight or obesity [32]. Trials that encompass more time surrounding pregnancy would also allow for longer interventions, which could help increase postpartum weight loss and lead to fewer women entering a second pregnancy with overweight or obesity. Combining maternal diet and exercise educational materials with information about breastfeeding may improve both infant feeding practices and postpartum weight loss, therefore increasing interpregnancy weight loss. Besides the potential benefits of preconception or postpartum weight loss, earlier interventions would allow time for educational messages about healthy diet and exercise to be repeated and may allow additional time for participants to move into more "ready" and actionable states of behavior change.

The current study only sent one text message a week over the eighteen weeks of the trial, totaling eighteen text messages. Participants may benefit from receiving more messages at a frequency higher than once per week. One study investigating the use of text messages in a weight maintenance program found that participants desired to receive at least one text message a day, preferably in the morning to increase daily motivation [64].

The current study only gathered participant data at enrollment and follow-up and did not measure engagement with the SMS program. Encouraging responses throughout the intervention may be helpful for engagement and retention. A pilot study investigating an SMS program for

managing GWG found that 86% of women in the intervention arm responded to prompts, and the intervention had a non-significant effect on GWG compared to the control [65]. The authors of the same study suggested that encouraging responses to messages may have increased the sense of accountability in participants and provided motivation for reaching goals [65].

The messages included in this trial were tailored to the target population, but not to individual participants. There is evidence that tailoring program messages to individuals can assist in education and encouraging behavior change [66]. One study found that computer-tailored nutrition messages were effective in reducing dietary fat intake [67]. A systematic review of tailored eHealth interventions for weight loss found that tailored interventions increased weight loss modestly in four of six studies considered [68]. Tailoring ranges from including participants' names in messages to using participant data collected to provide feedback and adjust materials to better suit participants during the intervention. This process may also improve participant engagement and retention on the basis that participants may find that information presented this way is more suited to their needs and will continue to use the program [68].

Combining mHealth or eHealth intervention modalities may also be helpful for effecting changes in behavior. In a pilot study aiming to improve postpartum weight loss, the intervention arm included SMS and a social media peer group and was found to increase weight lost compared to the control group receiving standard care [27]. A cluster RCT found that an intervention utilizing SMS and a weight loss website was effective in increasing weight lost and proportion of participants returning to pre-pregnancy weight than a control [14].

Since this research is aimed at a low-income population, future studies should also include the costs of such programs and measures of cost-effectiveness.

Conclusions

This trial to prevent excessive GWG utilized a modality for providing educational information that addressed barriers to program participation for low-income women, who are especially at risk for overweight, obesity, and excessive GWG. Evidence-based guidelines and social cognitive theory were used to develop targeted messages which were distributed via SMS. After eighteen weeks of one SMS per week, no significant difference in GWG or exceeding IOM guidelines was found between intervention and control groups. Future studies with larger samples sizes, more intensive and longer interventions and more robust outcomes, including measurement of dietary patterns and behavior change, are needed to determine the effectiveness and practicality of SMS for this purpose.

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Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Appendix: Tables and Figures

Table 1. Prisma Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	1-2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	2-3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	3
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	n/a
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	4
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	4-5
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	4
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	5
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	5
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	n/a
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	n/a

Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	n/a

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	n/a
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	n/a
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	33
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	5-13, 34
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	n/a
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	n/a
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	n/a
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	n/a
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	n/a
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	13-15
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	13-15
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	13-15
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	15

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

*Page numbers refer to page in thesis

Figure 1. PRISMA Flow Diagram

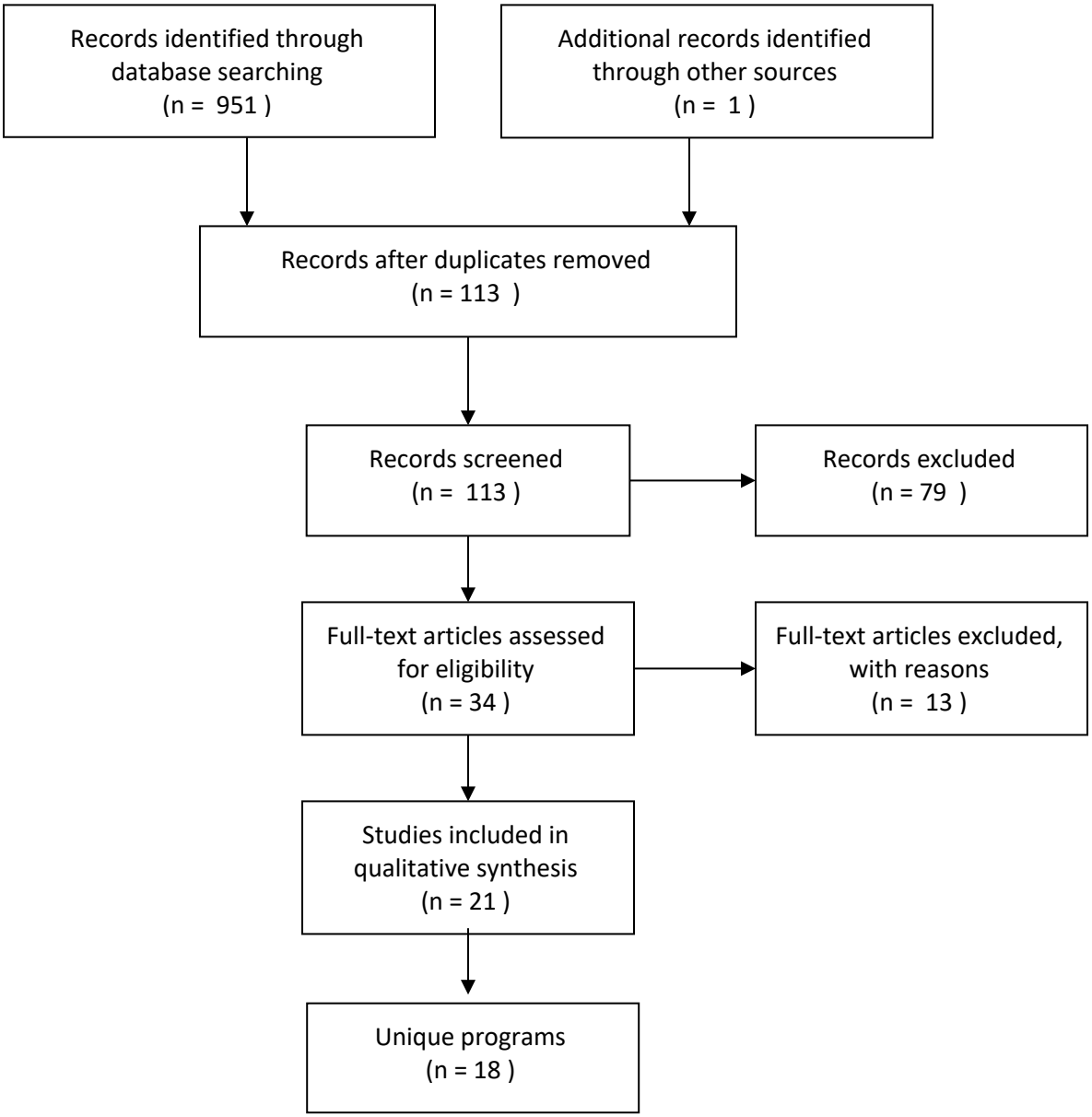

Table 2. Programs included in systematic review

Author & Year	Intervention Title	Target population	Design	Objectives	Type of technology	Program activities	Results: nutrition-related behaviors	Health Category
Arora et al. 2012 [17]	TExT-MED	Adults w/ diabetes	Single group	Examine feasibility, acceptability, and impact of SMS-based health program on diabetes knowledge and related behaviors	SMS	21 weekly SMS (3 per day) on the following topics: educational/motivational, medication reminder, healthy living challenges, trivia questions, phone link w/ free gift to manage DM	Significant improvement in daily FV consumption from baseline	Adult health
Borrelli et al 2019 [15]	N/A	Caregivers of young children	Pilot RCT	Examine feasibility, acceptability, and impact of SMS-based intervention to improve pediatric oral health behaviors and parent knowledge/attitudes	SMS	2 daily interactive SMS with feedback on progress to goals and oral health tips on brushing, visiting the dentist, healthy eating, feeding with bottle or sippy cup, intake of sugar-sweetened beverages	No nutrition related behaviors measured	Oral health
Fiks et al 2017 [69]	Grow2Gether	Overweight/obese pregnant women	RCT	Examine feasibility, acceptability, and impact of social media-based peer support group on measures of maternal and infant health in a larger sample	SM* groups, video-based curriculum inside SM	Private Facebook group with other mothers Video-based curriculum focused on parenting and infant growth: infant feeding practices, infant sleep, parenting, maternal well-being Two in-person meetings	Better healthy feeding behavior scores over control	Maternal/ child health
Griffin et al 2018 [25]	My Quest	Rural-dwelling women	Single-group pre-/ posttest	Examine impact of SMS-based program on dietary and physical activity behaviors of rural-dwelling women	SMS, eNewsletters	Daily SMS with tips, web links, goal-setting prompts, reminders, questions that required responses Weekly newsletter via email with tips, reminders, low-cost healthy recipes	Significant improvements in 5/6 dietary behaviors from baseline	Weight loss
Gruver et al 2016 [20]	Grow2Gether	Obese new mothers	Single group pilot	Examine feasibility and acceptability of a social media-based peer support group	SM groups, video-based curriculum inside SM	Private Facebook group with other mothers Video-based curriculum focused on parenting and infant growth: infant feeding practices, infant sleep, parenting, maternal well-being Two in-person meetings	No dietary related behaviors measured	Maternal/ child health

Haines et al 2013 [26]	Healthy Habits, Happy Homes	Families with young children	RCT	Examine efficacy of intervention on improving household routines and decreasing child obesity	SMS	Motivational coaching home visits and phone calls from health educator Mailed education materials and incentives 1-2 weekly SMS on adoption of healthy household routines, such as limiting TV time and eating meals as a family	Intervention did not increase frequency of family meals from baseline or over comparison	Child/ infant health
Harari et al 2018 [22]	LATCH	Pregnant WIC BFPCP participants	Pilot RCT	Examine feasibility and acceptability of intervention on behaviors related to breastfeeding	SMS	Standard care of WIC BFPC program 2-way SMS with personalized, automated messages (participants could respond to their assigned PC)	Non-significant effect of intervention on BF exclusivity @ 2 weeks, time to contact BFPC was significantly shorter in intervention compared to control	Breast-feeding
Herring et al 2014 [27]	Healthy4Baby	Overweight/obese, urban, new mothers	Pilot RCT	Examine feasibility, acceptability, and impact of SMS-based intervention on postpartum weight loss	SMS, SM	Bi-weekly phone calls with trained health coach Skills training and self-monitoring done in Facebook and through daily SMS Private Facebook group for participant interaction	Non-significant effect of intervention on reduction of unhealthy food consumption compared to control	Weight loss
Kellams et al 2016 [18]	The Prenatal Education Video Study	Pregnant women	RCT	Examine efficacy of prenatal education video viewed in the hospital on behaviors related to breastfeeding	Video	25-minute educational breastfeeding video viewed in hospital	No effect of intervention on initiation or exclusivity of breastfeeding in hospital compared to control	Breast-feeding
Martinez-Brockman et al 2018 [70]	LATCH	Pregnant WIC BFPCP participants	Multi-site RCT	Examine impact of intervention on behaviors related to breastfeeding	SMS	Standard care of WIC BFPC program 2-way SMS with personalized, automated messages (participants could respond to their assigned PC)	Significantly more intervention participants contacted their BFPC within 48 hours of birth Non-significant effect of intervention on exclusivity at 2 weeks, no association @ 3 months	Breast-feeding
Neuen-schwander	N/A	Adults	Multi-site RCT	Examine impact of web-based nutrition	Website	SNAP-Ed lessons converted to web format	Significant improvement of almost	Adult health

et al 2013 [23]				education program on changes of nutrition behaviors			all nutrition behaviors from baseline Results of knowledge measures comparable to in-person program	
Nollen et al 2014 [24]	N/A	Young, racial/ethnic minority girls	Pilot RCT	Examine feasibility and efficacy of intervention on obesogenic behaviors	Handheld computer	Handheld computer program with goal setting, planning, cues to action, self-monitoring, feedback and reinforcement	Higher users of intervention showed greater reductions of SSB Small effects of intervention on increased FV and decreased SSB	Child/ infant health
Nundy et al 2013 [16]	N/A	Adults who experiencec acute decompensated heart failure	Single group	Examine feasibility and acceptability of SMS-based program on self-management of heart condition	SMS	Daily SMS with self-care reminders and patient education on diet, symptom recognition, and healthcare navigation	Significant improvement of eating low salt diet and maintaining when eating out from baseline	Adult nutrition
Palacios et al 2018 [13]	N/A	WIC-participating caregivers of infants	Multi-site RCT	Examine feasibility and efficacy of intervention for improving infant feeding practices, preventing excessive infant weight gain	SMS	Standard WIC care 1 SMS per week	No significant effects of intervention on feeding behaviors Trend toward intervention caregivers stopping feeding when baby seemed full	Child/ infant health
Phelan et al 2017 [14]	Fit Moms/ Mamás Activas	Postpartum women	Multi-site, cluster RCT	Examine efficacy of intervention for improving postpartum weight loss	Website, SMS	Standard WIC care Weight loss website and 4 SMS per week with calorie goals, physical activity goals, guidance, resources, feedback, weekly lessons, web diary, weight and activity tracker, videos, message board Monthly face-to-face meetings	No significant effect of intervention of caloric intake	Weight loss
Power et al 2018 [29]	Txt4HappyKids	Parents	Single-group pilot	Examine efficacy and acceptability of SMS intervention to promote FV intake	SMS	2 SMS per week encouraging parents to serve their children more fruits and vegetables	No significant effect on FV intake related behaviors from baseline	Child/ infant health

Sun et al 2017 [21]	N/A	Chinese mothers of young children	Pilot RCT	Examine feasibility and impact of intervention for improving health behaviors	Educational modules on tablet computer	8 weekly, 30 min tablet-based educational modules	No effect of intervention on child eating behaviors or mother's eating style, Small effect of intervention on mother's eating related to hunger score	Maternal/ child health
Thompson et al 2012 [19]	N/A	Spanish-speaking parents of young children	RCT	Examine efficacy of educational modules to increase nutrition knowledge	Educational modules on computer	Educational modules estimated to take 25 min to view	No nutrition related behaviors measured	Child/ infant health
Trude et al 2018 [71]	BHCK	Caregivers of children	Group RCT	Examine the impact of multilevel, multicomponent intervention on youth food purchasing and consumption	SMS, SM	Program worked in community to encourage stocking of healthier snacks in corner stores 14 in-person sessions led by youth leaders Social media posts and 3 SMS per week targeting caregivers	Positive, significant effect of intervention on purchasing of healthier food compared to control Significant decrease in proportion of kcals from sweets in intervention youth compared to control	Child/ infant health
Trude et al 2018 [72]	BHCK	Caregivers of children	Group RCT	Examine the impact of the intervention on the food-related behaviors of caregivers of participating youth	SMS, SM	Program worked in community to encourage stocking of healthier snacks in corner stores 14 in-person sessions led by youth leaders Social media posts and 3 SMS per week targeting caregivers	Higher scores of exposure to social media and SMS were associated with both greater daily FV intake and greater unhealthy food acquisition	Adult health
Wright et al 2013 [28]	HEAT	Caregivers of young obese children	RCT	Examine feasibility, acceptability, and initial efficacy of intervention for improving health behaviors and weight	IVR	IVR calls for children on healthy eating and activity IVR calls for caregivers on creating healthy environment at home, being a healthy role model, parenting, encouragement of child for healthy behaviors	Intervention parents ate significantly more fruit, less vegetables than control Higher parent users consumed significantly less kcals than lower users	Child/ infant health

*SM = Social media.

Figure 2. Consort diagram of flow of participants through the study

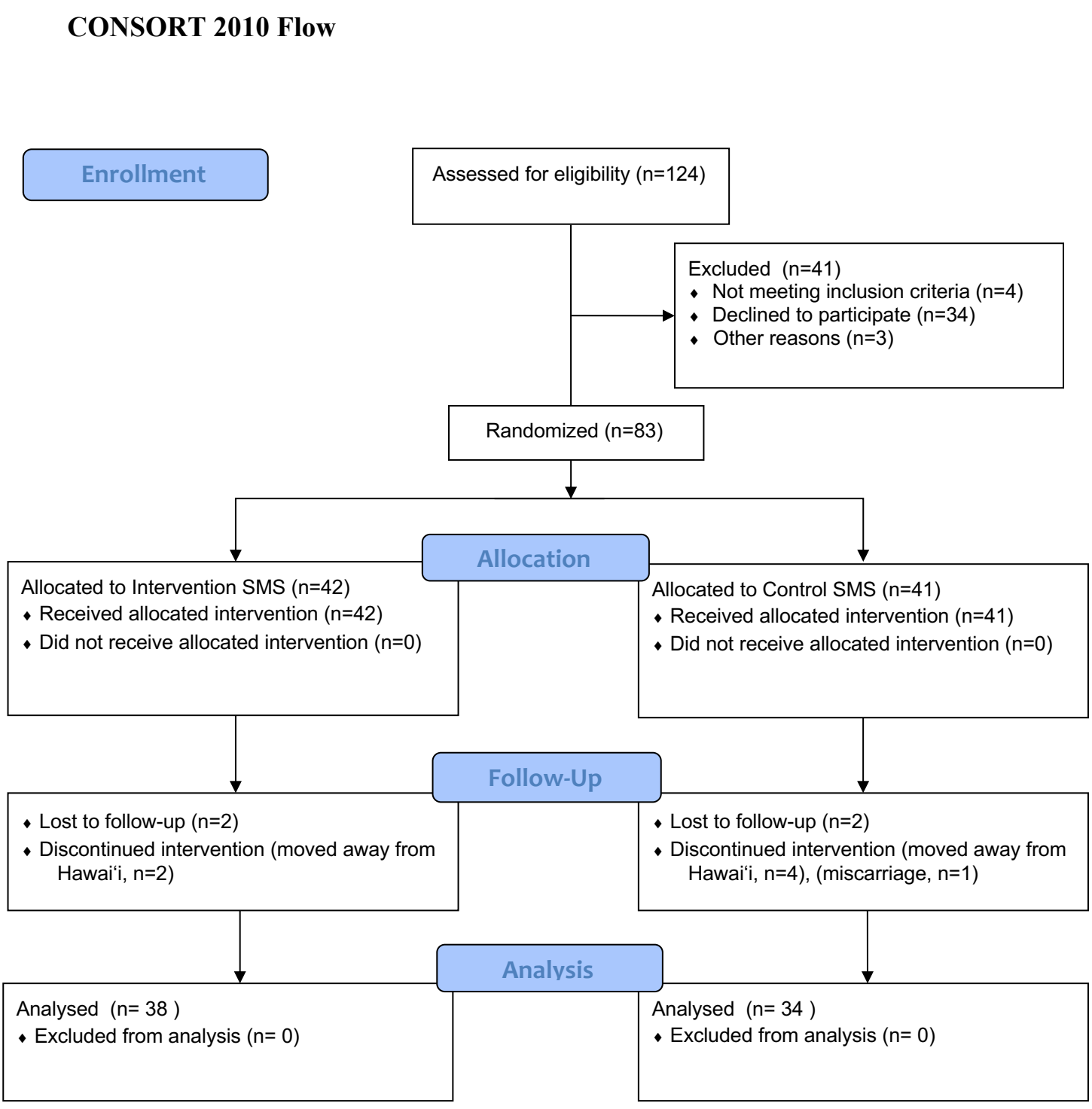

Figure 3. Theory of change diagram for using SMS in prevention of excessive GWG.

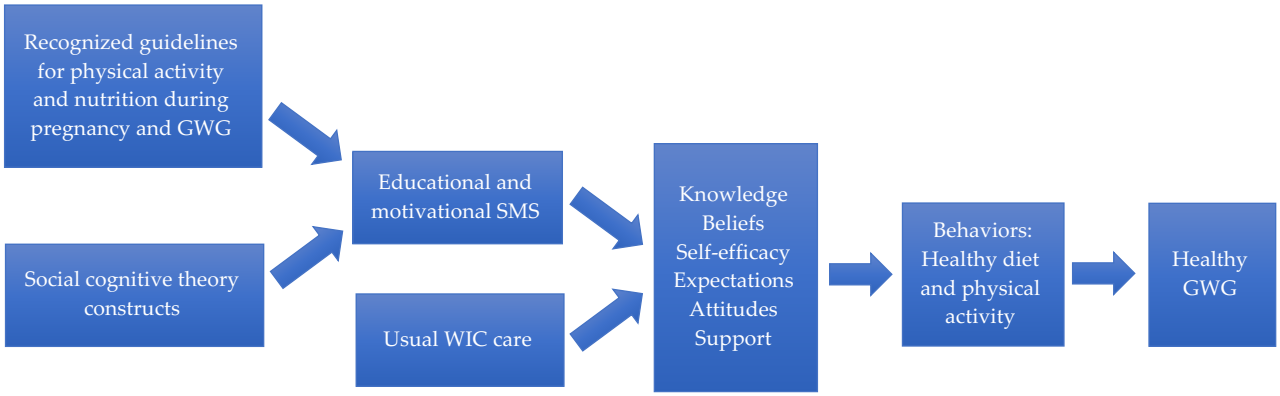

Table 3. Institute of Medicine guidelines for gestational weight gain for singleton pregnancies [17]

	Healthy BMI (18.5-24.9 kg/m^2)	**Overweight BMI (25.0-29.9 kg/m^2)**	**Obese BMI (Greater than 30.0 kg/m^2)**
Suggested range (kg)	11.5-16.0	7.0-11.5	5.0-9.0
Excessive (kg)	>16.0	>11.5	>9.0

Table 4. Baseline characteristics of the sample

	Control (n=41)		Intervention (n=42)		
	Mean	**SD**	**Mean**	**SD**	**p-value**
Age	**27.2**	**5.51**	**26.9**	**5.40**	**0.748**
Number of children	**1.27**	**1.47**	**1.50**	**1.33**	**0.453**
Pre-pregnancy weight (kg)	**76.2**	**15.9**	**80.6**	**17.7**	**0.238**
Pre-pregnancy BMI	**29.8**	**5.42**	**30.4**	**6.04**	**0.618**
Race/Ethnicity[1]	**n**	**%**	**n**	**%**	**p-value**
Asian	**11**	**26.8**	**7**	**16.7**	**1.00**
American Indian	**4**	**9.76**	**3**	**7.14**	**0.392**
Black	**6**	**14.6**	**8**	**19.1**	**0.808**
Hispanic	**8**	**20.0**	**17**	**40.5**	**0.076**
Native Hawaiian	**11**	**26.8**	**11**	**26.2**	**1.00**
Pacific Islander	**9**	**22.0**	**10**	**23.8**	**1.00**
White	**19**	**46.3**	**19**	**45.2**	**1.00**
Education	**n**	**%**	**n**	**%**	**p-value**
Less than college	**17**	**41.5**	**19**	**45.2**	
Some college	**17**	**41.5**	**19**	**45.2**	**0.121**
College or higher	**7**	**17.1**	**4**	**9.52**	
BMI Category	**n**	**%**	**n**	**%**	**p-value**
Healthy weight	**7**	**17.1**	**4**	**9.52**	
Overweight	**15**	**36.6**	**19**	**45.2**	**0.528**
Obese	**19**	**46.3**	**19**	**45.2**	

[1]Of the 83 participants at baseline, 45 (54.2%) self-identified multiple races/ethnicities.

Table 5. Participants exceeding or not exceeding IOM GWG guidelines by treatment group and BMI category (n=72).

		Participants exceeding guidelines n (%)	**Participants not exceeding guidelines n (%)**	**p-value**
Group	Intervention	23 (60.5%)	15 (39.5%)	0.509
	Control	17 (50.0%)	17 (50.0%)	
BMI	Healthy	7 (77.8%)	2 (22.2%)	0.357
	Overweight	14 (51.8%)	13 (48.2%)	
	Obese	19 (52.8%)	17 (47.2%)	

Table 6. Association of GWG with age, weight before pregnancy, height, and number of children.

	Beta (95%CI)	**p-value**
Intercept	32.5 (18.6, 46.5)	<0.0001
Age 25-34 vs. age 18-24	-1.31 (-7.16, 4.55)	0.662
Age 35+ vs. age 18-24	11.5 (1.7, 21.2)	0.021
Age 35+ vs. age 25-34	12.8 (3.9, 21.6)	0.005
Weight before pregnancy	-0.20 (-0.37, -0.04)	0.016
Height	0.71 (-0.22, 1.65)	0.136
1-2 children vs. none	-0.31 (-6.64, 6.02)	0.924
3-5 children vs. none	-7.02 (-15.03, 0.98)	0.086
3-5 children vs. 1-2 children	-6.6 (-13.5, 0.05)	0.051

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