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Healthy Motivations for Moms-To-Be (Healthy MoM2B) Study: A Mobile Health Intervention Targeting Gestational Weight Gain among U.S. Women

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Dedication

The words of this dissertation are dedicated to the people, opportunities, interactions, and pure leaps of faith that led me here. The spaces between each word are dedicated to the Dr. Dahl fan club because you kept me going and focused on the goal. A special dedication is for my parents and siblings for encouraging this journey and seeing me through. Thank you for always welcoming me home with open arms. More importantly, thank you for sharing me with the world. Each time I moved states for more education, I gained new friends, learned to understand the world through a broader lens, and began to find my voice. I am a better person because of it. To the love of my life, Trenton, thank you for providing endless love, confidence, and support over these four years. You heard every idea I had and provided the space for me to work and focus when I needed it. Thank you. I am beyond excited to begin the next part of our lives together. Finally, the last page of this dissertation is dedicated to myself for setting ambitious goals, staying focused, and achieving the ultimate title bump.

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Abstract

INTRODUCTION: Almost one-half of all pregnant women in the U.S. exceed the Institute of Medicine's (IOM) gestational weight gain (GWG) guidelines. Healthy GWG is critical for reducing adverse health outcomes associated with excessive GWG for the mother and infant. Electronic health (e-health) interventions delivered through mobile apps and websites hold potential as readily available resources for targeting health behaviors and monitoring GWG during pregnancy. The development of the Healthy Motivations for Moms-To-Be (HM2B) intervention was informed by health behavior theories, a systematic review of existing in-person and technology mediated interventions (Aim 1 of this dissertation), and results of an online needs assessment (Aim 2) of pregnant women's weight-related knowledge, behaviors, interests in various e-health intervention components. Participants were randomized to receive one of two intervention conditions (Aim 3). Participants in the Healthy Eating and Physical Activity (HEPA) condition received targeted GWG goals (based on pre-pregnancy Body Mass Index (BMI)), as well as evidence-based behavioral strategies to encourage healthy GWG, while the comparison condition received content related to Stress Reduction and Management (SRAM) techniques to reduce overall stress levels during pregnancy. Participants used a study website to track individual health behaviors and outcomes respective of their study conditions, access informational podcasts, and read weekly tips for having a healthy pregnancy. The website was developed by the TecHealth Center. In

addition, participants were assigned to a group of 8-10 other pregnant women and virtually connected through a commercially-available free mobile app called MakeMe, for 12 consecutive weeks. Each week, participants were provided a behavioral goal to aim for on 5 of the 7 days during the week. Social support elements (i.e., comments and "thumbs up" to teammates' activity) were included in the mobile app to encourage participation, social support, and maintenance of the behavioral goal. The purpose of this study was determine the impact of a mobile health intervention, Healthy Motivations for Moms-To-Be (HM2B), targeting healthy eating and physical activity (HEPA) on GWG and increase the proportion of women who gain within the Institute of Medicine's (IOM) guidelines for healthy gestational weight gain (GWG).

METHODS: Healthy pregnant women (N=140) living in the U.S. were recruited through social media to participate in a randomized controlled electronic health intervention, which consisted of a mobile app for facilitating group-based healthy behavior challenges and a website for tracking health outcomes (i.e., GWG). The intervention condition targeted HEPA behaviors during pregnancy, while the comparison condition focused on stress reduction and management during pregnancy. Pre-pregnancy weight and weight at delivery were self-reported to determine GWG in relation to IOM guidelines. Participants completed online surveys at baseline (<20 weeks) and upon completion of the 12 week group-based intervention. Surveys included the Rapid Eating Assessment for Participants-Shortened (REAP-S) scale for measuring typical dietary intake.

RESULTS: Participants who completed their delivery outcomes survey were included in the analysis (n=87). The sample was predominately white (81.6%) and highly educated (advanced degree beyond Bachelor's; 58.6%). Regarding adherence to IOM guidelines,

there was a promising but not significant difference in the proportion of women gaining adequate weight in the intervention versus comparison group (36% vs. 25%) or in the proportion of women who exceeded IOM guidelines (43% vs. 53%, respectively, p=0.42). There was a significant difference observed in post-intervention healthy eating behaviors reported between groups (F (1,87)=4.07, p=0.047), where HEPA participants reported healthier eating scores on the Rapid Eating Assessment for Participants (REAP) scale.

CONCLUSIONS: Although the effect of the intervention on reducing excessive GWG was not significant, the HM2B study demonstrated potential in facilitating healthy behavior change through group-based goal setting and self-monitoring using a mobile app. Future studies should explore opportunities for increasing user engagement and interaction for sustained use of eHealth interventions.

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Chapter 1: Introduction

1.1 Problem Identification

Upwards of one-half (46-50%) of pregnant women in the United States exceed the IOM recommendations for healthy gestational weight gain (GWG).[1–4] Excessive weight gain during pregnancy has been linked to several adverse maternal and infant health outcomes such as hypertension,[5,6] cesarean delivery,[5–7] and large-for-gestational age infants.[5–7] There are long-term weight-related impacts for the mother and child due to excessive GWG as well. Mothers are at increased risk for postpartum weight retention[7–11] and children are more likely to have greater adiposity in infancy and childhood.[12,13] Obesity is a growing public health problem and pregnancy may be a critical period for reducing the prevalence of obesity among women and children.[14,15]

The IOM recommends the communication of risks associated with excessive GWG during prenatal care[3]; however, providers often report barriers to addressing weight gain during pregnancy, such as low patient-provider morale, inadequate time for incorporating weight counseling into prenatal appointments, and lack of knowledge of current recommendations or nutritional guidance.[16–21] To reduce excessive GWG and alleviate provider burden, several behavioral interventions have targeted diet and exercise lifestyle behaviors for pregnant women, yielding success in reducing the proportion of women with excessive GWG by an average of 20%.[22,23]

The field of e-health refers to technologies that are developed or used to deliver or enhance public health and medical interventions. Mobile apps, websites, text messaging,

and social media are accessible platforms for prenatal information delivery to many U.S. women, with 94% of U.S. women owning a cellphone, 75% owning a smartphone,[24] and 73% using social media.[25] The accessibility of communicating health information over mobile platforms is promising in terms of reducing participation burden, however the application of e-Health to GWG is understudied.[26,27]

1.2 Broad Objectives of the Present Study

The goal of the present study is to evaluate the effectiveness of the Healthy Motivation for Moms-To-Be (HM2B) intervention in helping pregnant women adhere to IOM GWG guidelines by: (1) disseminating an intervention remotely through technology to increase accessibility; and (2) incorporating behavioral intervention strategies to enhance social support. There are very few evidence-based mobile apps available for nutrition and PA during pregnancy[28] and this e-Health intervention may alleviate the burden on physicians and clinical staff in providing weight counseling and monitoring health status of patients.[29]

This research project is part of a broader research agenda that posits healthy GWG may be achieved through behavioral intervention and may potentially reduce adverse maternal and infant health outcomes associated with excessive weight gain during pregnancy. The purposes of this proposed research are to examine the use of a mobile application (mobile app) for collaborative group-based health behavior challenges and a mobile website for self-monitoring and health-related pregnancy resources for pregnant women living in the United States. The overall goal of the proposed research project is to provide women with target GWG goals aligned with the IOM guidelines and evidence-based behavioral strategies to achieve healthy GWG during pregnancy. The

primary research hypothesis for this project is that the HM2B intervention will help a significantly greater proportion of women stay within IOM guidelines for GWG versus women assigned to the comparison group, and similarly, the intervention group will gain less weight than the comparison group. Secondary exploratory analyses will examine the effect of the intervention on infant birth weight outcomes.

The expected outcomes of this research are 1) a critical review of the uses of technology within interventions disseminating health-related information to pregnant women, 2) an understanding of health information needs and technology uses of pregnant women and the potential for using mobile technology to disseminate weight-related information, 3) identification of health behavior strategies, such as informative podcasts or group-based challenges, that are associated with pregnant women achieving healthy GWG and 4) an exploratory summary of the intervention's effect on infant health outcomes, such as preterm birth status, low birth weight, and large-for-gestational age (LGA).

1.3 Conceptual Model

Figure 1.1 will be used to describe the relationship between inputs of the mobile app (i.e., individual characteristics, social influence, behavioral expectations, and behavioral intention) and outcome measures (i.e., IOM guideline adherence, amount of weight gained during pregnancy, and infant's birth weight). By using a diverse and broad population, there is a need to consider **individual characteristics** that may influence participation in the research study. Age will play an important role in the research study, as mothers experience pregnancy differently depending on age group. For HM2B, the participants will be eligible to enroll if they are between the ages of 20-35 years old.

Within this age range, it's possible that there will be variability in behavioral intention to change, behavioral expectations (what outcomes the individual believes to be achievable), and/or how influential their social roles are depending on participants' age. Weight status of participants upon entering the study will influence the targeted IOM guidelines for GWG. Based on participants' BMI upon entry into the study and goals generated to reflect the IOM guidelines, there may be variation in participants' willingness to engage in the social aspects of the intervention due to fear or embarrassment, as well as behavioral hesitations for participants to log their weight on a weekly basis (self-monitoring).

A comparison of behavioral expectations, social influence, behavioral intention to change, use of mobile app features, and/or average amount of weight exceeding IOM guidelines by dichotomized pre-pregnancy weight status groups: normal and overweight/obese. Education level, household income, and race/ethnicity have been shown to influence weight status, so these factors will be considered in data analyses, if the sample is diverse enough. Lastly, since this is a national sample, geographical location of participants' residence may play a role in behavioral expectations, social influence, behavioral intention, mobile app use, and average amount of gestational weight gained.

Rooted in Unified Theory of Acceptance and Use of Technology (UTAUT),[30] **Behavioral Expectations** and **Social Influence** have been included in the model. **Behavioral Expectations** reflect many of the cognitive factors included in the Social Cognitive Theory: knowledge, self-efficacy, self-regulation, and expectancies related to behaviors and outcomes.[31] For the purpose of this study, each cognitive factor will

contribute to the overall expectations a participant sets regarding weight gain during pregnancy. Outcome and behavior expectancies address a woman's perception of the IOM guidelines and beliefs in appropriate, healthy gestational weight gain. These expectations may contribute to overall behavioral intention to perform a behavior, or the expectations may be reflected directly in the amount of weight gained during pregnancy. **Social Influence** is comprised of one's social network support (i.e., relationships, companionships), emotional support through their social circles (i.e., encouragement, motivation), informational support provided by social group members (i.e., advice, suggestions, referrals), and social esteem which can be described as one's comfort within a social group (i.e., validation, sense of belonging).[30–33] Social Influence may directly impact one's total amount of weight gained throughout pregnancy, or it may play into one's behavioral intention to change.

Behavioral Intention is the most important component of this model because one's intention is the driving force behind whether an action is made.[33] For the purpose of our study, we plan to look at how one's behavioral intention influences their use of the mobile app. Technology attitudes are included in the model to address voluntariness of app use, experiences with mobile health app, and number of social interactions, challenges achieved, and points earned.[30,34] For instance, if one participant successfully met all of the weekly challenges, she will have earned more engagement points than a participant who only participated in five challenges. The interactions that happen within the social app group and the number of points earned may serve as a continuous reinforcement for using the app. Similarly, there may be a two-way relationship observed between voluntariness of use and mobile app experience since challenges will not be

mandatory, continued use may be sustained by experience with the mobile app and challenges provided. It is possible that the better a participants' mobile app experience is, the more likely a participant will continue to use the app throughout the program. These attitudes may influence how much effort a participant contributes to the weight tracking feature of the app, interactions on discussion boards, and overall usage of the app. Furthermore, existing attitudes about technology can influence one's goal performance, social interactions, or utilization of facilitating conditions. For instance, someone may utilize the app to read the weekly challenge, but not track weight gain progress because of discomfort with sharing that information electronically.

This conceptual model includes goal-oriented performance and effort expectancies, social influence, and facilitating conditions such as accessibility and availability of resources within the environment. These components of the model address the behavioral expectations of participants when provided targeted IOM guidelines. The ability to comment or provide social support to group members will generate a social network of expectant mothers who may have ideas or experiences to share. Ideally, the expectations of meeting IOM guidelines combined with social influence from peers will generate motivation towards behavioral intention to track one's weight. Additionally, by providing this intervention through a mobile platform, we are increasing accessibility opportunities, which is a facilitating condition for this intervention. By using the commercially available mobile app, MakeMe,[35] downloaded from iTunes or Google Play, the participants will be invited to join a weekly health challenge with their groups. The app allows for progress tracking and photo or written descriptions of the completed activity.[35] The health challenges will target nutrition and physical activity in an effort to

reduce the average amount of maternal weight gained during pregnancy. Depending on a participant's experience using the mobile app and participating in challenges, there may be variability in adherence to the intervention components and ultimately, their success with meeting IOM recommendations.

The impact variable is to **reduce the proportion of women exceeding IOM GWG recommendations**, and as a result, lower the mean total gestational weight gain, with the overall goals of reducing adverse health outcomes of pregnant women. This study will also examine the impact of the intervention on changing diet and physical activity behaviors. This study will also request the infant data: birth date, length, and weight to determine **prematurity** and **birth weight status**, which are documented birth outcomes associated with excessive gestational weight gain during pregnancy,[36] for exploratory secondary analyses. The HM2B sample size is not adequate enough to draw **significant conclusions regarding GWG and birth outcomes, but the exploratory** secondary analyses will be used to determine any differences in birth outcomes among intervention and comparison groups. These exploratory analyses address the Life Course concepts regarding long-term impacts of GWG in relation to fetal health outcomes, childhood obesity for the offspring, and maternal postpartum weight retention.[37,38]

Other potential infant health outcomes of this study include reduced risk for long-term or latent adverse health outcomes, such as possible predisposition to obesity in adulthood for the offspring. Additionally, mothers in the intervention group may retain less weight during the postpartum period compared with the control group. However, due to time constraints for this project, these outcomes will not be measured.

1.4 Specific Aims and Hypotheses for Proposed Dissertation Research

1.4.a. Aim 1: Systematic Review

The purpose of Aim 1 was to conduct a systematic review of technology-mediated interventions (e.g. mobile apps, websites, text messaging) for the prevention of excessive GWG during pregnancy, regardless of gravida. The focus of this review was on interventional delivery practices during pregnancy, types of technology used, and successful strategies for promoting healthy GWG. Additionally, a subset review of studies focused on population demographics (ie., race and parity) was conducted.

Research Question 1a: What types of technology are used in the prevention of excessive GWG during pregnancy and which platforms are the most common?

Research Question 1b: What are the behavioral strategies and features used in technology-mediated interventions (such as weight tracking or social networking features) for promoting healthy GWG?

1.4.b. Aim 2: Formative Research

The purpose of Aim 2 was to analyze data from a needs assessment collected in April 2016 via an online survey of a national sample of pregnant women (n=445) regarding weight-related knowledge and behaviors, sources of prenatal health information, and interest in participating in a mobile health intervention. The sample for Aim 2 was not limited to parity or BMI to determine a realistic sample to recruit and focus the intervention on. Collecting input from pregnant women who have been pregnant before helped to capture opinions on pregnancy and weight-related topics from experienced moms, who may have retrospective input regarding health information needs and weight-related behaviors during pregnancy. This needs assessment identified

recruitment strategies, health information needs of pregnant women in the U.S., and was used to determine the demographics of the HM2B target sample.

Hypothesis 2a: Pregnant women who do not report receiving GWG recommendations from their health care practitioners will report a greater total amount of weight gain they believe is appropriate for pregnancy compared to women who report receiving weight gain recommendations from their providers.

Hypothesis 2b: Overweight and obese pregnant women will show significantly greater interest in using a mobile app for tracking gestational weight gain compared to normal weight pregnant women.

Research Question 2c: What are participants' levels of interest in using a mobile app for communicating with other pregnant women, using a mobile app for tracking weight gain, receiving weekly group-based challenges related to healthy eating and physical activity, listening to pregnancy health-related podcasts?

Research Question 2d: What sources of information do pregnant women in the US rely on most often for nutrition and physical activity related content?

1.4.c. Aim 3: Intervention Outcomes

The purpose of Aim 3 was to develop and assess the impact of a mobile health intervention on GWG of pregnant women receiving a healthy eating and physical activity (HEPA) focused intervention versus a comparator group receiving a non-nutrition/PA focused health promotion program. Participants were randomly assigned to their groups and remained in the same group from baseline ($\leq$ 20 weeks pregnant) through delivery (~40 weeks pregnant). The e-Health intervention was disseminated using a commercially available free mobile app for weekly group-based health related challenges. Each week

participants submitted their self-reported weight to their personal profile on our study website, where they could also access 10 informational podcasts, weekly pregnancy tips, and view a GWG chart of plotted weigh-in data points (intervention only). After delivery, participants self-reported the infant measurements (length and weight), as well as birthdate and gender. Objective measures of maternal weight were collected through photo verification of the participants' scale display at three time points: baseline, 32-weeks, and post-delivery.

Hypothesis 3a1: The intervention group will have lower total GWG and a greater proportion of women with total GWG within IOM guidelines versus the comparison group at delivery.

Hypothesis 3a2: Motivation to change behaviors (i.e., healthy eating, sleep, physical activity) will be significantly improved through the group-based challenges of the respective groups.

Research Question 3a3: Did infant birth weight significantly differ between intervention and comparison groups?

A second component of Aim 3 tested the usability and feasibility of a mobile app for a GWG intervention. To determine the best approach to disseminating a mobile health intervention through group-based challenges, we collected feedback on the preference of challenges tested during the study and the process of receiving and engaging with weekly challenges through the mobile app. For this study, data recorded by trained researchers included: total group points, individual points, number of group challenges met, number of "bumps" (positive reinforcement) within the group challenge, number of comments,

and content of comments. An "engagement score" was calculated for each participant and averaged together with teammates' scores for group level analyses. Additionally, we collected process and content feedback from participants at the end of the pilot study regarding the weekly group-based challenges.

Hypothesis 3b1: The mean engagement, satisfaction, and intent to continue use scores will not significantly differ between the intervention and comparison groups indicating overall interest in using the mobile app and participating in a mobile health group-based challenge, regardless of health topics.

Hypothesis 3b2: The level of engagement in the group-based challenges will be significantly negatively associated with amount of weight gained in the intervention group versus the comparison group.

Hypothesis 3b3: The number of podcasts listened to and overall engagement score will be significantly positively associated with meeting IOM guidelines for the intervention group participants versus the comparison group.

Research Question 3b4: Did participants find the mobile app user-friendly?

Research Question 3b5: Which topics and challenges were participants most interested in related to behavior change?

1.5 Justification for the Research

The proportion of U.S. women exceeding recommendation for healthy GWG has steadily increased in the past decade. The HM2B intervention will contribute to the field of health promotion by responding to the IOM and ACOG's recommendations for action to provide targeted messaging and reinforcement strategies that encourage adherence to guidelines for weight gain during pregnancy.[3,39] This will be achieved by providing

nutrition and PA behavioral strategies to an at-risk population (pregnant women) and by collecting weight measurements over pregnancy and at delivery. Furthermore, HM2B will be delivered through a commercially available mobile app, increasing opportunities for accessibility, study participation, and increased generalizability.

This research project will also contribute to the field of mobile health, using technology to disseminate health promotion information and deliver interventions to an at-risk population. HM2B is grounded in health behavior and communication theories and will be the first of its kind to test the effectiveness of a completely remotely-delivered behavioral intervention on weight management for pregnancy, not limited by geographical area. Additionally, HM2B will identify behavioral strategies for promoting prenatal health information through a mobile intervention. While there are mobile apps available with GWG tracking features, few are grounded in health behavior theory and provide comprehensive behavioral reinforcements.[28] The HM2B intervention is an attempt to provide an evidence-based approach to self-monitoring GWG while alleviating the burdens of in-person intervention delivery. Finally, this research may potentially reduce adverse health outcomes associated with overweight and obesity for the mother and infant.

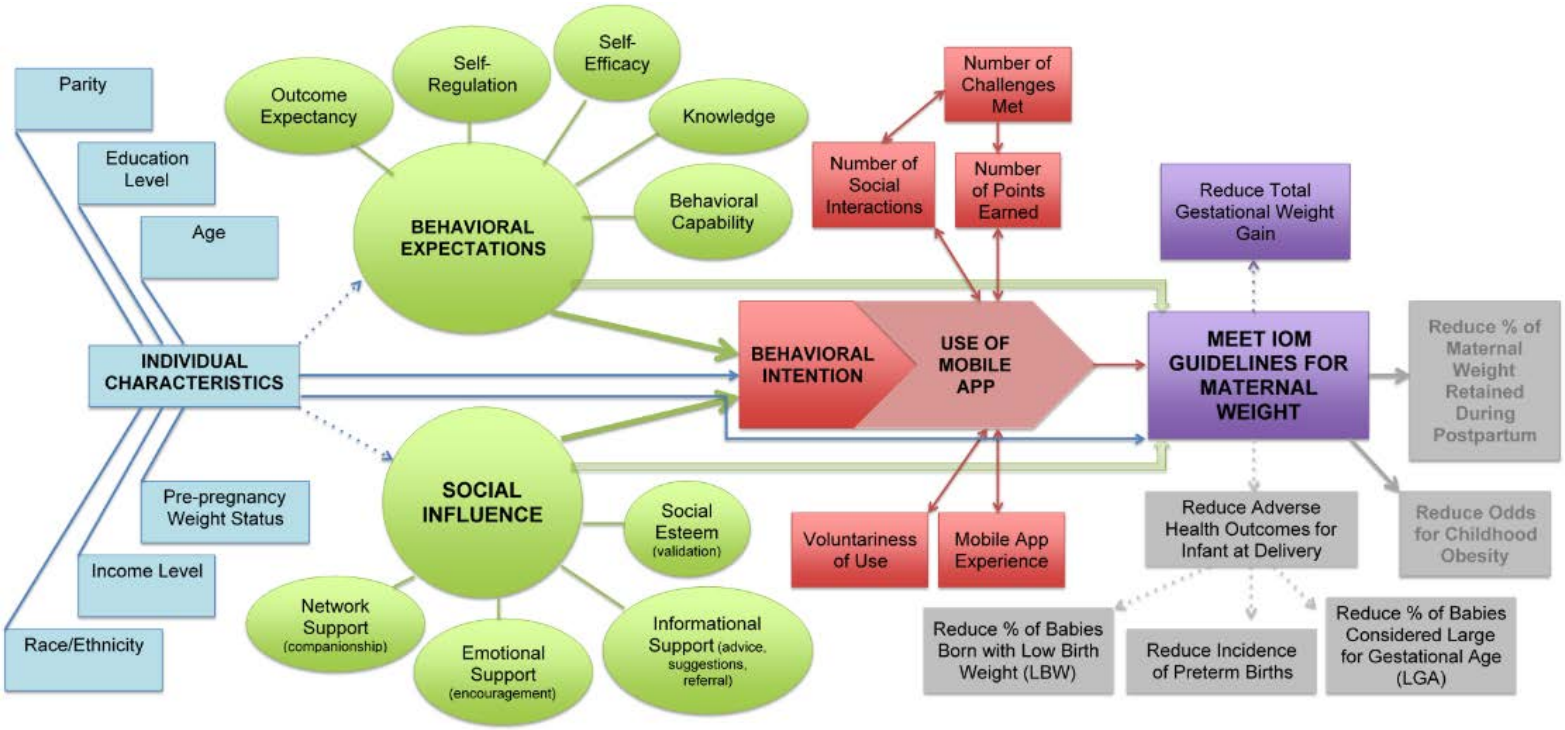

Figure 1.1. Conceptual Model

Chapter 2: Background and Significance

2.1. Gestational Weight Gain Recommendations

Obesity is a complex public health issue affecting an estimated 40.5% of adult women in the United States.[14] In an effort to address growing concerns regarding obesity, the Institute of Medicine (IOM) developed a set of GWG recommendations based on pre-pregnancy body mass index (BMI).[40,41] The IOM guidelines were revised in 2009 to provide practitioners BMI-specific weight gain ranges, including trimester weight gain rates.[40] For women entering pregnancy underweight (BMI below 18.4 kg/m^2), the guidelines suggest a range of 28-40 pounds for healthy GWG, while normal weight women (BMI between 18.5-24.9 kg/m^2) are recommended to gain 25-35 pounds.[3] For overweight women (BMI=25.0-29.9) the recommended total weight gain range is 15-25 pounds, with a 0.6 pounds/week rate of weight gain in the second and third trimesters.[3,40] Obese women (BMI>30) are recommended a total weight gain range of 11-20 pounds, with a 0.5 pounds/week rate of weight gain in the second and third trimesters.[3,40] The healthy GWG guidelines for women carrying twins or multiples also vary based on pre-pregnancy BMI.[3]

About one-half (46%) of all pregnant women in the United States exceed the Institute of Medicine's (IOM) 2009 recommendations for weight gain during pregnancy, regardless of pre-pregnancy BMI.[3,40] Compared to normal weight women, overweight

and obese women are nearly two times more likely to exceed IOM recommendations for GWG.[3,4,17]

2.2. Associated Risks of Excessive Gestational Weight Gain

Excessive GWG has been positively associated with increased risk of gestational diabetes, hypertensive disorders such as preeclampsia, and permanent postpartum weight retention.[8,11,39,42–47] Overweight and obese women are at increased risk of excessive gestational weight gain (GWG) and postpartum weight retention compared to normal weight women.[8,11,43] Furthermore, excessive gestational weight gain among overweight and obese women has been associated with increased odds of postpartum weight retention (OR=1.07, 95%CI=1.02-1.12).[7] Adverse obstetric health outcomes associated with excessive GWG include increased rate of failed induction, operative vaginal deliveries, cesarean delivery,[48,49] stillbirth,[50] and antenatal and postpartum depression.[51] Excessive GWG is also positively related to adiposity among offspring[7,36,39,52,53] and may be prevented or reduced through diet or exercise, or a combination of interventions.[23] For the infant, there are both short- and long-term health consequences associated with excessive gestational weight gain during pregnancy which include: preterm birth, fetal growth, infant mortality, birth defects, birth weight, stillbirth, neonatal body composition, infant weight gain, breastfeeding initiation and maintenance, childhood obesity, type 2 diabetes, and neurodevelopment.[39]

2.3. Expert Recommendations and Past Intervention Strategies

As stated in the section above, the IOM provided evidence-based recommendations for weight gain during pregnancy, by trimester and an overall amount.[3,40] While it would be ideal to raise awareness and reduce overweight and obesity among women of childbearing age prior to becoming pregnant,[50,53–55] nearly half of

pregnancies are unintended[22] so conducting studies during the preconception window has proved challenging due to retention, chance of unintended pregnancy, infertility, and several other factors.[56] Patterns of excessive GWG in the first half of pregnancy have been associated with greater risk of unfavorable infant health outcomes, such as large-for-gestational-age (odds ratio: 2.5, 95% CI: 2.1-3.1, $p<0.001$).[57] Therefore, interventions for increasing weight-related knowledge and changing weight-related behaviors in early pregnancy has been a main focus of public health efforts.[57] Interventions targeting the first trimester are optimal, as excessive weight gain during the first trimester is predictive of excessive GWG for the entire pregnancy, especially among overweight and obese women (90% probability of excessive GWG).[58]

The IOM suggestions for action include that prenatal health care practitioners should offer counseling on dietary intake and physical activity tailored to their life circumstances.[40] In agreement, ACOG recommends that a discussion between the health care practitioner and patients regarding appropriate weight gain and diet and exercise should occur at the initial prenatal appointment and periodically throughout pregnancy.[39] Providing GWG guidelines at the initial prenatal appointment is particularly crucial in an effort to reduce the nearly two-thirds of overweight and obese pregnant women exceeding IOM recommendations.[59]

Significant findings show that overweight and obesity, and in some cases, excessive gestational weight gain, are associated with adverse health outcomes for the mother and infant. Insulin resistance and gestational diabetes risks are significantly increased when a woman enters pregnancy with an obese BMI.[43,60] In the long-term, gestational diabetes increases a woman's risk of developing type 2 diabetes at least

seven-fold.[61] Similarly, relative risk for developing gestational hypertension is 1.7 for overweight and 2.2 for obese women in relation to normal weight women.[62] Preeclampsia among obese women is twice as prevalent compared to normal weight women, and prevalence increases three times as much among obese women.[63]

Several reviews of literature have concluded that there is moderate to strong evidence to support the association of excessive gestational weight gain with postpartum weight retention.[8,11,43] In the systematic review by Siega-Riz et al. (2009), the authors found moderate, consistent evidence of higher postpartum weight retention among women who exceeded IOM guidelines for GWG in the short term (<12 weeks[9,64–66]) as well as in the long-term (6-18 months[9,45,64,67–69]) postpartum period.[43] Furthermore, excessive GWG during pregnancy has been shown to elevate risks of overweight or obesity in offspring (27 to 73%), compared to those who meet IOM guidelines.[12,52,70] Weekly goal setting[71] and use of technology for monitoring nutrition behaviors[72,73] are potential strategies for reducing weight retention in the postpartum period for mothers.[74]

While the relationship between BMI during pregnancy and the long-term consequences of developing one or more of the aforementioned health conditions is well documented, little is known about the associations between increasing GWG and health conditions mainly due to inconclusive findings,[43] with the exception of postpartum weight retention.[58,74] To reduce excessive GWG and postpartum weight retention, recommendations for behavioral modification during pregnancy and postpartum include nutrition counseling, regular physical activity, and goal setting.[71,74]

2.3.a. Gestational Weight Gain Interventions

Behavioral lifestyle interventions have been used as a method for weight loss and weight maintenance efforts. There have been several behavioral interventions targeting

GWG that draw on similar behavioral strategies seen in weight loss interventions. In a systematic review by Flynn et al. (2004),[75]13 randomized controlled trials provided dietary interventions to overweight and obese pregnant women, and within those, eight studies aimed to reduce GWG through dietary modification and physical activity.[76–83] Intervention delivery varied from nutrition brochures,[79,83] a diet plan provided to participants to follow independently[78,80] to 10 one-hour consultations with a Registered Dietitian.[82] Only one study from this review was conducted among obese women in the United States,[77] and only two studies included overweight women in their samples[76,78] indicating a gap in the literature around effective weight-related intervention strategies for pregnant women of different BMI statuses in the U.S.,[75] which the HM2B study aims to address. Furthermore, Flynn et al.'s systematic review identified several methodological variations across the selected interventions and therefore the authors were unable to provide clinical guidelines for addressing GWG through behavioral modification among overweight and obese pregnant women.[75]

Likewise, a Cochrane Review of interventions for preventing excessive GWG during pregnancy selected 27 studies of nearly 4,000 women for analysis but could not draw statistically significant conclusions due to inconsistent results and/or methodological differences.[22] Within this review by Muktabhant et al. (2012),[22] only two studies with a total of 247 women showed a positive treatment effect associated with behavioral counseling versus standard care in a pooled analysis (RR 0.72, 95% CI: 0.54,0.95, I^2=0%).[84,85] In one of those studies shown to have a positive treatment effect, Polley et al.(2002) employed a stepped-care behavioral intervention where normal and overweight pregnant women (N=110) received weight gain information, healthy eating

and exercise education, and materials for tracking their GWG (such as weight gain graphs) and if women exceeded weight gain goals, a more intense individualized counseling session was introduced.[85] Normal weight women receiving the intervention were significantly less likely to exceed IOM guidelines compared to the standard care group (33 vs 58%, p<0.005), however more overweight women in the intervention (59%) exceeded recommendations for GWG compared to their standard care counterparts (32%, *p*=0.09).[85] At their first postpartum clinic visit, there was no significant intervention effect found on postpartum weight retention of normal or overweight participants compared to participants in a usual care group.[85]

In the second effective intervention, a randomized controlled trial by Phelan et al. (2011), was called *Fit for Delivery* and provided intervention participants (N=401 normal, overweight, and obese pregnant women) with an individualized counseling session with a trained interventionist to discuss appropriate GWG targets, weight gain charts, physical activity, and nutrition in an attempt to prevent excessive GWG and postpartum weight retention.[84] Intervention participants also received brief supportive phone calls with the dietitian on three occasions during the study as well as body-weight scales, food records, and pedometers to promote behavior change and program adherence.[84] Overweight and obese women in this intervention did not show a significant reduction in excessive GWG compared to their standard care counterparts (OR to exceed IOM recommendations: 0.1.4, 95% CI: 0.70, 2.7, *p*=0.33), whereas normal weight women in the intervention did see a significant reduction versus standard care (OR: 0.38, 95% CI: 0.20, 0.87, *p*=0.003).[84] When participants exceeded IOM guidelines for GWG, results showed that the intervention women were more likely to return to pre-pregnancy

weight at 12 months postpartum compared to the control participants who exceeded IOM guidelines which indicates that although the intervention may not have prevented all women from exceeding IOM guidelines, there was some behavioral effect that transferred to postpartum weight loss.[86]

Of the two major reviews outlined in this section, neither were able to draw conclusions regarding intervention effects for reducing excessive GWG. This presents a challenge when providing standards of care recommendations for health care practitioners regarding GWG guidelines and best practices for behavioral modification. Although the reviews provided little guidance for best practices, the studies included several behavior change strategies for encouraging and reinforcing weight-related health behaviors in the prevention of excessive GWG.

2.3.b. Behavioral Strategies Used to Target Healthy Gestational Weight Gain

Multiple systematic reviews and meta-analyses have been conducted in the topic area of GWG, however most findings were inconclusive due to large variation in methodologies.[8,11,22,23,43,75] While these findings do not draw clear recommendations for best practices, specific behavioral strategies within the studies have shown promising intervention effects. This section will review several intervention strategies used and outcomes observed.

2.3.b.1. Dietary Counseling

A popular method for supporting weight-related behavioral change is dietary counseling. Several studies employed Registered Dietitians or food technologists to administer diet-related counseling, ranging from brief five minute sessions to hour-long consultations or group-based counseling.[77,78,80–82,87] Other studies provided recommendations or advice through health coaches, interventionists, or health care

practitioners, such as nurses and midwives.[76,77,83] Often times, dietary interventions combined a variety of behavioral tools such as education materials or food diaries along with their counselling.

For example, a randomized controlled study of obese pregnant women in Denmark (N=35) found that GWG to 13-15 pounds was effective when the intervention group received 10 one-hour sessions with a Registered Dietitian during pregnancy compared to a control group that did not receive one-on-one counseling.[82] This intervention provided obese pregnant women with dietary intake recommendations and specific macronutrient composition of their diets to inform healthy eating behaviors.[82] Similarly, another study conducted among obese Swedish pregnant women found that an intervention that provided participants with a 30-minute individual visit with a midwife each week, where the participant received motivational discussions on how to change behavior and learn about strategies specific to her needs led to significantly lower GWG (7.52 kg, SD=15.40) compared to a control group (9.78 kg, SD=16.24, p=0.001), after adjusting for socio-demographic variables.[88] By providing women with specific recommendations on how to manage their GWG guidelines, these studies indicate that IOM guidelines may be achieved.

2.3.b.2. Physical Activity

Evidence suggests that physical activity has an important role in weight management during pregnancy, specifically for preventing excessive GWG.[23] However, the effects of dose and exercise type on GWG are inconclusive.[89] Some interventions are designed to expand the nutrition counseling sessions to include physical activity content and measure activity as an outcome related to weight gain control.[79]

For example, a group of researchers in Canada successfully introduced exercise

into a randomized controlled trial through a community-based exercise program of walking, aerobics, stretching, and strength exercises practiced three to five times per week and two individual counseling sessions and dietary interviews with a Registered Dietitian, while the control group received educational materials regarding nutrition and physical activity during pregnancy.[90] Results indicated that the participants enrolled in the intervention group had a descriptively lower mean weight gain (14.1 kg, SD=6.0) compared to the control group participants (15.2 kg, SD=5.9), but this finding was not statistically significant.[90] However, physical activity levels were significantly higher two months after enrollment among intervention group participants (Physical Activity Index=1.85, SD=0.44) compared to the control group participants (1.45, SD=0.72) which may have been a result of community engagement, social support, or availability of fitness opportunities.[90] This study indicates a need for targeted interventions that meet the needs of the population, identified through conducting needs assessments and pilot studies to inform future research, or qualitative interviews with pregnant women within a community.[90,91]

2.3.b.3. Informational/Behavioral Tools

Health care providers are often charged with the task to communicate and monitor GWG. When reviewing the literature around health care practitioners' role in preventing excessive GWG, one concern shared by providers was the need for tools or educational materials to address GWG during prenatal appointments.[17] In response, a study by Marsh et al. (2014) supplied health care practitioners with a tool to promote weight loss in the preconception period, but no findings were reported on the use of and effectiveness of the tool in practice.[55] Likewise, another study examined the efficacy of an intervention that provided OB/GYN clinics with GWG graphs based on pre-pregnancy BMI groups, along

with an optional 2-hour orientation program to understand the use of the materials, however outcomes of the clinical component were not reported.[45] Overall, the literature was inconclusive on whether supporting materials would lead to an increase in conversations with patients and their awareness and understanding of GWG recommendations. Supporting materials or interventions may also help to address the providers in recommending accurate weight guidelines[92], as one study found that when participants received weight gain advice (41.7%), overweight/obese women received incorrect weight gain guidelines advising too much weight (22.2%) compared to normal weight women (2.3%, $p<0.001$).[93]

A study based in upstate New York targeted pregnant women who were classified as having a normal or overweight BMI with a health education intervention that provided five newsletters on pregnancy related information on nutrition, GWG, and physical activity.[45] The study found that among low-income women, more women in the control condition receiving no educational component (52%) gained an excess amount of weight during pregnancy compared to women in the intervention group (33%) and of the low-income subgroup, overweight women in the intervention group were less likely to retain more than 2.27 kg compared to other income and BMI classifications (OR=0.24, 95% CI: 0.07-0.89).[45]

A food diary, pedometer, and written education materials were provided as part of a lifestyle modification program to improve healthy eating and exercise among obese pregnant women in New York City in an effort to reduce excessive GWG and adverse pregnancy outcomes.[94] Results of this study showed significantly less weight gained during pregnancy for obese women in the intervention groups (17.76 lbs., SD=16.30)

compared to obese women in the control groups (34.00 lbs., SD=16.58, p=0.003).[94] The intervention was effective in some sub-groups such as obese women, but not all BMI classifications.[94]

2.3.b.4. Group-Based Challenges

Several of the interventions discussed earlier highlight the positive impact of one-on-one health coaching sessions or group-based education regarding weight gain, nutrition, and physical activity during pregnancy.[82,85,88,90,95–98] As the Social Cognitive Theory[31] and Theory of Planned Behavior and Reasoned Action (TPB/RA)[33] posit, social norms play a role in an individual's health behavior change, while the Unified Theory of Acceptance and Use of Technology expands on this by indicating a direct relationship between social influence and behavioral intention, and behavioral intention has a direct relationship to behavior as demonstrated by both TPB/RA and UTAUT.[30]

Capitalizing on social networks or group-based interventions may increase the social connections and support that have been shown to positively influence one's behavioral intention. Therefore, a potential strategy to reduce intervention resources and accessibility concerns associated with individual or group-based counseling would be to create and facilitate group-based health-related challenges within a mobile platform. Using a commercially available, free mobile app, or online social network, participants with access to a smartphone or computer can be connected to other pregnant women to engage in health-behavior challenges targeted at nutrition and physical activity needs during pregnancy. Although this type of intervention has not been conducted specifically with overweight and obese pregnant women, several studies have examined the use of group-based challenges and goal setting for promoting healthy behaviors.

Health behavior challenges have been explored through online networks, but not specifically among pregnant women online. Although pregnancy-specific challenges have not been studied, health behavior change can be achieved remotely, through social networks and may be a viable option for the online community of pregnant women.[99,100] In a study using Twitter to promote a core-strengthening exercise challenge (#PlankADay), male and female (non-pregnant) users online were connected to participate in daily physical activity (planking).[101] Of the 277 participants in the challenge, 105 completed surveys about their experience.[101] Engagement in the challenge was measured by 72% of participants tweeting their planks daily for 1 month and 47% continuing for 8 or more weeks.[101] The challenge-based experience of #PlankADay increased participant enjoyment of core exercises (M=7.05, SD=2.2) since before the challenge (M=4.52, SD=3.0) ($t(101)=9.98$, $p<0.001$) and tweeting about their planks increased their motivation (88%).[101] Furthermore, 82% of participants indicated that having other Twitter followers respond to their #PlankADay tweets, improved their motivation.[101]

Similarly, another study used social media (Facebook) to challenge male and female (non-pregnant) users to participate in physical activity races (i.e., running, walking, cycling, triathlons) and found that participants reported a greater mean number of races completed and total mileage covered in the year of the social media challenge (#13-in-2013) compared to their records the previous year.[102] The use of a social media physical activity challenge showed a reduction in self-reported body weight at the end of the challenge.[102] Competition through these social media challenges was a motivation for participants to join the study.[102]

To increase social network interactions and support, the challenge-based concept for health promotion may be beneficial for weight management of pregnant women as well. This concept will be tested through the HM2B intervention to increase healthy eating habits and physical activity by weekly group challenges where users can track their achievements through a commercially available, free mobile app called MakeMe.[35] The app was freely available in the iTunes and GooglePlay store until December 2018 and rewarded participation and challenge completion through a points-based system, a motivational tool that has shown to increase and maintain participation in weight-related interventions.[32,100]

A systematic review of lifestyle interventions found five studies[48,82,85,86,103] using goal-setting strategies for preventing excessive gestational weight gain.[71] GWG was lower in the intervention group compared to the standard care group for three studies in the review.[48,86,103] Regarding goal setting components within the interventions, no overall purpose goals/reasons for managing weight during pregnancy were provided, but targeted goals based on weight gain guidelines were established in all of the interventions.[48,82,85,86,103] Additionally, all five studies provided weight monitoring throughout the intervention, use of weight gain graphs, verbal feedback and all but one[48] provided self-monitoring tools such as body weight scales, food records, and pedometers, making it difficult to determine which components were effective.[48,82,85,86,103] Only one study[82] provided a theoretical foundation for goal setting in the intervention design, indicating a greater need for theory based interventions targeting GWG.[71]

2.4. Use of Mobile Technology in Health Behavior Interventions

ACOG provides recommendations for practitioners to advise women about GWG, nutrition, and physical activity during the initial prenatal appointment and periodically

throughout the pregnancy.[39] A limitation to reducing excessive GWG in previous studies was that weight and nutrition counseling and education was often not provided through prenatal appointments due to time constraints or physician burden[18] or because many women do not qualify or participate in additional educational programs such as WIC.[104–107] The aforementioned pregnancy intervention studies included individual counseling sessions that tend to be labor-, resource-, and cost-intensive.[108] In order to identify opportunities to expand the reach and scope of these studies, additional modes of intervention delivery should be explored. One solution to this problem is introducing technology-mediated interventions to disseminate nutrition and weight counseling to pregnant women.[109]

Technology provides a solution to participation challenges associated with in-person behavioral interventions such as work schedules, lack of transportation, and childcare for older children.[99] Mobile apps, websites, text messaging, and social media are accessible platforms for prenatal information delivery to many U.S. women, with 94% of U.S. women owning a cellphone, 75% owning a smartphone,[110] and 73% using social media.[25] The accessibility of communicating health information over mobile platforms is promising in terms of reducing participation burden, however most technology-mediated interventions rely on phone calls and text messaging rather than mobile apps or websites for content delivery.[26,27] Internet websites, text messaging, and mobile apps have been identified as viable resources for a diverse population of racial/ethnic and socioeconomic groups.[99,111]

In a recent review of 87 mobile apps available on the marketplace using “weight” and “pregnancy” as search terms and using a weight tracking feature, only 19 (22%) apps

provided accurate GWG guidelines and fewer (<10%) had nutrition and physical activity guidance for achieving healthy GWG.[28] Despite the availability of apps advertising pregnancy weight-related content and features, current apps are inadequate to support healthy weight monitoring during pregnancy.[28] Furthermore, practitioners are concerned with the source and reliability of pregnancy-related health information shared via commercially available apps[28,112,113] creating an additional barrier to supplementing prenatal care and GWG monitoring with technology.

On the practical side of health promotion, practitioners could use these technology-based resources as a supplement to their prenatal care[17,114] and stimulate patient engagement and participation in weight counseling.[97] Furthermore, studies have used technology as a way to connect participants through a social network, which can provide social support, information, motivation, a sense of accountability, greater adherence, and a place to share personal testimonies.[115–118]

Women may seek information through technology-based resources because of the lack of discussion, counseling, or education around nutrition and weight provided in prenatal care visits.[17,18] In a descriptive study examining the use of online resources during pregnancy, most pregnant women reported accessing the Internet for information related to their pregnancy, childbirth, or expected baby's development (84%) and over half of the women (54%) used online resources at the beginning of pregnancy compared to the end (17%).[119] Most women (65%) reported their online sources as highly reliable, but this was driven by women being selective in finding Internet resources related to pregnancy information, through confirmation of information with other websites or checking cited references for additional information.[119]

The concern of practitioners regarding misinformation provided through these outside sources is valid[120]; however, the need for additional resources addressing nutrition, physical activity, and appropriate GWG for pregnant women is important as well, especially during early pregnancy.[57,119] In order to address these concerns, additional research is needed to understand the quality of information, how it is accessed, and the impact of improving diet and physical activity on GWG and health-related behaviors.[26,119] Furthermore, bridging the gap between provider and patient communication is vital for providing women with health recommendations and reliable resources, which may be achieved through the implementation of technology-based resources in prenatal settings.

2.4.a. Websites

The Internet serves as an accessible platform for women to seek information related to pregnancy. Mothers tend to seek information through websites and interactive forums like blogs and chat groups. This has the potential to lead to misinformation, a major concern of practitioners.[120] One study addressed the need for process evaluations to be conducted in order to understand the effectiveness of online interventions. The study found that greater intervention dose received or higher engagement with the intervention led to improved health outcomes.[121] Additionally, weight-tracking tools are commonly used features of online weight-related interventions.[121]

Several studies conducted in the Netherlands evaluated the use of websites targeting pregnant women. One such eHealth program was developed for pregnant women (N=488) in midwifery care to provide using a website containing quizzes with questions tailored to their current stage of pregnancy and five different topics (nutrition, exercise, lifestyle, smoking, and safety). The study found that 16% of women (n=80) did

not access any information once registered on the website.[122] The most useful topics provided through the website were gestational age-specific pregnancy information, nutrition, safety, and lifestyle, according to participants.[122] The authors suggest that eHealth programs are feasible to be implemented into midwifery care[122]; however, the low utilization of the midwifery care platform in the United States suggests that additional research is needed for integration of eHealth in our prenatal health care approach.

2.4.b. Email

An email-based program in the Netherlands called "Hello World" provided pregnant women with pregnancy-related quizzes tailored to gestational age and healthy lifestyle promotion.[123] Women with lower education showed greater appreciation for the program (52%) compared to women with higher education levels (44%).[123] Program reach and use were evaluated and indicated a positive association between the number of quizzes taken by women and their reported healthy lifestyle behaviors (i.e., smoking, fruit and vegetable intake, and physical activity).[124] However, this evaluation was limited due to underrepresentation of immigrants and low-educated women in the study population as well as a low target population reach (4%). While many behavioral interventions use email to communicate with participants regularly, the "Hello World" intervention was the only one to test email as an intervention delivery mode.

2.4.c. Mobile Phones

2.4.c.1. Text messaging

Mobile phone technology has revolutionized the way people communicate on a regular basis. Short messaging services (SMS), commonly referred to as "text messaging" is a promising platform for behavior change interventions.[98,111] A study by

Cormick et al. (2012) investigated the interest of text messaging interventions among pregnant women conducted in Argentina and found that 95.9% of participants (N=146) were willing to receive one-way health related text messaging during their pregnancy and 55.5% of participants asked for texts to begin within their first trimester.[111] Participants indicated their ideal dosage of informational text messages would be 1-3 times per week (82.8%).[111] In the same study, only 87% of women were willing to receive phone calls during pregnancy.[111] Regarding the content of text message-based interventions for pregnancy, women indicated high levels of interest in receiving information about pregnancy and newborn diet (90% and 91%, respectively) but showed less interest in physical activity during pregnancy (73%).[111]

A feasibility study was conducted in England to evaluate a project called MomTech, which addressed maternal obesity management during pregnancy through one-way text-messaging health behavior change techniques that were predetermined and selected by participants to receive.[72] The intervention used personalized support and praise and behavior change strategies to encourage and motivate women to achieve a healthy weight gain during pregnancy.[72] Obese women who participated in the text-messaging intervention gained less weight during pregnancy than the control group (6.65 kg and 9.74 kg, respectively) and were less likely to exceed the Institute of Medicine's (IOM) guidelines for GWG (28% and 50%, respectively).[72] A limitation to this study was the small sample size (N=14) and lack of diversity across participants which requires further investigation.[72]

Similarly, another study piloted a two-way text-messaging intervention aimed at healthy GWG among overweight and obese women (PregCHAT).[98] Four health

behaviors were targeted to increase physical activity, avoid unhealthy foods, and increase daily fruit and vegetable intake.[98] The control group received "Text4Baby," which provides general pregnancy info via one-way text messaging and is not diet/exercise specific.[98] The pilot study found no differential treatment effect for physical activity level or nutrition scores, however the control group gained more weight by 40 weeks pregnancy compared to the intervention arm (6-7 pounds).[98] Regarding feasibility and acceptability, the authors found that 86% of participants in the intervention (PregCHAT) arm read and responded to texts and the majority (71%) said they would recommend the PregCHAT program to a friend.[98]

2.4.c.2. Mobile apps

Mobile apps provide a convenient, readily available, and personalized resource for women during pregnancy.[125] Smartphones are a popular device for Internet access among pregnant women.[99] Mobile health-based interventions could be used as a parallel or supplemental tool for prenatal and perinatal care[114] and have been received by pregnant women as a preferred method (89%) of receiving information compared to websites.[99] A study found that pregnant women were more likely to access mobile apps for journaling compared to paper and pen, but found no significant differences in blood pressure, weight gain throughout pregnancy, or birth weight between the methods.[97]

While accessibility seems favorable for mobile apps, the content of apps available for pregnant women tend to focus around fetal or infant development, symptoms related to the pregnancy, and fetal heart rate monitoring,[125] rather than behavioral strategies for healthy weight gain. Additionally, there is an abundance of commercially available weight-related, physical activity, and nutrition mobile apps to choose from, as well as pregnancy-focused mobile apps, however, content within such apps are not focused

around weight-related needs of pregnant women. A rarity among these apps is a method for tracking weight-gain during pregnancy or a healthy lifestyle tool targeted at women during pregnancy. Therefore, the potential of such mobile apps and their overall impact on GWG remains uncertain.

Few studies have considered the use of mobile apps for monitoring and intervening on GWG in pregnant women. In response to the gap in the literature, a group of researchers developed a mobile app called Eating4Two to provide pregnant women in Australia with real-time feedback on their weight gain throughout pregnancy with a GWG graph and nutrition library which included facts about nutrients, foods, menus, behaviors, and symptoms.[126] The app was pilot tested with 10 pregnant women following a demonstration of how to use the app and the different available functions within the user profile.[126] Feedback on the Eating4Two app was collected in focus group sessions, an online survey, and an interview in an effort to make improvements in the app design and functionality.[126] A major critique from participants of the Eating4Two app was the GWG graphing function that displayed ranges (based on IOM guidelines) but lacked absolute numbers, something that women felt would be a helpful feature in understanding their weight gain.[126] To date, this study was not tested in a larger clinical trial, but offers critical feedback for future GWG interventions through mobile applications.

A qualitative study of first-time mothers using mobile apps during pregnancy found that a major concern of participants was the source of health-related information that the app provided.[120] Unreliable sources or recommendations through such apps may have a significant impact on the health of the patient and baby, which is an important consideration for inclusion of online or mobile resources in health behavior or pregnancy

research.[120,125] First-time mothers also wanted to connect with others to obtain more information and receive social support.[120] Mobile apps and online resources can provide this service for women who would otherwise lack that social support or empowerment by creating a network[117] of pregnant women. One study found that women were more receptive to a mobile app for healthy GWG if it provided interactive resources such as a participant entering their current weight amount and receiving real-time feedback of gestation-specific information.[99,127] Since mobile apps for tracking GWG and maternal health are limited, it is important to pilot test features of a mobile app prior to full-scale interventions to determine what types of information and tools are most desired from the target population.[127]

2.4.d. Mixed Technologies

As technology has evolved, website content is readily available on mobile devices through website browsers or mobile app versions of the website content. A mixed-methods study in Australia analyzed formative research from focus groups of pre- and postnatal women and health care practitioners to guide the design of a website and mobile app offering pregnancy-related health information.[128] Pregnant women commented on the need for reliable resources, a concern shared by primary health care practitioners, and suggested physicians recommend reputable websites for women to seek information related to health topics during pregnancy.[128] After a year of implementation, reach and scope of the website and mobile app, *Ngala Healthy You, Healthy Baby (HYHB)*, was analyzed.[128] The website and mobile app were designed to provide prenatal patients with personalized tools for tracking weight, diet, physical activity, emotional wellbeing, and sleep patterns specific to their gestational age, and served as resource hub of clinically appropriate online resources.[128] Hearn et al. (2014) found that the mobile app was a tool

that helped engage pregnant patients with evidence-based online resources and track GWG, while the website served as a more comprehensive, detailed, and more frequently accessed resource about which was determined by page views.[128]

The feasibility of mHealth lifestyle interventions in pregnancy is understudied. In a qualitative analysis of views of women and health professionals on the use of mHealth interventions during pregnancy, a study found that both groups agreed mobile phones would be a good access point in pregnancy, but expressed concern over the reliability of information provided and a need for evidence-based sources for content available through mHealth interventions.[114] Similarly, another group of researchers published their study protocol for a randomized controlled trial in Dublin that focuses on pregnancy, exercise, and nutrition using a smart phone app, but there has been no data provided regarding the feasibility and acceptability of their app to date.[129]

2.5. Significance

2.5.a. Rates of Overweight and Obesity Among Pregnant and Postpartum Women

Women of childbearing age are more likely to be overweight or obese than normal weight[53] and rates of overweight and obesity are increasing among pregnant and postpartum women.[36,130] Most women gain an excess amount of weight during their pregnancies,[2] which can lead to postpartum weight retention.[43,84,86] Obesity is a serious public health problem that burdens our health care system. Through behavioral interventions, we may be able to empower women with the appropriate knowledge and skills to reduce rates of overweight and obesity among pregnant and postpartum women.[23,45,82,84,90,95]

2.5.b. Adverse Maternal and Infant Health Outcomes

GWG is a modifiable factor that may significantly reduce adverse maternal and infant health outcomes.[2,131,132] Adverse maternal health outcomes associated with entering pregnancy overweight or obese and/or gaining an excessive amount of weight during pregnancy include: gestational diabetes, hypertension (including preeclampsia and eclampsia), labor and delivery complications, postpartum weight retention, postpartum depression, lactation challenges, subsequent maternal obesity, and increased risk for type 2 diabetes and cardiovascular disease.[39] For the infant, there are both short- and long-term health consequences associated with excessive gestational weight gain during pregnancy that include: preterm birth, fetal growth, infant mortality, birth defects, birth weight, stillbirth, neonatal body composition, infant weight gain, breastfeeding initiation and maintenance, childhood obesity, type 2 diabetes, and neurodevelopment.[39]

2.5.c. Promising Avenues for Technology-Mediated Health Behavior Interventions

This proposed research project contributes to health behavior science and technology-mediated interventions. Numerous studies[72,73,98,111,121,123,124,126,133–137] have used technology-mediated dissemination such as text messaging, email, and websites for addressing health during pregnancy; however, this study will add to the literature by using a commercially available, group-based mobile app (MakeMe[35]) to connect and form social networks of currently pregnant women in the United States working towards similar weight-related goals. Additionally, this study will include podcasts for behavioral reinforcements, targeting theoretical constructs like behavioral capability, knowledge, and social support, and will analyze the impact of the technology-mediated components on gestational weight outcomes, which was a limitation of several previously conducted studies. The development of HM2B intervention components will target different

theoretical constructs to enhance behavioral expectations (i.e., self-efficacy and knowledge), social influence (i.e., network support and self-esteem/validation) leading to behavioral intention and motivation to change.

2.6. Innovation

This research is innovative in several ways. First, current modes of delivering health behavior interventions are costly and may be limited in reach and scope. Weight counseling may be limited by physician accessibility, availability, or capacity.[108,138,139] Technology offers a scalable solution to this problem, so this intervention will be completely remotely-delivered, allowing for a greater reach of pregnant women living in the United States. By using a commercially available mobile app and group-based health behavior challenges, this project will reduce costs associated with one-on-one health coaching, time and personnel to deliver in-person interventions, and accessibility and availability issues often mentioned as a barrier to recruitment and retention efforts.[140]

Second, this intervention will employ social support strategies by grouping pregnant women into small groups assigned with a weekly weight-related health goal. Social support during pregnancy has been associated with a reduction in anxiety and postpartum depression.[141,142] Social support provided through this intervention may also provide women a sense of accountability in meeting weekly health behavior challenges.

Anticipated limitations of this study include reaching an ethnically and geographically diverse sample of pregnant women as well as retention, adherence, and dropout over the program period (enrollment at <20 weeks through delivery). We may also recruit women who are have higher behavioral intention to change health behaviors using technology compared to the general population, since recruitment methods will strongly rely on online social network advertisements. Furthermore, this study may be

limited in collecting objective measures of weight for participants due to the nature of the intervention being remotely delivered and recruitment through social networks and not targeted OB/GYN clinics which could potentially grant access to medical record abstraction.

2.7. Summary of the Current Status of Problem

To summarize the literature reviewed in this section, it's evident that pregnancy is a critical time point to intervene and engage with women on health topics related to weight to reduce long-term impacts of obesity during pregnancy on chronic conditions and adiposity among mothers and children. Overweight and obese participants with fertility issues have been noted as having high dropout rates in lifestyle intervention programs, which may be another limitation to these types of studies.[56] Moreover, the literature suggests that excessive GWG prevention during a woman's first pregnancy might be beneficial for reducing postpartum weight retention and beginning subsequent pregnancies at a higher BMI.[44]

Several studies reviewed in this section also reported a lack of diversity among samples. Findings of the reviewed interventions rarely included race/ethnicity outcomes and noted predominantly white, educated samples.[45,85,90,91] A few of the studies examined income level related to GWG and adverse health outcomes.[45,143] Overall, the studies were not diverse or generalizable outside of their sample demographics. This is an important consideration when examining weight-related health behaviors, GWG outcomes, and practice implications since certain demographics are at increased risk for overweight and obesity.[74] While including an diverse sample in weight-related interventions may expand the generalizability of findings, it may also increase variability in outcomes because of

how GWG may be experienced by different race/ethnicities,[74] income,[45,106] or education levels.[53]

Specific nutrient guidelines were rarely mentioned in the intervention description of the studies with the exception of one study that provided individualized macronutrient targets.[82] Almost all studies that provided individualized counseling mentioned the importance of continued support and access over a one-time or brief introduction to GWG and nutrition.[82,88] There was a lack of theoretical models used to guide the interventions[71] and the inconsistent inclusion of physical activity within the interventions[89] added limitations to determining best practices for weight management during pregnancy.

Based on the comprehensive review of literature regarding technology use for disseminating weight gain recommendations and nutrition information during pregnancy, the following gaps were determined: lack of available theory-driven mobile apps for pregnant women to track GWG,[28,126,128] lack of U.S.-based studies[122–124,126,128] and as a consequence, lack of diversity in the samples, need for provider buy-in for online and mobile resources,[17,99] inclusion of interactive resources within the technology-based resources,[99] need for detailed GWG graphs and recommendations within the resources,[126] and lack of randomized controlled-trials investigating the use and impact of online and mobile resources for monitoring GWG.

In conclusion, the literature does not provide a solution for addressing the growing prevalence of overweight and obesity and excessive GWG across a broad population. From a health promotion standpoint, it's important to consider intervening on women with an overweight or obese pre-pregnancy BMI to prevent excessive weight gain

and potential postpartum weight retention to reduce the prevalence of overweight and obesity among women of childbearing age.[74]

Since most of the studies in this literature review suggested weekly interaction with women had the greatest impact, considerations for logistics and roles of health care practitioners need to be made. To avoid health care practitioner burden,[128] technology-based dissemination on a consistent basis during pregnancy may alleviate the demand on health care clinics and provide greater access to hard-to-reach populations,[109] as well as reduce the costs for treating adverse health outcomes associated with starting pregnancy at a high BMI and gaining an excessive amount of weight during pregnancy. Once a comprehensive program is implemented, the role of race/ethnicity can be assessed as well as income level and education attainment. Understanding these factors will help determine how certain populations may require additional support or intervention. The concern for and impact of excessive GWG will not be reduced without the help of thoughtful, feasible, and effective health promotion interventions.

Chapter 3: Methods

This chapter presents methodological approaches for each specific aim outlined in Chapter 1. A summary table of data analyses performed by specific aim hypotheses is provided at the end of the chapter (Table 3.1).

3.1. Overview

The Healthy Motivations for Moms-To-Be (HM2B) project builds on the Health in Pregnancy and Postpartum (HIPP) Study, funded by an NIH R01 (PIs: Wilcox/Liu), in which participants with overweight and obesity located near Columbia, Charleston, and Sumter, SC receive an individualized nutrition and PA education intervention, targeted weight and activity recommendations aligned with the IOM guidelines, and a series of behavioral reinforcements to encourage nutrition and PA during pregnancy and postpartum.[133] HIPP recruitment proved to be challenging due to the intervention time commitment of mothers attending 10 two-hour group education sessions weekly during their pregnancy. Due to this challenge, the intervention was adjusted to two in-depth counseling sessions (one in early pregnancy and one in early postpartum) and telephone counseling that started in early pregnancy and continued through 6 months postpartum.[133]

Using a remotely delivered platform for intervention delivery to scale up traditional in-person intervention methods, the HM2B study used components (i.e., podcasts) and strategies (i.e., goal setting) of the HIPP intervention. The completely remotely delivered platform allowed for dissemination to pregnant mothers across the United States. There are limited lifestyle interventions using evidence-based mobile apps

available for nutrition and PA during pregnancy,[26–28] and technology-mediated interventions may alleviate the burden on physicians and clinical staff in providing weight counseling and monitoring health status of patients.[21,138,144,145] If successful at reducing the proportion of women who exceed IOM guidelines for gestational weight gain, we plan to test this with a large-scaled sample to examine its effectiveness.

3.2. Study Setting

The study setting for this project was to be remotely delivered through social media (specific aims 2-3), mobile apps (specific aim 3), email (specific aims 2-3), and websites (specific aim 3) to pregnant women living in the United States. Eligible participants for the intervention (specific aim 3) must have owned a smartphone and were willing to download the commercially available MakeMe mobile app,[35] the setting for social interactions among group members. Additionally, participants must have provided a valid email address to receive study updates.

3.3. Aim 1: Systematic Review

The purpose of Aim 1 was to conduct a systematic review of technology-mediated interventions targeting GWG supported by mobile apps, websites, text messaging, DVDs, telephone calls, emails, social media, Wi-Fi enabled bathroom scales, and wearable activity trackers. Understanding how technology was used as a delivery mode or behavioral tool in prior GWG interventions was important to guide the development of the HM2B intervention.

3.3.a. Search Strategy

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used as a methodological template for this review.[146] Three broad search terms were identified to reflect the aim: technology, pregnancy, and

gestational weight gain. The comprehensive list of search terms is provided in Table 3.2. These terms were used to identify potential articles for review from the PubMed and Web of Science databases. Medical Subject Headings (MeSH) were used to capture all related search terms within the vocabulary of indices in PubMed.[147] A meta-analysis of GWG outcomes was not conducted due to variability in the methodologies used.

3.4. Aim 2: Needs Assessment

The purpose of this aim was to conduct a needs assessment of pregnant women's weight-related knowledge and sources for prenatal care information, and to identify interests in e-health intervention features targeting the prevention of excessive GWG to inform the development of a randomized controlled trial.

3.4.a. Data collection

In April 2016, a convenience sample of pregnant women (n=329; recruitment goal=100) were recruited through social media sites (i.e., Facebook and Twitter) to participate in a one-time online survey regarding weight-related knowledge, pregnancy-related information sources, and interest in potential e-health intervention features. Posts on social media were developed as the primary recruitment method based on the success of prior interventions seeking a large convenience sample of women.[140,148] Funds for recruitment were not available for this needs assessment; therefore, low-cost sampling methods were critical.[148] The recruitment text was shared on the research teams' personal Facebook and Twitter profiles using specific hashtags (i.e., #pregnant) to publicly appear in social media users' search for related topics. The recruitment text asked viewers to share the post within their networks to extend the organic reach of the post. Lastly, pregnancy-related groups, doulas and OB/GYN Facebook pages in major cities across the U.S. were identified and messaged with a request to share the recruitment text.

3.4.b. Measurement

The survey was hosted on SurveyGizmo.com under a password protected account. Interested participants were first prompted to read and sign an informed consent form (Appendix A). Next, a brief 4-item eligibility screening form was completed, and eligible participants were prompted to continue to the full survey (Appendix B). Women were eligible to participate if they met the following inclusion criteria at the time of the survey: pregnant, resident of the United States, between the ages of 20-35, and an owner of a smartphone. The survey included questions about sample demographics, weight-related information, health-related topics discussed with health care practitioners during prenatal appointments, resources used for seeking health-related information, interest in pregnancy health-related podcasts, and interest in mobile apps for pregnancy health-related challenges and content. Some of the questions used in this survey were adapted from the Center for Disease Control and Prevention's (CDC) Pregnancy Risk Assessment Monitoring System (PRAMS).[149] Participants who completed the survey were entered into a raffle drawing to receive one of six $25 Amazon.com gift cards. On average, the survey took 13 minutes to complete.

3.4.c. Data Analysis

Using BMI, participants were categorized as underweight/normal weight or overweight/obese. Participants' perceived healthy amount of GWG was coded as "below," "within," and "above" IOM recommendations based on participants' pre-pregnancy BMI. Chi-square analyses were used for examining the needs and interests of participants by parity, race/ethnicity, and BMI classification. One-way ANOVA and Tukey HSD post-hoc tests were used to test differences between the dependent (needs and interests) and independent variables (parous state and BMI). All models controlled

for age, gestational age, race/ethnicity, marital status, employment status, relationship status, and education. Data were analyzed using IBM SPSS Statistical Software Version 64.[150] The statistical significance value was set at $p<0.05$.

3.5. Aim 3: HM2B Intervention

The purpose of Aim 3 was to develop and assess the impact of a mobile health intervention on GWG of pregnant women. HM2B was a randomized controlled trial with an intervention group targeting healthy eating and physical activity (HEPA) behaviors while a comparator condition received content related to stress reduction and management (SRAM). HM2B used digital technologies for all study procedures (e.g., recruitment, enrollment, data collection, intervention delivery, and distribution of incentives). The Institutional Review Board at the University of South Carolina approved the outlined activities in the informed consent (Appendix C).

3.5.a. Recruitment

A voluntary response sample of pregnant women living in the United States were recruited through paid, targeted advertisements on Facebook and Twitter (Appendix D) to complete an online screener for eligibility (Appendix E). Eligible participants were in early pregnancy ($\leq$20 weeks), between the ages of 20-35, residing in the United States, with a pre-pregnancy BMI classification $\geq$ 18.5 kg/m^2. In order to estimate a sample size with significant power, we selected a study that compared the rate of overweight and obese women in an intervention and control group exceeding IOM guidelines.[78] Other studies included normal weight women in their sample, which limited the available studies to base our power calculation off of. In this particular study by Petrella et al. (2014) the sample size was 61 participants with 33 participants in the intervention group and 28 in the control group.[78] Their study was powered on the hypothesis that the

intervention would reduce the rate of women exceeding IOM guidelines by 50%.[78] A two-tailed z-test of proportions was employed to estimate the sample size required to have statistically significant power (80%) based on the finding that gestational weight was gained within IOM guidelines for the intervention (66.7%) and control (39.2%) groups[78] for an estimated sample size of 98, with 49 participants assigned to the intervention and comparison groups each. Accounting for 20% attrition, recruitment aims were approximately 118 participants (about 60 per group).

Eligible participants were asked to complete the baseline questionnaire prior to randomization (Appendix F). Once completed, participants were randomly assigned to one of two intervention conditions for the duration of the study. Randomization was stratified by the dichotomous pre-pregnancy BMI value to ensure equal representation of BMI across the conditions. After randomization, participants were provided orientation materials (Appendix G) to download the mobile app and website. This orientation process was strategically placed after randomization to ensure that the website content was appropriate for the respective HEPA or SRAM group. Additionally, during the orientation process, participants were asked to verify their baseline weight by uploading a photo of their scale display to the mobile app. Once the onboarding process was completed, participants were eligible to begin receiving the group-based intervention components.

3.5.b. Intervention Description

For twelve consecutive weeks, participants were asked to connect with other pregnant women through a mobile app to work towards healthy behavioral goals. The time frame for the group-based component was restricted to 12-weeks to prevent participant drop-off within the teams as delivery dates approached. Additionally, there

was an individualized component of the study where participants accessed a study website from baseline through delivery. To assist with maintenance of behaviors, participants were encouraged to use the individualized website through delivery. Descriptions of the group-based app component and individualized website are provided in this section.

3.5.b.1. MakeMe Mobile App

Participants used a commercially available, free mobile app through iTunes and GooglePlay marketplaces called MakeMe.[35] The app uses group-based challenges to reach a common, customizable goal. In addition, the intervention used a mobile-friendly website created for this study. Participants enrolled in the intervention study were asked to create a profile on the MakeMe app.[35] Participants were then randomly assigned to a group of 8-10 participants and when a group was "full," participants in the group received a challenge code via email to enter into the MakeMe app (Figure 3.1). The groups of participants remained the same throughout the study to provide a consistent support system. Within the app, participants were able to log their activities, post text or photos on a group feed, and send a "bump" of positive reinforcement to a group member for their activities.

The weekly challenges were predetermined and the same topic for all participants in their respective groups (intervention and comparison) each week, regardless of gestational age. The health behavior challenges focused on healthy eating and physical activity for the intervention groups and non-diet/PA challenges for the comparison groups (i.e., stress reduction and stress management) (Table 3.3). A total of 12 weekly challenges were predetermined for each condition and used on a rolling basis, so that

regardless of when a team was formed, all teams in the respective condition would be on the same schedule for challenges.

The research team set up the weekly challenge via the MakeMe app and included the specific custom challenge task, the start date and duration of the challenge (one week), the frequency of the challenge (number of times per week), and the consequence for not making the challenge (Figure 3.2). Regarding the consequence feature that was built into the MakeMe app, a constant "tell us why" consequence was used to encourage participants to share their struggles and barriers to behavior change. The start date for each challenge was set for Monday and participants were challenged to complete the task on five of the seven days in the assigned week.

Participants were asked to log when they "Make" a challenge. When a participant completed the challenge on all 5 of the 7 days, they received one HM2B point. If they attempted but did not meet the challenge on 5 of the 7 days in the given week, they received half a point. These points were tracked by trained research assistants and entered into the study website every Friday to encourage cross-group competition and motivation for health behavior change.

3.5.b.2. HM2B Website

In addition to the MakeMe app, the participants used a mobile-friendly, study-specific website with a personalized profile to access content using a unique ID and password (Figure 3.3). The website was constructed by a team of programmers at the TecHealth Center at the University of South Carolina. The website hosted GWG outcome tracking tool (e.g., GWG or stress level), study forms, a leaderboard of all team points achieved in the weekly challenge, weekly pregnancy tips and resources, and

informational and theory-grounded podcasts targeted to the intervention or comparison group health behavior topics, and contact information for the research staff (Figure 3.3).

Participants in the intervention group received website content around achieving adequate GWG through HEPA behaviors. The GWG graph was personalized using baseline survey data including pre-pregnancy BMI, gestational age, and photo-verified weight at baseline. The research team entered this information into the user profile on the back-end to generate an appropriate GWG chart with accurate IOM recommendations based on pre-pregnancy BMI and weekly rate of weight gain. To track GWG, participants were reminded via email to weigh in (Figure 3.4) through the study website weekly. Once a participant in the intervention group logged her weight, the GWG chart appeared with all previous and most recent data points plotted along the upper and lower recommended amount of GWG, according to IOM guidelines (Figure 3.4). The 10 podcasts were available for participants to listen to at any time and were adapted from the HIPP study and focused on HEPA topics and strategies for overcoming related barriers in pregnancy (Table 3.4).[133]

Website content was focused on stress reduction and management (SRAM) topics for the comparison condition. Comparison group participants did not have access to the weigh-in page or a GWG chart on the website. Instead, they were prompted with a stress scale measure to log their perceived level of stress from 0-10, “not at all stressed” to “extremely stressed.” There were 10 podcasts available on the website that were modified from freely available guided relaxation and meditation podcasts online (Table 3.4).

Both groups had access to a leaderboard which listed out the top teams for each weekly challenge. Individual points earned through the weekly behavioral challenges

were not displayed in the HM2B website chart, only group-level data. Furthermore, participants in the HEPA condition were unable to access the SRAM materials on the study website and vice versa.

3.5.c. Measurements

Aim 3 included five measurement components: screening eligibility questionnaire (see Appendix E), baseline survey (see Appendix F), photo-verified weight collection, a final survey administered at the end of the 12 behavioral challenges (see Appendix H), and a delivery outcomes survey administered between 1-4 weeks postpartum (see Appendix I). The eligibility questionnaire screened for participants who met the inclusion criteria: currently within early pregnancy ($\leq$20 weeks gestation), pre-pregnancy BMI greater than 18.5 kg/m^2, resident of the United States, between the ages of 20-35, ownership of a smartphone, agreement to use the smartphone to participate in study activities, and access to a scale for weekly weigh-ins. The questionnaire also screened out participants who met exclusion criteria for participation in the study.

We employed the same exclusion criteria that was utilized in the HIPP study, which included incompetent cervix; multiple gestation; fetal anomaly; uncontrolled hypertension, type 1 diabetes, or thyroid disease; being hospitalized for a mental health or substance-abuse disorder in the past 6 months; persistent bleeding in the 1st trimester; history of 3 or more consecutive first trimester miscarriages; past history of anorexia and bulimia; current eating disorder; actively suicidal; prior or planned bariatric surgery; continued use of weight loss medication; and any physical disabilities that prevent her from exercising.

Several of the assessment methods are derived from existing survey tools such as Behavioral Risk Factor Surveillance Survey,[151] Pregnancy Risk Assessment Monitoring

System (PRAMS),[152] Leisure Time Activity Questionnaire,[153] Rapid Eating and Activity Assessment for Participants-Short (REAP-S),[154] and the Behavior, Environment, and Changeability Survey (BECS).[155]

The baseline survey included questions on the following:

- participant demographics (age, race/ethnicity, household income, employment status, educational attainment, etc.) (BRFSS, PRAMS),
- weight-related knowledge (recommended weight gain for pre-pregnancy BMI) and behaviors (self-weighing frequency) (PRAMS),
- physical activity levels (typical week estimate of time spent doing strenuous, moderate, and mild exercise) (Leisure Time Activity Questionnaire, REAP-S),
- dietary assessment of weekly eating habits and meal related activities (REAP-S),
- levels of perceived social support for healthy eating and exercise,[156]
- perceived confidence to change exercise behaviors,[156]
- motivation to change eating and exercise behaviors,[155,157]
- and resources used for pregnancy health-related information.

Body Mass Index was calculated using self-reported height and pre-pregnancy weight, as well as photo-verification of participant weight at three time points: baseline, 32-weeks, and postpartum. Height was reported in feet and inches and weight in pounds. These values were converted to a BMI score using the following standard equation: BMI=[weight (lbs.) / height (in.)^2]x703. This value was kept as a continuous variable

(raw BMI score) for correlation analyses and converted to a dichotomous value (normal or overweight/obese) for logistic regressions and chi-square analyses.

The final intervention survey included the same items as the baseline survey, plus an additional set of questions to assess participants' experience with the following intervention components: usability of the mobile app, weekly challenges, and group-based interactions and features (perceived social support from teammates, points achieved, and "bumps" of positive reinforcement shared). Lastly, the delivery outcomes form collected after delivery requested birth outcome data such as the baby's length, weight, birthdate, gender, presence of macrosomia, small- or large-for-gestational-age, delivery method (vaginal versus cesarean), and interest in future studies.

Since the intervention itself includes the use of the mobile app MakeMe, trained researchers tracked weekly activity by entering participant engagement, points earned, and challenges completed. The podcasts and weekly tips for having a healthy pregnancy were hosted on the study website which tracked participant views by participant ID.

3.5.d. Data Analysis

Data were analyzed using SPSS statistical software.[150] Intervention outcomes were assessed in a variety of ways. Gestational weight gain is a primary outcome and was defined in two ways for our analyses: adequate, inadequate, and excessive GWG in regard to IOM guidelines and total gestational weight gain (pounds) from pre-pregnancy weight to delivery. Weight gain was computed as delivery weight minus self-reported pre-pregnancy weight and then used in an independent samples t-test to determine significant differences in mean amount of weight gained by the intervention and comparison groups, and weight class (overweight compared to obese). Large for gestational age (LGA) was coded as a dichotomous variable indicating yes or no for the

birth outcome. For **hypothesis 3a1**, a variable of meeting IOM guidelines (adequate, inadequate, and excessive) was tested using an ANOVA analysis of intervention and comparison groups to determine the differences in the proportion of women with GWG within IOM guidelines. Additionally, paired samples t-tests was conducted to test **hypothesis 3a2:** motivation to change behaviors (i.e., healthy eating, sleep, physical activity) will be significantly increased from baseline to delivery through the group-based challenges of the respective groups. Descriptive statistics were used to summarize BMI and demographic characteristics of the sample, feedback from the participants regarding overall enjoyment, ease of use of the app, and quality of the challenges and podcasts. Finally, birth outcomes were analyzed using independent samples t-tests analysis to test **research question 3a3:** did birth weight outcomes significantly differ between intervention and comparison groups?

Regarding usability and feasibility of the HM2B intervention, engagement was summarized as a total score for each independent participant, and then averaged for the intervention and comparison groups. A linear regression model was computed to test **hypothesis 3b1:** the mean engagement, satisfaction, and intent to continue use scores will not differ significantly between the intervention and comparison groups, indicating overall interest in using the mobile app and participating in a mobile health group-based challenge, regardless of health topics. Similarly, linear regression models will test **hypothesis 3b2:** the level of engagement in the group-based challenges will be significantly negatively associated with amount of weight gained in the intervention group versus the comparison group. Logistic regression models were used to test **hypothesis 3b3**: the number of podcasts listened to and overall engagement score will be

significantly positively associated to meeting IOM guidelines for the intervention group participants versus the comparison group. If applicable, we will control for individual characteristics such as age, pre-pregnancy BMI, race/ethnicity, etc.

Descriptive statistics and chi-square analyses will be used to summarize participant feedback by BMI and parity regarding **research question 3b4**: did participants find the mobile app user-friendly and **research question 3b**: which topics and challenges were participants most interested in related to behavior change.

Table 3.1. List of research hypotheses and analyses conducted

Aim	Hypothesis/Research Question	Measure	Statistical Test
1: Systematic Review	1a: What types of technology are used in the prevention of excessive GWG during pregnancy and which platforms are the most common?	Existing literature	Descriptive statistics
	1b. What are the behavioral strategies and features used in technology-mediated interventions (such as weight tracking or social networking features) for promoting healthy GWG?	Existing literature	Descriptive statistics
2: Needs Assessment	2a: Pregnant women who do not report receiving GWG recommendations from their health care practitioners will report a greater total amount of weight gain they believe is appropriate for pregnancy compared to women who report receiving weight gain recommendations from their providers.	PHRAMES Survey - PRAMS physician topics discussed at prenatal appointments - Estimated appropriate GWG	Chi-square
	2b: Overweight and obese pregnant women will show significantly greater interest in using a mobile app for tracking gestational weight gain compared to normal weight pregnant women.	PHRAMES Survey - BMI from self-reported height and weight (BRFSS) - Interest in eHealth components	Independent samples *t*-test
	2c: What are participants' levels of interest in using a mobile app for communicating with other pregnant women, using a mobile app for tracking weight gain, receiving weekly group-based challenges related to healthy eating and physical activity, listening to pregnancy health-related podcasts?	PHRAMES Survey - Interest in eHealth components	Descriptive; ANOVA (race/ethnicity, parity, BMI)
	2d: What sources of information do pregnant women in the US rely on most often for nutrition and physical activity related content?	PHRAMES Survey - Recall question for resources used in current pregnancy	Descriptive; ANOVA

			(race/ethnicity, parity, BMI)
3: Intervention Outcomes	3a1: The intervention group will have lower total GWG and a greater proportion of women with total GWG within IOM guidelines versus the comparison group at delivery.	Delivery outcomes survey (self-reported weight) - Computed as adequate, inadequate, and excessive GWG	Chi-square
	3a2: Motivation to change behaviors (i.e., healthy eating, sleep, physical activity) will be significantly improved through the group-based challenges of the respective groups.	Baseline and final surveys - Motivation to change - REAP-S measure	Paired samples *t*-test
	3a3: Did infant birth weight significantly differ between intervention and comparison groups?	Delivery outcomes survey (self-reported infant measures)	Independent samples *t*-test
	3b1: The mean engagement, satisfaction, and intent to continue use scores will not significantly differ between the intervention and comparison groups indicating overall interest in using the mobile app and participating in a mobile health group-based challenge, regardless of health topics.	User engagement scores calculated from: - Participation in weekly challenges - Outcome tracking (GWG or stress) on the study website - Podcast downloads - Weekly tip link clicks	Independent samples *t*-test
	3b2: The level of engagement in the group-based challenges will be significantly negatively associated with amount of weight gained in the intervention group versus the comparison group.	Team engagement scores calculated by average user scores	Linear regression
	The number of podcasts listened to and overall engagement score will be significantly positively associated with meeting IOM guidelines for the intervention group participants versus the comparison group.	User engagement scores; Delivery outcomes survey (self-reported weight) - Computed as adequate, inadequate, and excessive GWG	Logistic regression
	3b4: Did participants find the mobile app user-friendly?	Final survey - Program feedback	Descriptive

	3b5: Which topics and challenges were participants most interested in related to behavior change?	Final survey - Program feedback	Descriptive

Table 3.2. Systematic Review Search Terms

Technology	**Pregnancy**
Technology [MeSH]	Pregnancy [MeSH]
Information science [MeSH]	Pregnant
Information systems	Prenatal
Telecommunications [MeSH]	Perinatal
Cell phone	**Weight**
Mobile applications	Body Weight [MeSH]
Mobile apps	Body Mass Index
Mobile app	BMI
Text message	Weight gain
Internet [MeSH]	Gestational weight
SMS	Gestational weight gain
Texting	Lifestyle
Telemetry	**Miscellaneous terms**
Electronic Mail	mHealth
Email	Accelerometry
Website	Actigraphy
Social media	Podcast
Twitter	Video
Facebook	Wearable
MySpace	
LinkedIn	
Instagram	
Pinterest	

Table 3.3. List of the group-based behavioral challenges for participants

HEPA weekly challenges	**Example daily subtext for group discussion**
1. Prepare a healthy dinner	What choices did you make to have a healthy dinner?
2. Engage in intentional physical activity for 20+ minutes	Tell the group what activity you did and how many minutes you were active!
3. Check out the nutrition label on your food	Measure out one serving size of a food item and upload a picture. Do you usually eat less or more than this serving?
4. Engage in intentional stretching for 20+ minutes	Focus on stretching your muscles daily. Tell the group where you feel the most aches and pains.
5. Prepare a healthy lunch	Here's the MyPlate guide for a balanced meal. How does your lunch compare?
6. Aim for 20+ minutes of physical activity	What are some of the challenges you're experiencing with staying physically active during pregnancy?
7. Eat the most colorful meal you can today	Fruits and veggies are a quick way to add color to your meal! What colors do you need to add in from the rainbow?
8. Engage in cardio exercise	What are some ways you can add in more steps during the day?
9. Prepare a healthy breakfast	Fiber is an important nutrient and can help relieve constipation during pregnancy. What breakfast foods do you enjoy that are high in fiber?
10. Set a HEPA goal for yourself	Are your goals S.M.A.R.T? (Specific, measurable, achievable, realistic, and timely)
11. Aim for 5 servings of fruits/veggies	What ideas can you share for adding in more fruits or vegetables during the day?
12. Aim for 12 cups of water	What strategies do you use to replace sugary sweetened beverages with healthier choices?
SRAM weekly challenges	**Example daily subtext for group discussion**
1. Share a gratitude journal entry	Tell us something you're thankful for today.
2. Phone a friend	Who do you rely on for emotional support?

3. Prepare for tomorrow	Share a method you use to keep track of the things you need to get done each day.
4. Declutter a space you've been avoiding	It can be your email, a junk drawer, a closet, etc! We love before and after pics!
5. Take a mindful moment and reflect on your day	Focus on something good that came out of your day and share with the group!
6. Be helpful to someone else	What are some things you anticipate needing help with once the baby arrives?
7. Take a 20-minute technology break	Tell the group what you did with your 20 minutes of technology free time!
8. Set a bedtime and track your sleep	Tell your group about the quality of sleep you've had lately
9. Stressed out? Tell us about it.	Talk about your stressors and how you've been handling the stress during your pregnancy.
10. Set a healthy goal for yourself.	Share a short-term health goal with the group!
11. Treat Yo'Self!	Self-care is important. Share some ideas with the group for reserving “me time” when the baby arrives.
12. Listen to music/podcasts	Have you listened to the HM2B podcasts on the website?

Table 3.4. List of podcast topics by intervention condition

HEPA Podcast Topic	Podcast Length
1. Basics for HEPA during pregnancy -MyPlate introduction/food groups -Healthy GWG -Exercise safety	17:45
2. Goal setting -Pedometer/tracking exercise -Focus on fruits and vegetables	20:08
3. Problem solving -Focus on whole grain -Myths and realities of HEPA in pregnancy	24:08
4. Breastfeeding	20:04
5. Social support -Meal planning -Focus on protein	22:17
6. Dealing with emotions -Shopping on a budget -Exercise intensity	17:01
7. Handling stress	29:03
8. Time management -Reading nutrition labels	21:17
9. Preventing relapse -Healthy meal options at restaurants	17:40
10. Preparing postpartum -Healthy snacks and beverages -Recap of nutrition topics	26:25
SRAM Podcast Topic	**Podcast Length**
1. Deep belly (bump) breathing	08:27
2. Hammock of relaxation (guided)	11:19
3. Stepping out of emotions that overwhelm you	10:51
4. Meditation to let worries and stress drift away	11:04
5. Increasing happiness and joy	09:31
6. Finding balance in life	09:08
7. Releasing anger and irritation	10:59
8. Get more confidence… NOW!	12:07
9. Energizing meditation	11:52
10. Doors of choice	12:03

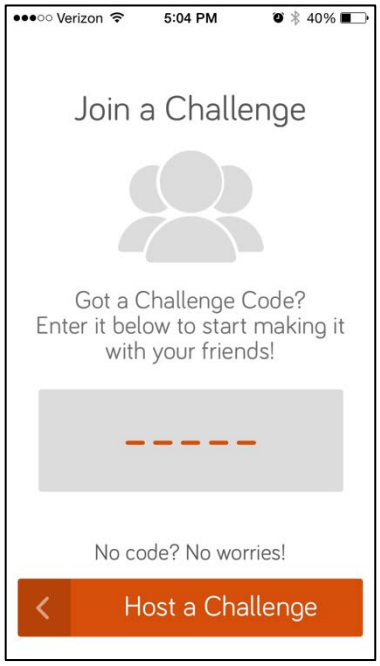

Figure 3.1. Screenshot of the MakeMe app home screen where participants can join the challenge by entering a five digit code

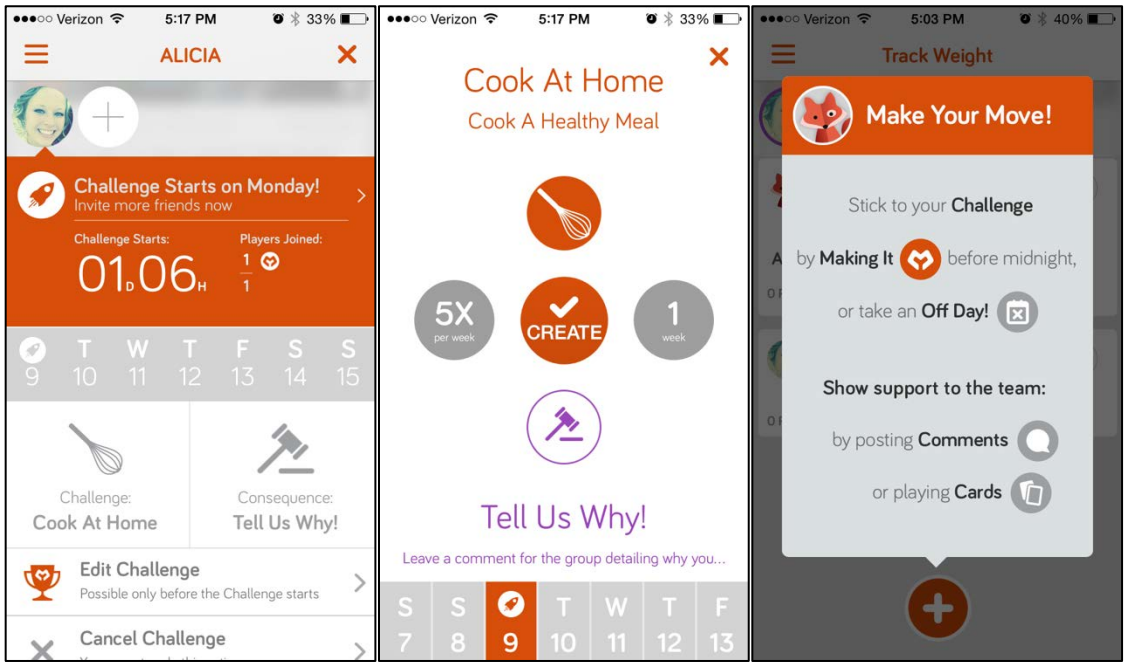

Figure 3.2. MakeMe app features and user-end screenshots of challenge participation, starting with a home page, description of the challenge, and log prompt.

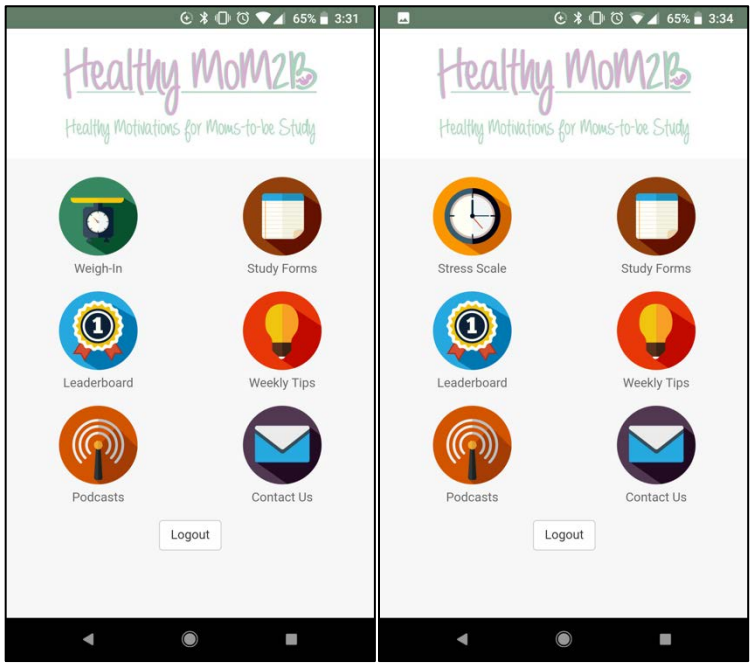

Figure 3.3. HM2B website user-end screenshots of the home screens for HEPA and SRAM, respectively

Figure 3.4. HM2B weigh-in screens for the HEPA intervention group participants only

Chapter 4: Results

4.1. Tapping technology for interventions targeting healthy gestational weight gain: A systematic review

Prepared for: *Obesity Reviews*
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ABSTRACT

INTRODUCTION: Nearly half of the pregnant women in the U.S. exceed the Institute of Medicine's recommendations for healthy gestational weight gain (GWG). Technology-mediated health interventions serve as a readily accessible resource for delivering pregnancy weight-related information and monitoring behaviors. This systematic review assessed the methodological designs and impact of technology-mediated interventions for the prevention of excessive GWG.

METHODS: From July 2016 through September 2017, PubMed and Web of Science databases were searched for randomized controlled trials (RCTs) using technology to promote healthy GWG. RCTs were not restricted to U.S. populations. Three broad search terms were identified to reflect the aim: technology, pregnancy, and GWG.

RESULTS: Nineteen technology-mediated RCTs were selected for inclusion (four ongoing trials). Technology varied in type and dose across the studies. Telephone calls were the most commonly reported technology component (42.1%), followed by text messages (31.6%) and wearable activity trackers (31.6%). Interventions mainly included e-Health content that was informational (42.0%) or involved health coaching strategies (36.8%). Four studies reported significant GWG differences across the full sample in favor of the interventions, while eight showed no significant effect across the full sample. Differences in BMI subgroups were observed in three studies. Four studies have not reported GWG outcomes to date.

DISCUSSION: This review found variation in the technology components used, limiting the ability to draw conclusions about effective practices. Studies that are adequately powered, recruit diverse populations, and examine the effectiveness of technology-

mediated methods for lifestyle interventions are needed to guide future e-Health interventions and resources.

MANUSCRIPT

INTRODUCTION:

The prevalence of overweight (Body Mass Index (BMI) between 25.0-29.9 kg/m^2) and obesity (BMI greater than or equal to 30 kg/m^2) among reproductive-aged women has significantly increased over time, with nearly one in four (23.4%) women entering pregnancy obese.[132,158] Pre-pregnancy obesity among non-Hispanic black women (32.6%) and Hispanic women (25.2%) of child-bearing age is higher compared to non-Hispanic white women (21.8%).[158] Furthermore, women of higher income households are less likely to be obese than those of low income households.[159]

These disproportional rates are concerning because women who enter pregnancy overweight or obese are at increased risk of excessive gestational weight gain (GWG) and postpartum weight retention compared to women with healthy weight.[7,8,39] While pre-pregnancy obesity is a risk factor for excessive GWG, nearly half (48%) of all pregnant women in the United States exceed the Institute of Medicine's (IOM) 2009 recommendations for healthy weight gain during pregnancy.[39] Obesity is a growing public health problem, and pregnancy may be a critical period for reducing the prevalence of obesity and related risks among women and children.

Excessive GWG has been associated with adverse maternal health outcomes, such as increased risk of gestational diabetes and hypertensive disorders.[91,109,160] Additionally, risk for postpartum weight retention is higher among women who exceed IOM weight gain recommendations during pregnancy.[8,10,11,43] Previous studies examining excessive

GWG have also found unfavorable health outcomes among infants, such as preterm birth, large-for-gestational-age, cesarean delivery, and obesity expressed later in life.[13,36,52,161] Pregnancy is a transitional time for a woman and can serve as a "teachable moment" for health-related knowledge and behaviors. Several behavioral interventions targeting dietary and physical activity behaviors for healthy GWG have been conducted, but these studies have been characterized by small sample sizes, low participant recruitment and retention, and lack of diversity, leading to concerns about generalizability.[22,23,29,71,162]

Meanwhile, technology-mediated interventions have been proposed as a potential solution for expanding the reach and scope of such behavioral interventions.[72,99,137] Internet websites, text messaging, and mobile apps have been identified as viable resources for a diverse population of racial/ethnic and socioeconomic groups.[99,110] Data regarding use of technology among racial groups indicates that 98% of U.S. adult Hispanics own a cell phone, followed by 94% of whites and 94% of African American adults.[24] Similarly, there are minimal differences in the ownership of cell phones by income bracket, where 92% of U.S. adults with a household income of less than $30,000 a year own a cell phone, adding justification to the increased accessibility of phone-based health intervention efforts.[24] By contrast, smartphone ownership varies by income bracket, where 64% of adults earning less than $30,000 per year own a smartphone and 93% of adults making $75,000 or more annually own a smartphone.[110] While the availability and accessibility of technology presents a potential to scale-up intervention efforts, there are major considerations for addressing participation barriers associated with technology. For instance, lower income participants may not have consistent access

to a cell phone service, despite ownership of the device. An interruption in service may affect participation in a mobile health intervention.

In a 2014 systematic review of pregnancy weight-related interventions using technology, O'Brien et al. found seven interventions that used technology to deliver intervention components.[26] The integration of technology into health promotion interventions was fairly new and developing at the time of publication. Due to the increasing interest in technology-based interventions and outreach, new technologies (i.e., wearables), and additional interventions reporting data on GWG outcomes having been added to the literature base, another review is warranted. The aim of the current review is to explore the literature and methodologies around technology-mediated interventions for the prevention of excessive GWG during pregnancy. The outcome of GWG is a primary focus of this systematic review because traditional intervention methods targeting nutrition and physical activity have yielded promising but modest effects on the reduction of GWG by about 20%[22,23] but there is a need to identify more effective and sustainable approaches to intervention delivery. The goal of this review is to understand the uses of technology in eHealth interventions and to identify any strategies that have been effective at reducing GWG. The previous review by O'Brien et al. (2014) called for research investigating the acceptance of mobile health interventions across sub-populations.[26] Therefore, this review will also take an in-depth look at the demographics of participants enrolled in each of the RCTs using technology for intervention delivery.

METHODS:

Eligibility criteria

The eligible studies for this systematic review included RCTs where technology was used for intervention delivery and GWG was reported as an outcome. For the purposes of this review, technology was defined as a tool to remotely deliver intervention content or support the application of the intervention (landline or mobile phones, mobile apps, websites, DVD videos of intervention content, e-mail, or wearable activity trackers). The inclusion of studies was not restricted by country, sample BMI, or type of technology used for intervention delivery. Studies were excluded from the review if they did not include a pregnant human population, did not examine GWG, or were not RCTs. Relevant systematic reviews were excluded but were assessed in detail for additional manuscripts not captured by the search terms. Publications were excluded if they were not available in English language.

Search strategy

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used as a methodological template for this review.[146] Three broad search terms were identified to reflect the aim: technology, pregnancy, and gestational weight gain. The comprehensive list of search terms is provided in Table 4.1. These terms were used to identify potential articles for review from the PubMed and Web of Science databases. Medical Subject Headings (MeSH) were used to capture all related search terms within the vocabulary of indices in PubMed.[147] Several search parameters were used including: publication between 01/01/2002 and 09/31/2017, based on the increasing Internet usage among U.S. adults following the millennium,[24] only English

language articles, and studies using human subjects. Literature was collected, reviewed, and summarized from July 2016 through December 2017 by the first (AD) and second (MW) authors.

Study selection

The search produced RCTs, prospective and retrospective cohort studies, observational studies, feasibility studies, ongoing trials, and qualitative interviews. For the purposes of this review, we excluded any study that was not considered a RCT. Ongoing clinical trials were included in the review to guide readers to upcoming findings. A meta-analysis of intervention outcome data was not conducted due to the minimal number of eligible studies and varying populations, intervention methods, and measurements used within the studies.

Data collection

Eligible studies from the initial search were reviewed independently and in duplicate by AD and MW. Titles that did not represent the purpose of the review were discarded, as well as duplicate titles across the two databases. Following the selection of eligible titles, AD and MW assessed the abstracts to determine if the descriptions met the criteria for inclusion and full study review. In some cases, there were multiple abstracts representing data from the same project; these were assessed separately and only one publication representing the best matched data for this review was included. If inclusion status could not be determined by the details provided in the abstract, the full article was pulled for review. Additionally, study design papers were included in this review to provide the reader with a comprehensive list of past and current studies using technology in intervention methods for reducing GWG. AD and MW settled initial inclusion

disagreements through a second review and discussion until consensus was reached. Full publications were reviewed from the remaining eligible abstracts, and details were extracted for the tables and figures in this manuscript. As the full publications were reviewed, additional relevant studies were pulled from the reference list to assess for inclusion.

RESULTS:

Study inclusion

The process of reviewing and selecting articles for inclusion in this systematic review is detailed in Figure 4.1. Nineteen RCTs met the inclusion criteria of technology-mediated interventions targeting GWG. Four of the 19 RCTs (21.1%) were ongoing at the time of the search and outcome data were not yet published, but study characteristics are presented when available.[109,129,163]

Study characteristics

Inclusion criteria for the selected studies are detailed in Table 4.2. Several of the studies (n=9) were conducted in US-based populations and sample sizes varied from 33 to 1722 (median=54, mean=298).[84,98,134,136,163–167] The remaining ten studies were conducted in other high-income countries.[72,76,80,83,109,129,168–171] Singleton pregnancies were the requirement for twelve studies and three studies required participants to be non-smokers. One study included only women who were at increased risk of GDM during their current pregnancy.[76] Parity was only specified in one study, which recruited first-time mothers only.[170]

Participant characteristics

The pooled RCTs included a total of 4,814 pregnant women. Several studies outlined specific BMI inclusion criteria. The most commonly recruited sample was a combination of women with overweight and obesity.[76,98,109,129,134,136,164,166,170,171] Two studies provided the intervention to women with obesity only[72,80] and one study included women with normal pre-pregnancy weight only.[168] The race and ethnicity of the samples were reported in nine of the studies. Seven of the nine studies (77.8%) reported a white majority sample,[72,80,84,98,134,163,171] two had a black majority sample,[136,164] and one reported more Hispanic participants than any other racial/ethnic group.[165] Participant income and education were reported inconsistently across the studies; therefore, comparisons of sample income and education levels were not possible. Low income status was an eligibility criterion for one study by Herring et al. (2016).[164]

Gestational weight gain

Total gestational weight gain

The primary outcome of interest for studies included in this systematic review was GWG. Table 4.3 provides an overview of the intervention components and primary outcomes of the studies. Nine of the nineteen studies under review (47.4%) measured GWG as a primary outcome and ten studies (52.6%) measured GWG as a secondary outcome. Five studies (26.3%) also examined the proportion of women with GDM diagnosis in pregnancy.[76,109,129,170,172] Table 4.4. summarizes the reported weight-related outcomes. Four of the studies included in this review (21.1%) have not reported weight-related outcomes to date.[109,129,163,172]

With regard to the reported intervention effects on GWG, five of the nineteen studies (26.3%) reported no significant difference in GWG between participants in an intervention or control condition.[98,136,165,168,171] Three studies (15.7%) reported a significant reduction in total GWG among all intervention participants as compared to a control condition, ranging from a 2.3-4.1 kg difference observed between intervention conditions (p-values<0.05).[80,164,170] The studies with significant effects on GWG varied by country including China,[170] Denmark,[80] and the United States.[164]

Participants in the intervention by Sun et al. (2016) had the greatest intervention effect (-4.1 kg, p<0.001) after receiving five nurse-provided individualized counseling sessions focused on diet, exercise, and weight gain, along with weekly phone calls or text messages using behavioral support strategies for healthy GWG.[170] The trial by Renault et al. (2014) monitored physical activity with a wearable pedometer and provided individual counseling with a Registered Dietitian, resulting in a significant difference in GWG between intervention and control conditions (-2.3 kg, p<0.01).[80] Lastly, the study by Herring et al. (2016) provided African American women (n=66) with a behavioral intervention for the promotion of physical activity and healthy eating.[164] The online components of Herring et al.'s intervention included a Facebook group for participants to virtually interact, individualized health coaching phone calls, personalized text messaging, and DVDs for the promotion of physical activity, resulting in a significant difference observed in mean GWG across intervention groups (-3.1 kg, p=0.03).[164]

Adherence to IOM guidelines

GWG was also presented as an outcome measure in studies referencing adherence to IOM guidelines for participants. Six studies (31.6%) reported the proportion of women

within or exceeding IOM recommendations for healthy GWG.[72,84,134,136,164,166,167] Three of these interventions reported a reduction the proportion of all participants exceeding IOM guidelines,[72,134,164] however, the study by Soltani et al. (2015) did not have a large enough sample size to warrant statistical significance.[72] The study by Redman et al. (2017) was a U.S. based study with 57 participants testing an in-person GWG focused intervention versus a remotely-delivered online intervention compared with a standard care control group.[134] The in-person and online versions of the SmartMoms program were effective at reducing the proportion of women who exceeded IOM guidelines (58%, 56%, and 85%, respectively, p=0.02).[134] Lastly, in addition to the significant effects on total GWG, intervention participants in the study by Herring et al. (2016) were less likely to exceed IOM guidelines compared to the control participants (37% vs. 66%, p=0.033).[164]

GWG outcomes by BMI subgroup

Four studies found significant differences for participants within specific pre-pregnancy BMI groups.[84,164,166,169] Hui et al. (2014) found significantly lower GWG among participants in the intervention group with pre-pregnancy normal weight compared to the control (-1.84 kg, p=0.03) but no significant intervention effect on participants with overweight (p=0.95).[169] Similarly, Harrison et al. (2013) showed favorable GWG outcomes among intervention participants with overweight compared to the control group (-1.8 kg, p<0.05) but no significant intervention effect on participants with obesity (p=0.32).[76] Phelan et al. (2011) showed positive intervention effects on GWG within IOM recommendations for participants with normal weight (0.9 kg, p=0.003), but no difference among participants with overweight or obesity (0.4 kg, p=0.33).[84] Likewise, in the study by Kong et al. (2014), intervention participants with

overweight were more likely to gain within IOM recommendations compared to the control group (55.6% vs. 20.0%).[166]

Three of the four studies with significant outcomes used only one form of technology which may be an indication of effective tools for BMI-specific groups. Phelan et al. (2011) relied solely on telephone calls with a dietitian for the technology component,[84] Kong et al. (2014) used wearable physical activity trackers in the intervention,[166] and Hui et al. (2014) provided informational DVDs to participants.[169]

Descriptions of technology-mediated interventions

Technology type, dose, and duration among the selected RCTs were also examined for this review. Variations were observed in the channels of communication (i.e., telephones, smartphones, wearable activity trackers, DVDs, Wi-Fi enabled bathroom scales, websites, emails, and social media) and the technology-based content (i.e., health coaching, group-based education, and self-monitoring) used across all the studies. The variations led to a challenging synthesis of best practices for technology-mediated interventions. Nine major channels of technology were used among the studies, with most studies (n=10, 52.6%) reporting the use of multiple technology channels. The details of the studies with significant GWG outcomes are presented in Table 4.5. The studies will first be presented by the technology-supported behavioral strategies and content used and then technology channel chosen for delivery (Table 4.6).

Health Coaching

A common strategy used in health behavior change is health coaching. Some of the studies in this review included group-based or individual in-person coaching sessions, while others used technology to provide phone-based health coaching calls and text

messages to prompt participants. Telephone-based counseling via calls or text messages varied by intensity and the person providing the coaching, such as a health care provider (i.e., nurse or midwife),[72,109] Registered Dietitian,[80,84,136,168] or interventionist/health coach.[76,164] For instance, Chao et al. (2017) provided weekly telephone counseling sessions with a dietitian lasting about 20 minutes for 10 weeks during pregnancy.[136] These intensive counseling sessions covered nutrition, exercise, and lifestyle modification strategies for weight control but the study found no significant effect on GWG.[136] Other studies like Harrison et al. (2013) provided four 45-minute, in-person behavioral lifestyle coaching sessions which were then supported by personalized text messages throughout the remainder of the pregnancy.[76]

Of the four studies with significant effects on GWG, three interventions used telephone counseling calls with participants.[80,164,170] The telephone calls varied in duration from five scheduled calls with a nurse[170] to biweekly calls from baseline through delivery (about 10 calls) with a Registered Dietitian[80] or health coach.[164]

Text messaging was used in several studies to prompt the participant to engage with the intervention and/or health coach.[72,76,98,109,164,170] Only one study using text messaging demonstrated significant effects of the intervention on GWG.[164] Two studies used text messaging as the primary technology-supported component and did not find significant effects of the intervention.[72,98] The study by Pollak et al. (2014) used two-way PregCHAT text messages between the interventionist and participant which focused on targeting four weight-related behaviors: 10,000 steps per day, avoiding sugary-sweetened beverages, consuming five servings of fruits and vegetables per day, and eliminating fast food intake.[98]

Behavioral Self-Monitoring

Self-monitoring of weight-related behaviors, such as dietary or physical activity, has been identified as an effective practice in weight control interventions. There were two main forms of self-monitoring using technology in the studies included in this review. Physical activity tracking through wearable pedometers was the most common form of self-monitoring using technology (n=6, 31.6%).[76,80,83,134,164,166] Three of the four studies with significant GWG effects used pedometers for tracking physical activity.[80,134,164]

Paper-based weight tracking has been used in interventions targeting GWG, but may now be enhanced by readily accessible GWG graphs stored on technology devices. Websites, mobile apps, or Internet-connected bathroom scales can provide a convenient way for entering and monitoring GWG data. Four studies included in this review used a technology-supported weight tracking component for the intervention.[83,134,136,163] For instance, the study by Redman et al. (2017) used Wi-Fi connected Bluetooth bathroom scales and a pedometer that transmitted weigh-in and physical activity information to a mobile app with personalized charts using the data points.

Gestational Weight Gain Support

Informational support around GWG, diet, and physical activity was the most common behavioral strategy used across the studies. Educational materials, dietary guidance, and GWG guidelines were shared through mobile apps, study websites, and DVDs.[83,129,134,164,165,167,169,171] Informational DVDs were common for providing information to participants in the reviewed studies (n=4, 21.1%) but may not be the

preferred form of information delivery as technology advances and newer communication modes (i.e., mobile apps) become popular.

In addition to informational support, online social support from peers was included in two interventions. Smith et al. (2016) used an online community forum on the website to connect participants and provide a space for conversation, while Herring et al. (2016) used a private Facebook group for study participants to stay connected during the study.[164,167]

Technology Summary

Telephone-based technology was used as the primary delivery channel for intervention content in several studies. Telephone calls were the most commonly reported delivery channel in the interventions (n=7, 36.8%),[80,84,109,136,164,168,170] followed by text messages (n=6, 31.6%),[72,76,98,109,164,170] and lastly mobile apps (n=3, 15.8%).[129,134,172] Technology-based intervention components for self-monitoring or participation engagement varied across the studies. Fewer studies used mobile apps (n=3, 15.8%), Wi-Fi enabled bathroom scales (n=3, 15.8%), websites (n=2, 10.5%), emails (n=2, 10.5%), or social media (i.e., Facebook; n=1, 0.05%).

Moreover, studies with GWG results favoring the intervention conditions used multiple forms of technology for intervention delivery.[80,134,164,170] Only one study used five different technology modalities (5.3%),[164] three studies used three forms of technology (15.8%),[109,134,172] six studies used two forms (31.6%),[72,76,80,129,136,170] while the remaining nine studies relied on one technology delivery platform (47.4%).[72,84,98,163,165,166,168,169,171] Six of the studies (66.7%) used wearable physical

activity trackers,[76,80,134,164,166] five (55.6%) used telephone calls[72,80,84,164,170] with a health coach or dietitian, and four (44.5%) used text messaging.[72,76,164]

The study by Herring et al. (2016) had the most diverse platform for the dissemination of intervention materials by technology using text messaging, Facebook groups, counseling phone calls, DVDs, and pedometers.[164] While this study showed a significant reduction in GWG for those receiving the intervention, specific intervention component effects were not examined, so it's difficult to discern which technology features were the most helpful or if the demonstrated effect was due to saturation of content across multiple sources of technology.[164]

Redman et al. (2017) used a three-arm randomization technique. One arm received a remotely delivered intervention using a mobile app and Wi-Fi enabled bathroom scale, a second arm received an in-person intervention, and the third condition served as a standard care control group.[134] This study reported a significant reduction in the proportion of participants with excessive GWG in the mobile group versus the standard care group (57% vs. 85%, p=0.02).[134] A significant effect was not observed between the remotely delivered technology-supported intervention and the in-person intervention,[134] indicating the potential for similar observed GWG effects when intervention content is delivered remotely versus face-to-face.

DISCUSSION

This comprehensive review synthesized GWG outcomes and methods from 19 technology-mediated interventions to inform the evidence base for e-Health interventions targeting GWG. This review summarizes results from 15 of the 19 included studies.

Summary of findings

GWG is modifiable through behavioral lifestyle interventions targeting diet and exercise,[52,75,162,173,174] however with the increasing popularity of eHealth tools and interventions, there is a need to identify the channels of communication or intervention components that are tech-based and effective. Within this review, six technology-mediated RCTs did not result in significant weight-related outcomes.[98,136,165,168,171] Four studies found significant results in BMI subgroups, but not across the entire sample.[84,166,169,175] Regarding BMI subgroups, participants with lower BMI had healthier GWG outcomes compared to their higher BMI counterparts.[76,84,90,166] Due to the variation in intervention methods, sample characteristics, and technology used, there is insufficient evidence to determine the effectiveness of technology-mediated interventions on preventing excessive GWG; however, the notable differences observed by BMI class favoring lower BMI groups suggests a need for tailored content or stepped-care approach to providing content across overweight and obese participants who are at greater risk for exceeding IOM recommendations.[176]

Overall, studies frequently used mobile phone technology for intervention delivery via phone calls (n=8), text messages (n=6), and mobile apps (n=3). Wearable physical activity technology was used in studies that focused on exercise as a behavioral target for weight maintenance.[166] Social media was the least reported form of technology support, used in only one study.[164] RCTs that reported significant effects in reducing GWG across all intervention participants relied on two or more forms of technology.[72,80,134,164,170] Of the six interventions with no demonstrated significant effect on GWG, the study by Chao et al. (2017) used two forms of technology and all other

studies provided only one technology component.[136] This finding indicates that offering a variety of technology platforms or greater saturation of information presented across multiple technologies may have a favorable effect on GWG outcomes.

Strengths and limitations

The strengths of this review include a robust search strategy following the PRISMA methodology[146] to reduce bias while systematically selecting articles from a broad search across two databases. This review included ongoing RCTs and reported their methodologies to outline future directions. When weight-related outcomes were available, data were presented and synthesized to contribute to the growing body of literature and interest regarding technology-mediated interventions, specifically mobile health. Furthermore, previous systematic reviews have examined targeted intervention efforts for specific BMI classifications (i.e., only reviewed interventions for reducing GWG among women with obesity). For this review, there were no BMI inclusion parameters set, so that any observed effects in technology-based interventions across BMI groups could be compared and synthesized. Another strength of this systematic review is the in-depth report of technology platforms used for intervention content and delivery channels across studies. This aim was examined in response to the future directions outlined in a systematic review of related literature by Lau et al. (2017).[27]

While the details of the individual studies provide a comprehensive overview of how technology is being used in lifestyle interventions for healthy GWG, the variations in design, methodologies, and technologies used across the studies presented a limitation for pooling results and conducting a meta-analysis. In response to the next steps for research proposed by O'Brien et al. (2014), population subgroups within the studies were

summarized and examined but the lack of variation in participant demographics, educational attainment, and income level did not establish best practices for population subgroups.[26] This is a repeated limitation in the literature and may be a result of the use of technology in intervention design, rather than recruitment efforts. As stated earlier, technology provides solutions to accessibility barriers for a majority of the population who own a phone, but there are competing barriers to consider when mobilizing traditional intervention methods with technology channels, such as consistent cellular service or ability to read and speak in English.

Other limitations include the search parameters set to capture publications within January 2002 and September 2017. By placing a time restriction on the search, it is possible that a few behavioral interventions conducted primarily over telephone calls or other earlier technologies were not captured in the review. The decision to exclude articles published prior to 2002 was based on the increasing Internet usage among U.S. adults following the millennium.[24] As previously mentioned, this review searched two databases for relevant literature, and therefore may have excluded relevant articles stored within databases other than PubMed and Web of Science. In an effort to reduce this limitation, additional Internet searches and reference lists within selected articles were reviewed. Lastly, approximately one fifth of the studies included in this review are ongoing and therefore, the synthesis of studies was limited to include outcomes only reported in fifteen RCTs, which was further limited by varying sample size, significant GWG outcomes, and lack of fully-powered studies.

Future Research

The use of health coaches or dietitians to deliver intervention content was a common practice across the studies, with the majority providing counseling via telephone calls or text messages. This traditional method of behavioral intervention delivery uses theory-driven practices to motivate behavior change and maintenance. A recommendation for future research is to examine more automated methods for intervention delivery and communication with participants to deliver healthy GWG guidance on a larger scale. For instance, interactive mobile apps,[28] websites, or physical activity wearables may offer behavioral tracking features, but these platforms were less commonly used in this review. As eHealth interventions gain momentum in a technology-driven society, it is important to parse out the trade-offs in intervention effects when using automated tools or intervention components. Similarly, the application of technology in the target population is critical in the success of the intervention.

Podcasts are a technology-based information delivery resource used in weight maintenance interventions[177–179] but were not used in any of the studies reviewed here. Additionally, online social networks can mimic in-person, group-based interventions.[32,180] The momentum behind new technology developments provides an opportunity for testing new avenues for intervention delivery.[181] Capitalizing on available and accessible technology resources may alleviate participant, researcher, or clinician burden by automating intervention delivery and is an important consideration for future research around technology-mediated interventions and telehealth care.[181]

Moreover, technology offers a solution for scaling up behavioral interventions while reducing participation barriers, such as transportation, childcare, and time.

However, the use of technology presents new challenges to consider. While a readily accessible, remotely delivered intervention may alleviate participation barriers like time to participate in group-based sessions, there is an increased risk for participant drop-out due to the lack of face-to-face interactions.[118,182] Another example of the technology trade-off is the costs associated with the development, management, and delivery of technology-mediated interventions compared to in-person delivery has not been examined for GWG interventions. There is a practical need for examining the cost-effectiveness of technology-mediated interventions versus in-person methods when scaling up interventions. Redman et al. (2017) was the only study to consider the cost-effectiveness of delivering intervention components remotely through technology compared to the standard in-person approach.[134] The remotely-delivered intervention cost an average of $97 per participant compared to the estimated $347 for participating in an in-person intervention ($p<0.001$).[134] Additional studies testing the effectiveness of intervention components remotely delivered through technology, versus in-person, are needed to establish a stronger evidence base for mobile health interventions.

While all the examined intervention studies used technology to deliver intervention components and communicate with participants, the individual effects and uses of the technology in the intervention were often not reported. Although the findings from the study by Fernandez et al. (2015) have not been reported yet, their study included a 3-arm RCT where two groups received access to a weight-focused website for different time periods while a third group served as the control.[163] The intervention is designed in a way to test the measurable effects of technology dosage for weight management among

pregnant and postpartum women, which may inform researchers about technology optimization for behavioral interventions in this population.[163]

Similarly, the majority of the studies were comprised of predominately white samples, but technology is a platform that is accessible and available across most population subgroups.[110] Technology-mediated interventions are often sought as a way to expand the reach and scope of studies; however, there are few studies in this review that target population subgroups such as low-income or minority groups.[136,164,165] Additional research is needed to test technology-mediated intervention components, acceptability, usability, and effectiveness on preventing excessive GWG in population subgroups, such as low-income or minority groups, and hard-to-reach communities, such as those who are uninsured or living in rural areas. Researchers should also consider the availability and accessibility of technology among racial/ethnic and low-income subgroups for program adherence and potential for large-scale implementation.

Conclusion

Pregnancy can serve as a "teachable moment" for the prevention of obesity among mothers and their offspring.[58] For years, the only option for behavioral intervention delivery was in-person sessions. Now, technology has become ubiquitous following the millennium, which presents an opportunity to connect with participants in new and innovative ways. Recently, public health efforts have focused on the inclusion of technology for intervention delivery methods through eHealth channels (i.e., wearable activity trackers, mobile apps, and phone-based counseling). A major consideration for developing eHealth interventions should be to consider the pros and cons of traditional, in-person methods and how technology can replicate to enhance such methods. There are

several benefits and barriers to traditional intervention methods when working with pregnant women. For instance, group-based educational sessions focused on nutrition and physical activity may increase knowledge, self-awareness, and motivation to change however challenges to participation may include time to attend sessions, transportation, and childcare, presenting several participation barriers and researcher burden.[23,71,121] Since the best practices for preventing excessive GWG remain unknown,[23] and technology is an accessible platform across different population subgroups,[110] there is opportunity to explore the potential benefits and acceptance of mobile health or eHealth interventions during pregnancy.

This review highlighted the various technology platforms and approaches used for intervention delivery and may help to inform future studies. However, the major findings of this review were the lack of diversity among samples reported in the studies, limited effectiveness of the interventions on GWG, and significant differences observed in GWG outcomes only when stratified by BMI groups in a few studies. Developing and testing tailored content for population subgroups, such as racial/ethnic groups or pre-pregnancy BMI, may enhance the uptake and observed effects of the technology-mediated GWG intervention and help address the higher prevalence of obesity among minority groups. Furthermore, RCTs comparing the effectiveness of the intervention by types, dosage, and saturation of technology for intervention delivery may be critical in the adherence of remotely-delivered interventions for GWG. This area of research has potential for growth and contribution to efforts aimed at reducing the prevalence of obesity among mothers and improving birth outcomes in mothers and their offspring.

Table 4.1.Search terms used in combination to identify eligible studies

Technology	**Pregnancy**
Technology [MeSH]	Pregnancy [MeSH]
Information science [MeSH]	Pregnant
Information systems	Prenatal
Telecommunications [MeSH]	Perinatal
Cell phone	**Weight**
Mobile applications	Body Weight [MeSH]
Mobile apps	Body Mass Index
Mobile app	BMI
Text message	Weight gain
Internet [MeSH]	Gestational weight
SMS	Gestational weight gain
Texting	Lifestyle
Telemetry	**Miscellaneous terms**
Electronic Mail	mHealth
Email	Accelerometry
Website	Actigraphy
Social media	Podcast
Twitter	Video
Facebook	Wearable
MySpace	
LinkedIn	
Instagram	
Pinterest	

Table 4.2 Inclusion criteria for selected studies

Author, year	Title	Trial registration number	Sample characteristics					
			Description	Country	N	BMI	Age	Gestational age (weeks)
Bogaerts et al., 2017[172]	INTER-ACT: prevention of pregnancy complications through an e-health driven interpregnancy lifestyle intervention - study protocol of a multicenter randomized controlled trial	NCT02989142	Postpartum women who gained in excess of IOM recs. in previous pregnancy; Singleton pregnancy; Access to a smartphone	Belgium	500	Any	≥18	≤15
Bosaeus et al., 2015[168]	A randomized longitudinal dietary intervention study during pregnancy: Effects on fish intake, phospholipids, and body composition		Women with normal weight enrolled in the BONCH study	Sweden	101	18.5-24.9	20-45	≤12
Chao et al., 2017[136]	A pilot randomized controlled trial of a technology-based approach for preventing excess weight gain during		Singleton pregnancy; No history of GDM, twins or multiples, HIV	USA - PA	41	25-50	18-40	≤16

	pregnancy among women with overweight							
Fernandez et al., 2015[163]	eMoms: Electronically mediated weight interventions for pregnant and postpartum women. Study design and baseline characteristics	NCT01331564	Singleton pregnancy	USA-NY	1722	18.6-34.9	18-35	≤20
Harrison et al., 2013[76]	Optimizing healthy gestational weight gain in women at high risk of gestational diabetes: A randomized controlled trial	ACTRN12608000233325	Women at increased risk of GDM; Singleton pregnancy; English fluency; No pre-existing chronic disease	Australia	228	≥ 25	n/a	12-15
Herring et al., 2016[164]	Preventing excessive gestational weight gain among African American women: A randomized clinical trial		African American; Low SES; Singleton pregnancy	USA - PA	66	≥25	≥18	<20
Hui et al., 2014[169]	Effects of a lifestyle intervention on dietary intake, physical activity level, and gestational	NCT00486629	No history of GDM	Canada	113	Any	n/a	≤20

	weight gain in pregnant women with different pre-pregnancy Body Mass Index in a randomized control trial							
Jackson et al., 2010[165]	Improving diet and exercise in pregnancy with Video Doctor counseling: A randomized trial		English fluency; Low income	USA - CA	327	Any	>18	<26
Kennelly et al., 2015[129]	Pregnancy, exercise, and nutrition research study with smart phone app support (Pears): Study protocol of a randomized controlled trial	ICTRN 29316280	Singleton pregnancy; Access to smartphone; no history of GDM	Ireland	506	≥25	18-45	10-15
Kong et al., 2014[166]	A pilot walking program promotes moderate-intensity physical activity during pregnancy		Singleton pregnancy; Non-smoker	USA-IA	42	≥25	18-45	<15
Nagle et al., 2013[109]	Primary prevention of gestational diabetes for women who are overweight and obese: A	ACTRN12611 3000125729	Singleton pregnancy; No history of diabetes or GDM; English fluency	Australia	370	≥ 25	n/a	≤ 14

	randomized controlled trial							
Phelan et al., 2011[84]	Randomized trial of a behavioral intervention to prevent excessive gestational weight gain: The Fit for Delivery Study	NCT01117961	Singleton pregnancy; Access to telephone; Non-smoker; English fluency	USA-RI	401	19.8-40	>18	10-16
Pollak et al., 2014[98]	Weight-related SMS texts promoting appropriate pregnancy weight gain: A pilot study		Registered for prenatal care at participating clinics; English fluency; Access to cell phone	USA-NC	33	25-40	≥18	12-21
Redman et al., 2017[134]	Effectiveness of SmartMoms, a novel eHealth intervention for management of gestational weight gain: Randomized controlled pilot trial	NCT01610752	Singleton pregnancy; within the first trimester; No history of fetal anomaly, hypertension, eating disorder, HIV, pre-existing diabetes	USA	54	25-40	18-40	≤ 14
Renault et al., 2014[80]	The Treatment of Obese Pregnant Women (TOP) study: A randomized controlled trial of the effect of physical	NCT01345149	Singleton pregnancy; Danish fluency	Denmark	425	≥30	>18	11-14

	activity intervention assessed by pedometer with or without dietary intervention in obese pregnant women							
Smith et al., 2016[167]	Web-based behavioral intervention increases maternal exercise but does not prevent excessive gestational weight gain in previously sedentary women	ISRCTN 38498311	Low physical activity; English fluency; Consistent Internet access; Willing to walk 30 minutes on most days of the week; Non-smoker; No history of GDM, pre-eclampsia, or pre-existing chronic disease	USA	51	≥18.5	18-45	10-14
Soltani et al., 2015[72]	Maternal obesity management using mobile technology: A feasibility study to evaluate a text messaging based complex intervention during pregnancy		Singleton pregnancy; English fluency	UK	28	≥30	≥18	8-10
Sun et al., 2015[170]	The effectiveness of lifestyle intervention in early pregnancy to prevent gestational diabetes mellitus in		Singleton pregnancy; Primipara (first pregnancy)	China	74	≥24	n/a	8-12

	Chinese overweight and obese women: A quasi-experimental study							
Szmeja et al., 2014[171]	Use of a DVD to provide dietary and lifestyle information to pregnant women who are overweight or obese: A nested randomised trial	SCTRN12607000161426	Singleton pregnancy; Enrolled in the Lifestyle Advice Group of the LIMIT trial	Australia	1108	≥25	>18	10-20

Table 4.3. Intervention details and primary outcomes measured

Study	Group Description	Technology Type and Dose	Data Collection Time Points	Primary Outcome	
				Outcome	**Measure**
Bogaerts et al., 2017[172]	**Intervention**: Three coaching sessions, one in each trimester of pregnancy, and 4 coaching sessions between week 6 and month 6 of postpartum. Intervention focuses on weight, diet, physical activity, and mental health.	Mobile application with a Bluetooth component that connects to a weighing scale and activity tracker	Week 6 and Month 6 of first pregnancy; every 6 months after delivery with excessive gestational weight gain in first pregnancy; before 15 weeks into second pregnancy; and weeks 20 and 35 of second pregnancy.	Pregnancy-induced hypertension	Elevations of blood pressure after 20 weeks gestation without significant proteinuria
				Gestational diabetes mellitus	50 g glucose challenge test and a two-hour 75 g oral glucose test
				Caesarean delivery	Surgical procedure
				Large-for-gestational age infant in the subsequent pregnancy	Birth weight >90th percentile
	Control: Standard OB/GYN care	None			
Boseaus et al., 2015[168]	**Intervention:** Dietary counseling with a focus on fish consumption	Phone calls from registered dietitians to increase adherence to the dietary recommendations	Baseline (1-12 weeks of pregnancy); second trimester; and third trimester	Fish intake	Self-reported food frequency questionnaire
	Control: Standard OB/GYN care	None		Serum levels of fatty acids	Blood draw

Chao et al., 2017[136]	**Intervention:** Weekly telephone counseling sessions and Wi-Fi scales to monitor weight from weeks 16 to 36 of pregnancy	A dietitian delivered a behavioral weight management intervention via weekly, 20-minute telephone calls between weeks 16-36 gestation. Includes nutrition, exercise, and lifestyle modification strategies for weight control.	Enrollment and final prenatal visit	Gestational weight gain	Anthropometric measurements
		Wi-Fi scales transmitted weights to personalized weight charts online for participants to monitor GWG.		Proportion of women exceeding IOM recommendations	
	Control: Standard OB/GYN care	None			
Fernandez et al., 2015[163]	**Intervention Group 1**: Online project website for tracking gestational weight gain, physical activity and diet goal setting	Study website with features for tracking weight during pregnancy and control content during postpartum	Baseline (<28 weeks gestation); late gestation (32 weeks-delivery); 6 weeks postpartum; 6 months postpartum; 12 months postpartum; and 18 months postpartum	Proportion of women exceeding IOM recommendations	Online Surveys
	Intervention Group 2: Online project website for tracking gestational weight gain, physical activity and diet goal setting followed by a similar website focused on postpartum weight loss	Study website with features for tracking weight during pregnancy and continued weight-related content during postpartum			Medical charts

	Control: Healthy pregnancy-focused content on a website without behavior change strategies, self-monitoring tools, or logistical tips	Study website with generic pregnancy health education content			Anthropometric measurements
Harrison et al., 2013[76]	**Intervention:** Participated in four, 45-minute individual behavior lifestyle sessions at 14-16, 20, 26 and 28 weeks gestation, informed by the HeLP-her lifestyle intervention program. Received guidance about healthy eating, physical activity and healthy GWG according to guidelines. Received contact and support text messages	Text messages, personalized by name of participant, were sent throughout the study that reinforced intervention health messages.	Baseline (12-25 weeks gestation); 28 weeks gestation; and 6 weeks postpartum.	Physical activity	Pedometer count and International Physical Activity Questionnaire (IPAQ)
		Use of pedometer throughout participation.		Gestational weight gain	Anthropometric measurements
				Gestational diabetes mellitus	50 g glucose challenge test and a two-hour 75 g oral glucose test
	Control: Received a brief, single non-interactive education session and brief written resources based on the generic Australian Dietary and Physical Activity Guidelines	None		Risk perception for development of gestational diabetes mellitus	Self-reported psychosocial measures
	Intervention: Energy intake, physical activity,	Text messages: skills training and self-monitoring	Baseline (≤20 weeks gestation);	Proportion of women with	Anthropometric measurements

Herring et al., 2016[164]	and self-weighing were targeted through the behavioral intervention which relied text messages, biweekly health coach calls, and Facebook group support for 12 weeks	texts with personalized feedback	36-37 weeks gestation; after delivery	excessive gestational weight gain	
		Facebook group: private for all intervention participants to connect and provide social support and additional skills training via links to websites and videos			
		Health coaching calls: weekly for the first two study weeks and then twice monthly thereafter			
		DVD and pedometers to promote activity			
	Control: Standard OB/GYN care	None			
Hui et al., 2014[169]	**Intervention:** Received one on one private dietary consultation at baseline and 2 months after. Complete a dietary recall and work with a counselor to create a diet plan and a weight goal	DVD to use at home about exercise techniques	Baseline (<10 weeks gestation); 2 months after baseline visit	Gestational weight gain	Abstracted clinical anthropometric measures
	Control: Standard OB/GYN care and a package with current information about healthy eating and physical activity during pregnancy	None			

Jackson et al., 2011[165]	**Intervention:** Received a Video Doctor session (10-15 min) at their clinic appointment and clinicians would be provided a cueing sheet based on participant responses during Video Doctor, as well as an educational worksheet	Video Doctor is a computer program delivered in the clinic setting via laptops	Baseline (<26 weeks gestation); follow-up (4 weeks after baseline)	Healthy food intake	18-item food frequency questionnaire
	Control: Standard OB/GYN care	None		Physical activity	Self-reported physical activity
Kennelly et al., 2015[129]	**Intervention**: Healthy lifestyle package was provided by a nutritionist and obstetrician with a single education session at baseline, followed by a smartphone application and emails	Smartphone app: provided a list of daily behavior, dietary, and PA tips, a section on the benefits of PA and suggested safe exercises, and low GI dietary recipes to follow	Baseline (10-15 weeks gestation); 28 weeks gestation; 34 weeks gestation; delivery	Gestational diabetes mellitus	Blood glucose test
		Emails every two weeks with the research team			
	Control: Standard OB/GYN care	None			
Kong et al., 2014[166]	**Intervention:** Received in-home treadmills for an unsupervised walking intervention	Wearable activity tracker	Baseline (10-14 weeks gestation); 17-19 weeks gestation; 27-29 weeks gestation; 34-36 weeks gestation	Moderate physical activity	StepWatch™ Activity Monitor
	Control: No walking program/treadmill provided	None			

Nagle et al., 2013[109]	**Intervention:** Participants will receive the EDGE program throughout pregnancy. Program consists of weekly telephone calls targeting healthy behavior change, goal setting, self-monitoring, tracking GWG.	Telephone calls (5 minutes) biweekly; text message or email biweekly.	Baseline (≤ 14 weeks gestation); 36 weeks gestation; after delivery	Gestational diabetes mellitus	Abstracted clinical records; Oral glucose test results
	Control: Standard OB/GYN care	None		Gestational weight gain	Abstracted clinical anthropometric measures
Phelan et al., 2011[84]	**Intervention:** Fit for Delivery intervention included a face-to-face visit with the interventionist to discuss appropriate weight gain, PA, and healthy eating; participants received body weight scales, food records, and pedometers for self-monitoring; weekly postcards sent with healthy eating and exercise habit prompts; weight gain graph with feedback at each clinic visit	3 brief (10-15 minute) supportive phone calls from a registered dietitian during the intervention; women exceeding guidelines received additional calls every 2 weeks until weight gain normalized	Baseline (10-16 weeks gestation); 30 weeks gestation; 6 months postpartum; 12 months postpartum	Gestational weight gain	Abstracted clinical anthropometric measures

	Control: Standard OB/GYN care, standard nutrition counseling provided by health professionals/WIC, brief face-to-face visit with interventionist at baseline, and 2-month interval newsletters about general health	None			
Pollak et al., 2014[98]	**Intervention:** Received PregCHAT text messages targeting four weight related behaviors: 10,000 steps/day, avoiding sugary-sweetened beverages, consuming five servings of fruits and vegetables/day, eliminating fast food intake; participant weight reported via text weekly	Three days of two-way text messages for 16 weeks, including progress report on behavioral goal setting	Baseline (≤ 21 weeks gestation); 22 weeks gestation; 32 weeks gestation	Gestational weight gain	Abstracted clinical anthropometric measures
	Control: Received Text4Baby content timed to a woman's due date	Three text messages per week with general pregnancy information		Healthy food intake	PrimeScreen - 18 item questionnaire
				Physical activity	Pregnancy Physical Activity Questionnaire (PPAQ)

Redman et al., 2017[134]	**Intervention Group 1:** Received the SmartMoms intervention in-person. Personalized weight graph and 18 lessons provided dietary intake advice, exercise advice, and trimester-specific content.	Wi-Fi scales; wearable activity tracker	Baseline (10-13 weeks gestation); 35-36 weeks gestation	Proportion of women exceeding IOM recommendations	Anthropometric measurements
	Intervention Group 2: Received the SmartMoms intervention remotely through mobile phones. Personalized weight graph and 18 lessons provided dietary intake advice, exercise advice, and trimester-specific content.	Wi-Fi scales transmitted weights to personalized weight charts online for participants to monitor GWG; wearable activity tracker; mobile app.			
	Control: Standard OB/GYN care	None			
Renault et al., 2014[80]	**Intervention Group 1:** Physical activity was encouraged with a daily step count and a pedometer worn for 7 days every 4 weeks	Wearable activity tracker	Baseline (≤ 16 weeks gestation); 18-22 weeks gestation; 36-37 weeks gestation	Gestational weight gain	Anthropometric measurements
	Intervention Group 2: Physical activity components outlined above and dietary intervention which included follow-up on a	Wearable activity tracker Phone calls with Registered Dietitian every two weeks			

	hypocaloric Mediterranean-style diet				
	Control: Standard OB/GYN care	None			
Smith et al., 2016[167]	**Intervention**: Use of website based on the social cognitive theory that provided prenatal diet and physical activity recommendations, physical activity goal setting modules, problem-solving modules, a journal, and community forum	Social cognitive theory-based website until delivery	Baseline (10-14 weeks gestation); 24-26 weeks gestation; 34-36 weeks gestation	Gestational weight gain	Anthropometric measurements
				Food intake	Self-report dietary record (3-days)
	Control: Standard OB/GYN care	None		Physical activity	Sense-Wear Mini armband
Soltani et al., 2015[72]	**Intervention:** Received two consultation visits and two clinical appointments, focused on goal setting for diet and exercise, then supported with text messages between visits	Motivational text messages to support behavior change sent daily	Baseline (10 weeks gestation); 14-16 weeks gestation; 16-18 weeks gestation; 28 weeks gestation; 36 weeks gestation	Gestational weight gain	Anthropometric measurements
		Phone calls at 20, 24, and 32 weeks			
	Control: Standard OB/GYN care	None			

Sun et al., 2015[170]	**Intervention:** Received five nurse-provided individualized counseling sessions focused on diet, exercise, and weight gain, weekly phone calls or text messages between visits on behavioral support strategies for healthy GWG	Weekly phone call or text messages	24 weeks gestation	Gestational diabetes mellitus	50 g glucose challenge test and a two-hour 75 g oral glucose test
	Control: Received one educational session with a nurse with general dietary, exercise, and weight gain info.	None			
Szmeja at al., 2014[171]	**Intervention:** Received the Lifestyle Advice content from the LIMIT trial, plus an informational DVD containing information about healthy eating during pregnancy, serving sizes, and exercise during pregnancy	Informational DVD	28 weeks gestation; 36 weeks gestation	Healthy Eating Index	Food frequency questionnaire
	Control: Received the Lifestyle Advice content from the LIMIT trial via standard written materials	None			

Table 4.4. Weight-related outcome measures

Authors	Reported gestational weight gain outcomes			Conclusion
	Intervention	Control	Difference	
Bogaerts et al., 2017[172]	TBD	TBD	TBD	TBD
Bosaeus et al., 2015[168]	11.6 (8.9, 13.9) kg	11.6 (9.5, 11.6) kg	0.0 kg, p=0.96	There was no significant difference in GWG between the groups.
Chao et al., 2017[136]	15.5 ±5.3 kg	13.3 ± 6.8 kg	2.2 kg, p=0.29	There was no significant difference in GWG using telemedicine.
Fernandez et al., 2015[163]	TBD	TBD	TBD	TBD
Harrison et al., 2013[76]	Overweight: 6.0 ± 2.2 kg Obese: 5.2 ± 2.6 kg	Overweight: 7.8 ± 3.4 kg Obese: 5.9 ± 3.5 kg	Overweight: 1.8 kg, p<0.05 Obese: 0.7 kg, p=0.32	Participants with overweight gained significantly less weight from participating in the intervention. There were no significant observations in weight gain among participants with obesity.
Herring et al., 2016[164]	8.7 kg Exceeded IOM guidelines: 37%	12.3 kg Exceeded IOM guidelines: 66%	3.1 kg, p=0.045 *adj. p=0.033	Participants in the intervention group gained significantly less weight compared to the control group. The intervention group was less likely to exceed IOM guidelines.

Hui et al., 2014[169]	Normal weight: 12.9 ± 3.72 kg Overweight: 15.21 ±7.50 kg	Normal weight: 16.23 ± 4.38 kg Overweight: 14.39 ± 7.05 kg	Normal weight: 1.84 kg (p=0.03) Overweight: 0.82 kg (p=0.26)	There was a significant difference in the total GWG of the women with normal weight, but there was no significant difference among women with overweight.
Jackson et al., 2011[165]	15.15 kg	15.24 kg	0.09 kg, p=0.95	There was no statistically significant difference in GWG between the groups.
Kennelly et al., 2015[129]	TBD	TBD	TBD	TBD
Kong et al., 2014[166]	Overweight: 10.53 ± 5.37 kg Exceeded IOM: 44.4% Obese: 12.07 ± 9.01 kg Exceeded IOM: 77.8%	Overweight: 9.94 ± 6.14 kg Exceeded IOM: 50.0% Obese: 12.48 ± 8.51 kg Exceeded IOM: 77.8%	Overweight: 0.59 kg Obese: 0.41 kg F=0.253, p=0.859	There was no significant difference in total GWG observed. Women with obesity were more likely to exceed IOM guidelines compared to women with overweight.
Nagle et al., 2013[109]	TBD	TBD	TBD	TBD
Phelan et al., 2011[84]	Normal weight: 15.3 ± 4.4 kg Exceeded IOM: 40.2% Overweight/obese: 14.7 ± 6.9 kg Exceeded IOM: 66.7%	Normal weight: 16.2 ± 4.6 kg Exceeded IOM: 52.1% Overweight/obese: 15.1 ± 7.5 kg Exceeded IOM: 61.1%	Normal weight: 0.9 kg OR: 0.38, p=0.003 Overweight/obese: 0.4 kg OR: 1.4, p=0.33	Participants with normal weight in the intervention group, compared with the control group, were significantly less likely to exceed IOM recommendations. There were no significant differences observed between women with overweight.

Pollak et al., 2014[98]	Mean weight at 40 weeks: 94.35 kg	Mean weight at 40 weeks: 95.25 kg	2.72 kg, *p*=0.24	GWG was less among the intervention group, but the difference was not statistically significant.
Redman et al., 2017[134]	In-Person Group Exceeded IOM: 56% Remote Group Exceeded IOM: 58%	Exceeded IOM: 85%	*p*=0.02	The SmartMoms intervention significantly reduced the proportion of participants with excessive GWG. There was no significant difference in the proportion of excessive GWG when comparing the in-person versus remote delivery.
Renault et al., 2014[80]	PA + D group: 8.6 (-9.6, 34.1) kg PA group: 9.4 (-3.4, 28.2) kg	10.9 (-4.4, 28.7) kg	*p*=0.008	Participants in the intervention groups gained significantly less weight compared with the control group. Individual intervention comparison showed that the PA group gained significantly less weight than the control group (p=0.042).
Smith et al., 2016[167]	13.6 $\pm$ 5.6 kg Exceeded IOM: 68.2%	11.2 $\pm$ 5.1 kg Exceeded IOM: 52.4%	2.4 kg	Participants in the intervention group gained more weight than the control group, although the difference was not significant.
Soltani et al., 2015[72]	5.6 $\pm$ 4.6 kg Exceeded IOM: 28%	9.7 $\pm$ 7.2 kg Exceeded IOM: 50%	4.1 kg	The small sample size did not warrant statistical significance, but the

				descriptive findings favor the intervention.
Sun et al., 2015[170]	6.86 ± 2.31 kg	10.08 ± 3.84 kg	3.22 kg, $p<0.001$	Participants in the intervention group gained significantly less weight compared with the control group.
Szmeja et al., 2014[171]	9.09 ± 5.75 kg	9.66 ± 5.73 kg	0.57 kg, $p=0.11$	There was no significant difference observed in total GWG.

Table 4.5. Significant weight related outcomes observed and the technology-based intervention components used.

Authors	**GWG difference between intervention and control groups**	**Technology used**
Sun (2016)[170]	-4.1 kg (p<0.001)	Phone calls, text messages
Herring (2016)[164]	-3.1 kg (p=0.03)	Phone calls, FB, text messages, DVD (PA)
Renault (2014)[80]	-2.3 kg (p<0.01)	Phone calls, pedometer
Hui (2014)[169]	-1.8 kg (p=0.03) **Normal weight only*	DVDs (PA)
Phelan (2011)[84]	40.2% intervention vs. 52.1% control participants exceeding IOM guidelines (p=0.03) **Normal weight only*	Phone calls
Redman (2017)[134]	58% intervention vs 85% control participants exceeding IOM guidelines (p=0.02)	Wi-Fi enabled bathroom scale, pedometer (FitBit), mobile app

Table 4.6. Technology-supported behavioral strategies used in the interventions

	Health Coaching			Self-Monitoring		Support	
Authors	Phone Calls	Text Messaging	Emails	Weight Tracking (i.e., Bluetooth Bathroom Scale, GWG graphs)	Physical Activity Tracking (i.e., pedometers)	Informational (i.e., DVDs, mobile apps)	Social (i.e., Facebook)
Bogaerts et al., 2017[172]				•	•	•	
Bosaeus et al., 2015[168]	•						
Chao et al., 2017[136]	•			•			
Fernandez et al., 2015[163]				•			
Harrison et al., 2013[76]		•			•		
Herring et al., 2016[164]	•	•	`		•	•	•
Hui et al., 2014[169]						•	
Jackson et al., 2010[165]						•	
Kennelly et al., 2015[129]			•			•	
Kong et al., 2014[166]					•		
Nagle et al., 2013[109]	•	•	•				
Phelan et al., 2011[84]	•						
Pollak et al., 2014[98]		•					
Redman et al., 2017[134]				•	•	•	
Renault et al., 2014[80]	•				•		
Smith et al., 2016[167]						•	•
Soltani et al., 2015[72]		•					
Sun et al., 2015[170]	•	•					
Szmeja et al., 2014[171]						•	
Total	**7**	**6**	**2**	**4**	**6**	**8**	**2**

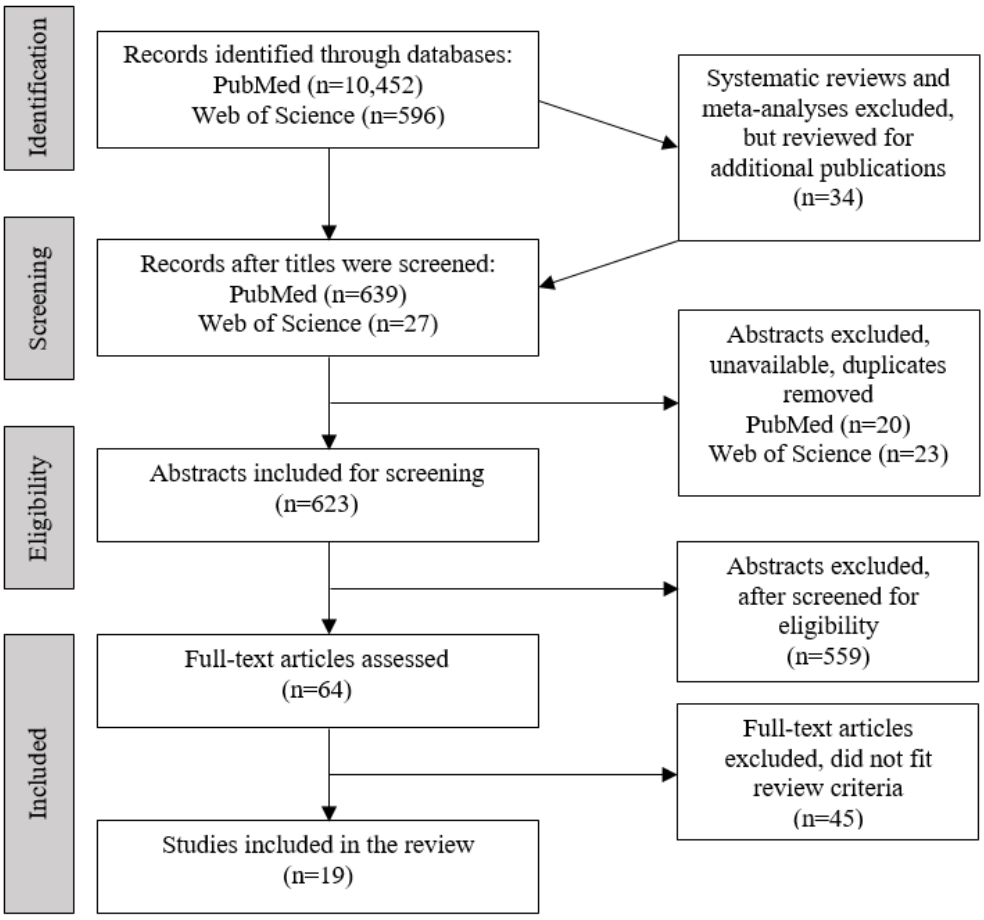

Figure 4.1. PRISMA flow diagram for study eligibility and inclusion

4.2. What (Pregnant) Women Want: Results from a Web-based Needs Assessment of Weight-Related Information Gaps and e-health Intervention Features for Pregnant Women in the U.S.

Prepared for: *Translational Behavioral Medicine*
Alicia A. Dahl, Gabrielle Turner McGrievy, Sara Wilcox, Jihong Liu, and Rachel E. Davis

ABSTRACT

BACKGROUND: Healthy gestational weight gain (GWG) is critical for reducing adverse pregnancy outcomes. Health care providers may not have the resources and specialized training to provide weight counseling to pregnant patients. Electronic health (e-health) interventions hold potential as important resources for pregnant women.

PURPOSE: This study identified weight-related knowledge and sources of prenatal health information and examined pregnant women's feedback on features considered for inclusion in an e-health intervention targeted at preventing excessive GWG.

METHODS: Using social media sites, pregnant women in the U.S. who owned a smartphone were recruited to complete an online survey (n=329). The survey included questions regarding weight-related topics discussed with prenatal health providers, uses of technology for health information during pregnancy, interest in pregnancy weight-related information (e.g., physical activity), and features (e.g., weight tracking tool and podcasts) delivered electronically. ANCOVA and chi-square analyses were used to examine differences by parity and weight status.

RESULTS: Half of participants reported having no discussion about GWG recommendations with providers. Overall, interest in weight tracking, podcasts, and group-based behavioral challenges was high. Multiparous women expressed less interest in listening to weekly podcasts on pregnancy-related topics than nulliparous women (66.7% vs. 80.3%, $p<0.01$). Overweight/obese participants were more interested in a mobile app for communicating with other pregnant women than normal weight participants (86.5% vs. 77.3%; $p=0.03$).

CONCLUSIONS: Given the interest in e-health interventions among pregnant women, future studies should examine their effectiveness in the prevention of excessive GWG. Tailoring based on parity and weight status may be necessary.

MANUSCRIPT

INTRODUCTION:

Obesity is a complex public health issue affecting an estimated 40.5% of adult women in the United States.[14] Pre-pregnancy body mass index (BMI) has been used to guide the Institute of Medicine's (IOM) 2009 recommendations for healthy gestational weight gain (GWG).[3] For women entering pregnancy underweight (BMI below 18.4 kg/m^2), the guidelines suggest a range of 28-40 pounds for healthy GWG, while normal weight women (BMI between 18.5-24.9 kg/m^2) are recommended to gain 25-35 pounds.[3] Women entering pregnancy overweight (BMI between 25.0-29.9 kg/m^2) are recommended to gain between 15-25 pounds, and women who are obese (BMI greater than or equal to 30 kg/m^2) are advised to gain 11-20 pounds.[3] The healthy GWG guidelines for women carrying twins or multiples also vary based on pre-pregnancy BMI.[3]

Despite these clear guidelines, nearly half of all pregnant women exceed IOM recommendations for healthy GWG.[3,39,40,183] Women who enter pregnancy overweight or obese are at increased risk for excessive GWG[158] and postpartum weight retention compared to normal weight women.[3,39,40,43] Excessive GWG is associated with adverse maternal and infant health outcomes such as pre-eclampsia,[160] hypertension, cesarean delivery, and large-for-gestational-age infants.[5,6]

The IOM recommends the communication of risks associated with excessive GWG during prenatal care;[3] however, providers often report barriers to addressing weight gain during pregnancy, such as low patient-provider morale, inadequate time for incorporating weight counseling into prenatal appointments, and lack of knowledge of current recommendations or nutritional guidance.[17,18,21,138,184,185] In an effort to reduce excessive GWG and alleviate provider burden, several behavioral interventions have targeted diet and exercise lifestyle modifications for pregnant women, yielding success in reducing the proportion of women with excessive GWG by an average of 20%.[22,23] These behavioral interventions are encouraging but a commonly-reported concern is the limited generalizability to low-income and minority populations. Furthermore, these interventions mainly recruited through clinic sites, enrolling women after the first trimester, which does little to address the need for early intervention for preventing excessive GWG.[22,23]

The field of e-health refers to technologies that are developed or used to deliver or enhance public health and medical interventions.[186] Technology offers a scalable solution to some of the repeated limitations in the literature around communicating GWG recommendations and monitoring GWG.[113] Mobile apps, websites, text messaging, and social media are accessible platforms for prenatal information delivery to many U.S. women, with 94% of U.S. women owning a cellphone, 75% owning a smartphone,[110] and 73% using social media.[25] The accessibility of communicating health information over mobile platforms is promising in terms of reducing participation burden, however most technology-mediated interventions rely on phone calls and text messaging rather than mobile apps or websites for content delivery.[26,27]

In a recent review of 87 mobile apps available on the marketplace using "weight" and "pregnancy" as search terms and using a weight tracking feature, only 19 (22%) apps provided accurate GWG guidelines and fewer (<10%) had nutrition and physical activity guidance for achieving healthy GWG.[28] Despite the availability of apps advertising pregnancy weight-related content and features, current apps are inadequate to support healthy weight monitoring during pregnancy.[28] Furthermore, practitioners are concerned with the source and reliability of pregnancy-related health information shared via commercially available apps[28,112,113] creating an additional barrier to supplementing prenatal care and GWG monitoring with technology.

The aim of this study was to conduct a needs assessment of pregnant women's weight-related knowledge and sources for prenatal care information, and to identify interests in e-health intervention features targeting the prevention of excessive GWG to inform the development of a randomized controlled trial.

METHODS:

Data collection

In April 2016, 421 pregnant women were recruited through social media sites (i.e., Facebook and Twitter) to participate in a one-time online survey regarding weight-related knowledge, pregnancy-related information sources, and interest in potential e-health intervention features. Posts on social media were developed as the primary recruitment method based on the success of prior interventions seeking a large convenience sample of women.[140,148] Funds for recruitment were not available for this needs assessment; therefore, low-cost sampling methods were critical.[148] The recruitment text was shared on the authors' personal Facebook and Twitter profiles using specific

hashtags (i.e., #pregnant) to publicly appear in social media users' search for related topics. The recruitment text asked viewers to share the post within their networks to extend the organic reach of the post. Lastly, pregnancy-related groups, doulas and OB/GYN Facebook pages in major cities across the U.S. were identified and messaged with a request to share the recruitment text.

The survey was hosted on SurveyGizmo.com under a password protected account. Interested participants were first prompted to read and sign an informed consent form. Next, a brief 4-item eligibility screening form was completed, and eligible participants were prompted to continue to the full survey. Women were eligible to participate if they met the following inclusion criteria at the time of the survey: pregnant, resident of the United States, between the ages of 20-35, and an owner of a smartphone. Participants who completed the survey were entered into a raffle drawing to receive one of six $25 Amazon.com gift cards. On average, the survey took 13 minutes to complete. The University of South Carolina Institutional Review Board approved this study.

Measures

The survey included 36 items to assess women's pregnancy history, weight-related knowledge, health topics discussed with health care providers, health information sought by women during pregnancy, and interests in e-Health interventions. Participants reported demographics (age, race/ethnicity, educational attainment, employment status, marital status) and a brief health status report (height, weight, parity, and presence of diabetes, depression, or high blood pressure). Pre-pregnancy BMI was calculated from self-reported height and weight questions from the Pregnancy Risk Assessment Monitoring System (PRAMS) Phase 7 Core.[187] Participants were asked to recall their

conversations with providers, “During your current pregnancy, has a physician (primary care provider or obstetrician) discussed weight gain recommendations with you?” To gauge the perception of healthy GWG, participants were asked to report how much weight they considered to be a healthy amount to gain over the course of the current pregnancy and were able to provide a single number or range of pounds.

Additionally, 22 pregnancy health-related topics were presented, and participants were asked to recall whether their provider discussed the topics during prenatal appointments, and if the participants were interested in learning about the topics. Response options were “yes” or “no” to a list of topics. For example, the topics included daily calorie recommendations, foods to avoid, postpartum depression, breastfeeding, gestational diabetes, infant development, physical activity safety guidelines, stress management, and weight counseling. Participants were also asked to identify their current sources of pregnancy health-related information, “During your current pregnancy, where do you get most of your information related to nutrition and physical activity? (Please check all that apply.)” Response options included: doctor, friends/family, websites, social media, mobile apps, books, and an option to fill in “other” sources of information. Lastly, participants were asked to provide their level of interest for using e-Health intervention features using a 5-point Likert scale (0-not at all interested, 4-extremely interested). For this paper, we dichotomized the values as “not at all interested” for values of 0 and “interested” for values 1-4. The proposed e-Health intervention features were: podcasts, online group-based challenges related to healthy eating or physical activity, communicating with other pregnant women through a mobile app, and tracking GWG

with a mobile app. These features were selected as potential components of a future e-Health intervention based on the research team's expertise.

Statistical analysis

Using BMI, participants were categorized as underweight/normal weight or overweight/obese. Participants' perceived healthy amount of GWG was coded as "below," "within," and "above" IOM recommendations based on participants' pre-pregnancy BMI. Chi-square analyses were employed for examining the needs and interests of participants by parity, race/ethnicity, and BMI classification. One-way ANOVA and Tukey HSD post-hoc tests to test differences between the dependent (needs and interests) and independent variables (parous state and BMI). All models were controlled for age, gestational age, race/ethnicity, marital status, employment status, relationship status, and education. Data were analyzed using IBM SPSS Statistical Software Version 64.[150] The statistical significance value was set at $p<0.05$.

RESULTS:

Results are presented as means $\pm$ standard deviations. Of the 421 eligible responses received, 329 were completed (completion rate: 78%). Analyses includes responses from the 329 eligible participants who completed the online survey. Participants were mostly white (94.5%), employed full time (62.9%), and had completed a four-year degree or higher (73.0%). Most women were in the second half of their pregnancy ($\geq$ 20 weeks) at the time of the survey, with the average gestational age of 23.6 $\pm$ 10.1 weeks. Mean pre-pregnancy BMI was 26.2 $\pm$ 6.5 kg/m^2, with a range of 16.6 - 51.4 kg/m^2. The sample had more women with normal weight (n=172, 52.3.0%) compared to overweight (n=75, 22.8%) and obesity (n=73, 22.2%). Nine women reported

underweight BMI (n=9, 2.7%). BMI varied significantly between white (26.0 ± 6.3 kg/m^2) and black women (35.3 ± 9.23 kg/m^2, p=0.01); therefore, race was included as a covariate in ANCOVA tests. BMI status did not significantly differ by parous state (p=0.79). Additional demographic data are presented in Table 4.7.

Weight-related knowledge

Estimated healthy gestational weight gain

Table 4.8 summarizes the amount of GWG participants considered to be healthy. Appropriate adjustments were made for the women carrying multiple babies during the pregnancy, as the IOM recommendations are greater than a singleton pregnancy.[39] The majority of participants (n=211, 65.1%) reported a healthy GWG amount within IOM recommendations for their respective BMI classifications. When these reported values for healthy GWG were compared across BMI groups, underweight and normal weight women were more likely to report a value within IOM recommendations (n=124, 58.8%) compared to overweight or obese participants (n=87, 41.2%, p<0.001). More women with overweight and obesity reported values above their respective IOM recommendations (n=49, 70.0%) than underweight or normal weight (n=21, 30.0%, p<0.001). The mean reported healthy GWG (pounds), by weight status group, were as follows: underweight (30.4 ± 3.93), normal weight (28.1 ± 6.77), overweight (24.1 ± 5.59), and obese (20.9 ± 7.54). The means for women with overweight and obesity were on the upper end of their respective recommendation ranges.

Prenatal care discussions

Gestational weight gain recommendations

Half (n=165, 50.9%) of the participants reported that they did not receive GWG recommendations from their health care provider during their pregnancy. There were no significant differences in this report across BMI groups ($\chi^2(1, 329)=0.02$, $p=0.91$); however, a higher proportion of women who were nulliparous (first-time moms) reported receiving GWG recommendations from their providers (n=88, 58.3%) as compared to multiparous women (n=74, 45.7%, $\chi^2(1, 329)=8.84$, $p<0.01$).

Furthermore, perceptions of healthy GWG were significantly related to participants' recall of health care provider guidance in this area ($\chi^2(1,329)=6.06$, $p=0.048$, Figure 4.2). Participants who reported they discussed GWG guidance with their health care providers were more likely to estimate a healthy GWG within their respective IOM recommendations (n=114, 71.7%) compared to those who did not overestimate a healthy GWG (n=45, 28.3%).

Health-related information needs

Participants indicated their interest in receiving health-related information during pregnancy and recalled topics discussed during prenatal appointments to identify information gaps. Of the 22 topics presented, preparing for delivery was the topic in which most women were interested (81.5%), but only half (50%) of the women reported receiving guidance on the topic. Other topics for which interest exceed provider discussion were infant development (73.6% participant interest vs 38.7% provider discussions), infant nutrition (71.3% vs. 24.7%), and breastfeeding (71.3% vs. 50.3%). Only one-third of participants expressed interest in learning about barriers to healthy

eating (33.4%), weight counseling (36.2%), and formula feeding (37.5%). Figure 4.3 summarizes the weight-related topics participants were interested in and discussed with providers. Across all weight-related topics, there was greater interest in learning about the topic by participants than reported discussion on the topic with their health care providers.

Sources of weight-related information during pregnancy

Figure 4.4 depicts the participants' sources of information for weight-related topics during pregnancy. Overall, websites were the most reported resource for information (n=196, 59.6%), followed by doctors (n=161, 48.9%) and friends/family (n=132, 40.1%). Mobile apps were commonly used for weight-related information as well (n=78, 23.7%), while books were the least-used resource (n=55, 16.7%). Compared to multiparous women, first-time moms reported greater use of books (32.7% vs. 67.3%, $p<0.01$), mobile apps (34.6% vs. 65.4%, $p<0.01$), friends/family (39.4% vs. 60.6%, $p<0.01$) and blogs (42% vs. 58%, $p=0.03$) for nutrition and physical activity related content during pregnancy.

Interest in e-Health intervention features

Overall, pregnant women expressed interest in using the presented e-Health intervention features, with the greatest interest expressed in a mobile app for tracking GWG (n=276, 83.9%), followed by a mobile app for communicating with other pregnant women (n=248, 81.5%). Almost one-quarter of participants expressed interest in the podcast feature (n=240, 72.9%). See Figure 4.5 for additional details.

Regarding BMI classification, overweight and obese women reported greater interest in a mobile app component to communicate with other pregnant women

compared to normal weight participants (86.5% vs. 77.3%, respectively, p=0.03). When e-Health features were examined by parity (Figure 4.5), first-time moms expressed significantly greater interest than multiparous women in receiving podcasts about having a healthy pregnancy (80.3% vs. 66.7%, respectively, p<0.01) and participating in group-based physical activity challenges (85.5% vs. 69.5%, respectively, p<0.001).

DISCUSSION:

The findings of this study indicated several health information gaps and needs of pregnant women living in the U.S. Perhaps the most significant finding was that half of the participants reported they did not receive healthy GWG recommendations from their provider, which is consistent with existing literature.[92,138,184] There was a strong association observed between participants who received IOM guidance from their provider and those who estimated healthy GWG. Of those women who reported their providers did communicate the recommendations, most were first-time moms which may be problematic for the multiparous women who often begin subsequent pregnancies with a higher BMI and require new IOM GWG recommendations.[53] Furthermore, when participants cited their perceived healthy GWG values, more overweight and obese women estimated a number above IOM recommendations. Women with overweight and obesity enter pregnancy with an increased risk for excessive GWG and postpartum weight retention;[1] however, when coupled with expectations for gaining weight above IOM recommendations, there is a potential greater risk for excessive GWG and therefore adverse health outcomes associated with obesity.[8,59,67,188,189]

Taken together, these findings demonstrate the critical role of patient-provider communication around GWG recommendations. Providers typically view excessive

GWG as a health concern for their patients[21] and women tend to value providers' advice around GWG recommendations.[138] However, several studies indicate a gap in the communication of GWG recommendations. From a public health perspective, the lack of guidance related to GWG and the misperceptions of healthy GWG indicates a greater need for routine communication regarding healthy GWG during all pregnancies, despite parous state or pre-pregnancy BMI. Addressing the commonly cited barriers for provider driven discussions around GWG is an important consideration for future public health efforts. For instance, in a national survey of obstetrics/gynecology residents, over half were not aware of IOM guidelines for healthy GWG, which is fundamental knowledge for providing effective and accurate GWG counseling.[19]

While health care providers may serve a critical role in the communication and monitoring of GWG, patients also reported frequently using websites, social media, and mobile apps for their pregnancy weight-related information. Consistent with existing literature around resources used for weight-related information during pregnancy, online websites were the most commonly cited resources,[144] which leaves pregnant women susceptible to misinformation.[114] However, the highly cited use of websites for pregnancy health-related information demonstrates potential for using Internet or other technologies as an intervention delivery platform. A few studies have used web-based resources for intervention delivery with modest effects on GWG.[121,128,163,167] As indicated by the high levels of interest across all proposed intervention features, electronic or mobile health interventions may serve as a viable health communication platform for GWG information and monitoring.[99,120,137,190,191]

All participants expressed high levels of interest in a variety of health-related topics that were not often reported as discussed during prenatal care. We did not expect all these topics to be covered by the prenatal care provider and our question did not specifically ask if participants wanted to discuss these topics with their providers, but simply if there was interest in learning about these subjects during pregnancy. Understandably, physician burden is reported as a barrier to providing comprehensive prenatal care that may require systems-level changes.[29,181,185] However, this conflict of patient interest and available provider resources presents an opportunity for public health education and health promotion to develop communication materials to supplement prenatal care. Furthermore, if participants are interested in learning about these subjects but do not receive information from their provider, the risk of misinformation sought through online resources becomes more prominent.

First-time moms were more interested in learning about general pregnancy health and weight-related topics compared to multiparous women. Pregnancy serves as a "teachable moment" for women[58] and for those experiencing pregnancy for the first time, there may be more motivation and interest in receiving health-related information. First-time moms may be more receptive to information about a variety of topics related to pregnancy, while multiparous women may feel that the information being shared is redundant or unnecessary. In this study, first-time moms expressed greater interest in the proposed intervention features that were information based (i.e., podcasts) and supported physical activity, compared to multiparous women. Based on the findings of this assessment, a potential solution for providing pregnant women with topics of interest would be to design intervention content or communicate information via different

platforms. Parity-specific intervention designs may improve participant retention and engagement as well.[120]

Strengths and limitations

The strengths of this study include the use of social media to recruit a convenience sample of pregnant women living in the U.S. The recruitment goal (N=100) was exceeded within a week, demonstrating the willingness of pregnant women to discuss their health information interests and needs. While this needs assessment was not unique in terms of identifying information gaps in prenatal care, this study was able to assess the potential for features in an e-Health intervention targeting GWG among pregnant women and examined differences by parity and BMI status.

There are some limitations to the current study. Due to the online nature of the recruitment and survey methods, it's possible that respondents provided misinformation regarding their current pregnancy, needs, or experiences. Health care providers were not involved in the study, and therefore could not verify respondents' information related to their pregnancies. Additionally, BMI was calculated using self-reported height and weight, which is subject to error, however a validation study found high correlation (r=0.99) between self-reported pre-pregnancy and clinically measured weight.[13] Regarding e-Health interventions, this survey asked for participants' interest levels in a set of pre-determined intervention features under consideration for a larger study. The list was not exhaustive and did not include all technologies (i.e., wearable fitness trackers). Furthermore, due to the recruitment via social media, we may have had greater interest in e-health features due to already high online engagers.

Lastly, the sample was not very diverse, reducing the generalizability of the findings. The recruitment of predominately white women is a common occurrence when using social media sites for recruitment methods.[148] In future studies, targeted messaging, images promoting diversity, and strategic placement of recruitment advertisements on social media websites may be a solution to recruiting more diverse samples.

CONCLUSION:

Targeted resources and efforts are needed to communicate and increase knowledge about healthy GWG among pregnant women with overweight and obesity. Focusing e-Health interventions around weight management information and GWG tracking may fill a need in prenatal care. Further research is needed to determine the effectiveness of an e-Heath intervention or supplemental care materials in the prevention of excessive GWG among pregnant women. Lastly, it may be advantageous for researchers to pilot test intervention features among nulliparous and multiparous women prior to dissemination.

Table 4.7. Sample characteristics of participants who completed the online survey (n=329)

	Nulliparous (n=152)	**Multiparous (n=177)**	
	Mean (SD)	**Mean (SD)**	***p*-value**
Age (years)	28.9 (3.2)	30.1 (3.2)	0.001
Gestational age (weeks)	24.9 (9.6)	22.5 (10.4)	0.03
Pre-pregnancy BMI (kg/m^2)	26.4 (6.4)	26.0 (6.5)	0.52
Pre-pregnancy BMI classification	**n (%)**	**n (%)**	
Underweight	3 (2.0)	6 (3.4)	0.77
Normal weight	77 (50.7)	95 (53.7)	
Overweight	36 (23.7)	39 (22.0)	
Obese	36 (23.7)	37 (20.9)	
Race			
White	138 (91.4)	161 (91.5)	0.49
Black/African American	3 (2.0)	5 (1.1)	
Asian	1 (0.7)	1 (0.6)	
Amer. Indian/Alaskan Native	2 (1.3)	0 (0.0)	
Multiracial	7 (4.6)	12 (6.8)	
Marital status			
Married	129 (84.9)	158 (89.3)	0.05
In a relationship	19 (12.5)	14 (7.9)	

Single	4 (2.6)	1 (0.6)	
Education			
Advanced degree (Master's, Doctoral, or other post-college degree)	69 (45.4)	54 (30.5)	0.02
College graduate (4-year)	46 (30.3)	71 (40.1)	
Some college or Associate's degree	33 (21.7)	40 (22.6)	
High school graduate or equivalent	4 (2.6)	12 (6.8)	
Employment status			
Full-time (30 hours or more per week)	121 (79.6)	86 (48.6)	<0.001
Part-time (less than 30 hours per week)	13 (8.6)	26 (14.7)	
A homemaker	7 (4.6)	47 (26.6)	
Unemployed	7 (4.6)	5 (2.8)	
Other	4 (2.6)	13 (7.4)	
Pregnancy characteristics			
Singleton pregnancy	138 (90.8)	162 (91.5)	0.20
Multiples (i.e., twins)	6 (3.9)	2 (1.1)	

Table 4.8. Participants' reported values of perceived healthy GWG compared to IOM recommendations (n=324)

	Below IOM	Within IOM	Above IOM
All participants *n (%)*	43 (13.3)	211 (65.1)	70 (21.6)
BMI classification *n (%)*			
Underweight/Normal weight	32 (74.4)	124 (58.8)	21 (30.0)
Overweight/Obese	11 (25.6)	87 (41.3)	49 (70.0)
Provider guidance on GWG *n (%)*			
No, guidelines were not discussed	25 (58.1)	97 (46.0)	43 (61.4)
Yes, guidelines were discussed	18 (41.9)	114 (54.0)	27 (38.6)

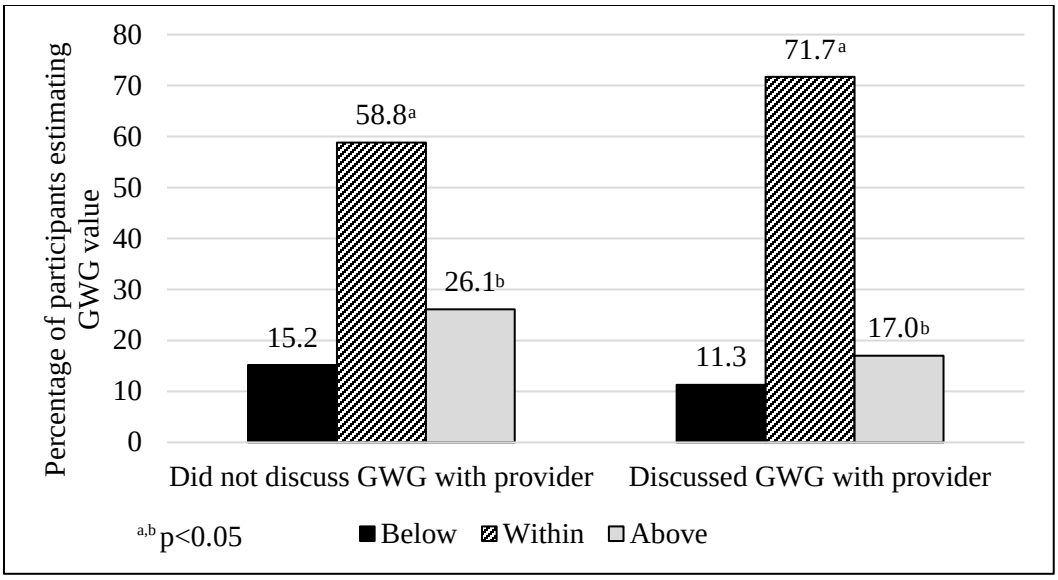

Figure 4.2. Percentage of participants who estimated GWG according to IOM recommendations by recalled discussions with providers around GWG (n=324)

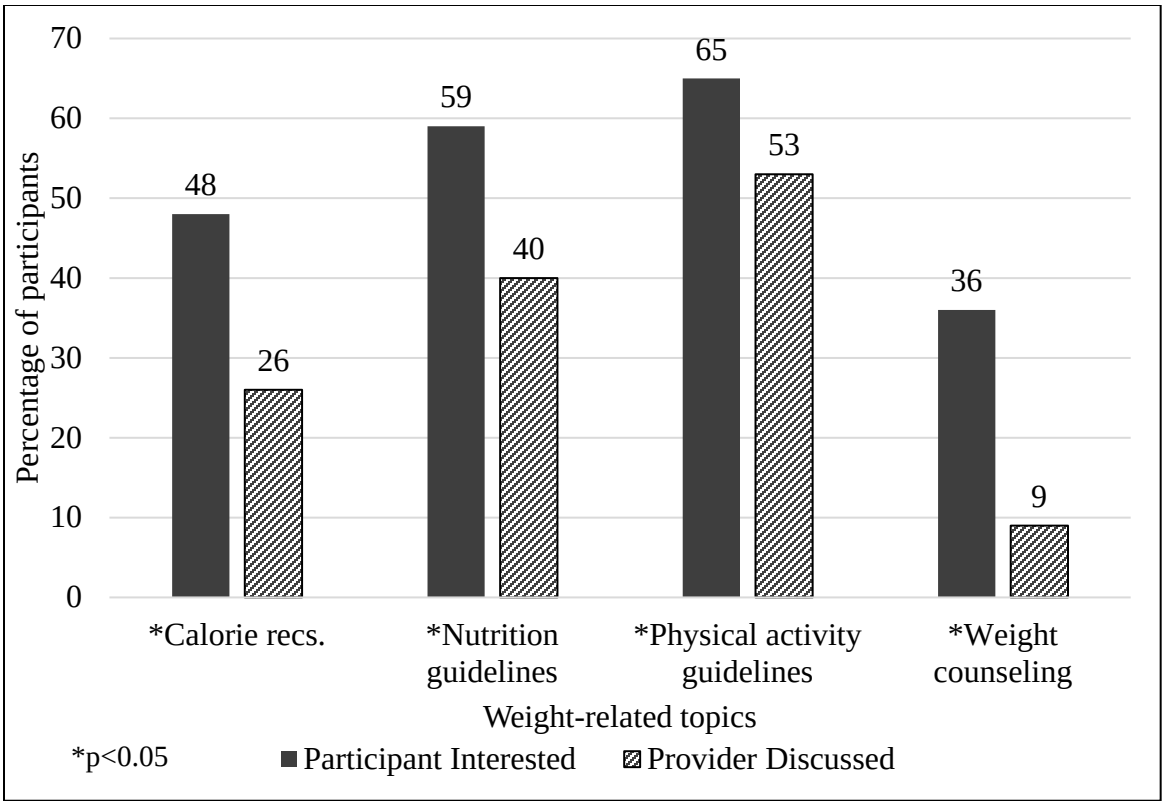

Figure 4.3. Percentage of participants interested in weight-related topics versus percentage of participants who reported provider discussions about those topics (n=324)

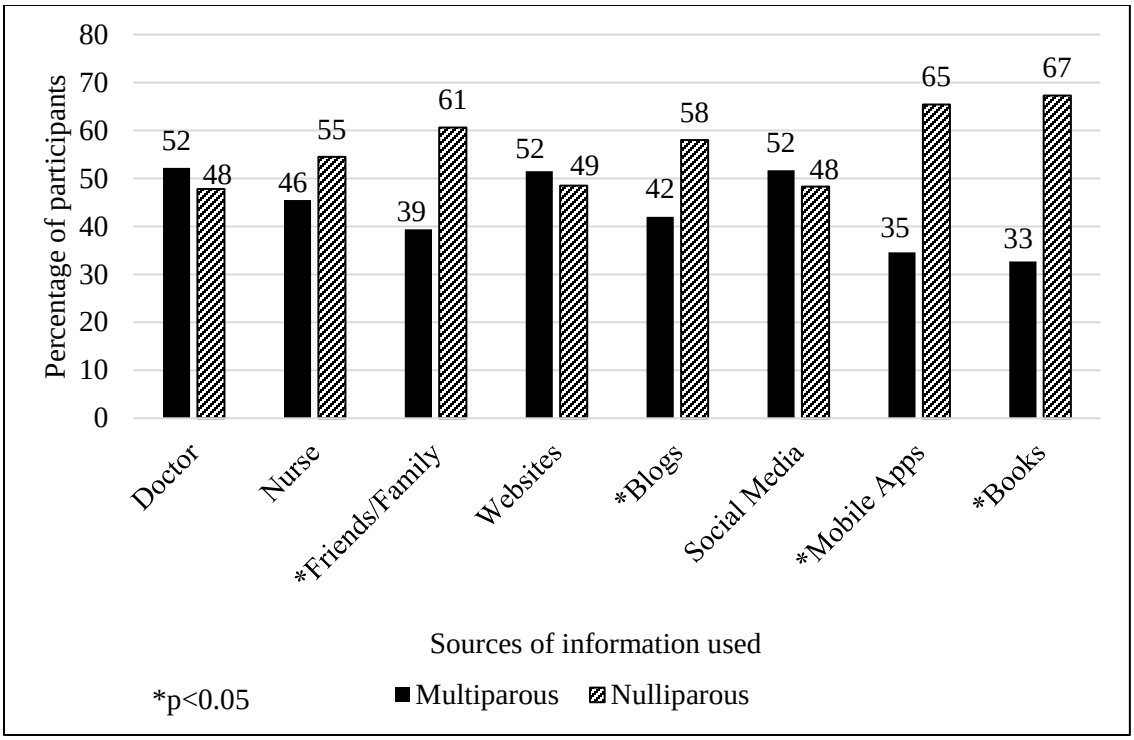

Figure 4.4. Percentage of participants using various resources for nutrition and physical activity information during pregnancy (n=324)

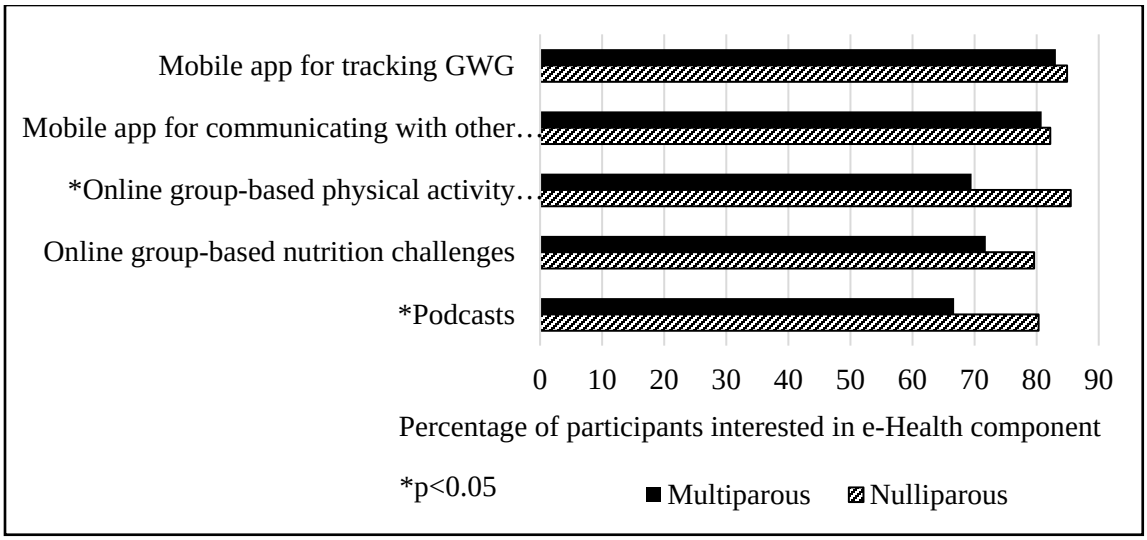

Figure 4.5. Percentage of participants reporting an interest in proposed e-Health intervention features by parity. (n=324)

4.3. The Healthy Motivations for Moms-To-Be Study: A Randomized Controlled e-Health Intervention to Reduce Excessive Gestational Weight Gain during Pregnancy

Prepared for: *Maternal and Child Health Journal*
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ABSTRACT

Objective: To determine the impact of a mobile health intervention pilot, Healthy Motivations for Moms-To-Be (HM2B), targeting healthy eating and physical activity (HEPA) on GWG and increase the proportion of women who gain within the Institute of Medicine's (IOM) guidelines for healthy gestational weight gain (GWG).

Methods: Healthy pregnant women (N=140) living in the U.S. were recruited through social media to participate in a randomized controlled electronic health intervention, which consisted of a mobile app for facilitating group-based healthy behavior challenges and a website for tracking health outcomes (i.e., GWG). The intervention condition targeted healthy eating and physical activity behaviors during pregnancy, while the comparison condition focused on stress reduction and management during pregnancy. Pre-pregnancy weight and weight at delivery were self-reported to determine GWG in relation to IOM guidelines.

Results: Participants who completed their delivery outcomes survey were included in the analysis (n=87). The sample was predominately white (81.6%) and highly educated (advanced degree beyond Bachelor's; 58.6%). Regarding adherence to IOM guidelines, there was a promising, but non-significant, proportion of women gaining adequate weight in the intervention versus comparison group (36% vs. 25%) while more women in the comparison group exceeded IOM guidelines compared to the intervention group (53% vs. 43%, p=0.42). There was a significantly positive difference observed in post-intervention healthy eating behaviors reported between groups (F (1, 87)=4.07, p=0.047).

Conclusions for practice: Although the effect of the intervention on reducing excessive GWG was not significant, the HM2B study demonstrated success in facilitating healthy

eating behavior change through group-based goal setting and monitoring using a mobile app. Future studies should explore opportunities for increasing user engagement and interaction for maintained use of eHealth interventions.

MANUSCRIPT

In response to the growing body of evidence linking excessive gestational weight gain (GWG) to adverse maternal and child health outcomes, the Institute of Medicine (IOM) established a set of recommendations for healthy GWG based on pre-pregnancy Body Mass Index (BMI).[3] For women entering pregnancy underweight (BMI below 18.4 kg/m^2), the guidelines suggest a range of 28-40 pounds for healthy GWG, while normal weight women (BMI between 18.5-24.9 kg/m^2) are recommended to gain 25-35 pounds.[3] For overweight women (BMI=25.0-29.9) the recommended total weight gain range is 15-25 pounds, with a 0.6 pounds/week rate of weight gain in the second and third trimesters.[3,40] Obese women (BMI>30) are recommended a total weight gain range of 11-20 pounds, with a 0.5 pounds/week rate of weight gain in the second and third trimesters.[3,40] Coupled with these recommendations, the IOM suggests prenatal counseling on diet and physical activity (PA) to help women gain a healthy amount of weight during pregnancy.[3] However, several studies have found that health care providers are not consistently sharing these guidelines and often report barriers to providing nutrition and PA counseling, such as lack of expertise and time restrictions.[16,144,152]

To address this need for communicating about and monitoring GWG, several behavioral interventions have aimed to reduce the proportion of women who exceeded IOM recommendations for healthy GWG, often resulting in modest outcomes or mixed results.[22,23,174,192] Traditional methods of intervention delivery can be labor and resource

intensive. With upwards of 50% of women exceeding IOM recommendations for healthy GWG,[2–4,7] there is a significant need for finding scalable approaches to behavioral interventions to reduce the prevalence of excessive GWG and associated adverse health outcomes.

Few pregnancy-focused behavioral interventions have used electronic technology for intervention content or delivery.[26,27] Technology serves as a readily available resource for most pregnant women in the U.S.,[99,144] increasing the potential scalability and reach of GWG interventions. Mobile apps may be a particularly accessible health communication platform as 76% of U.S. adults own a smartphone.[24] Related to pregnancy, a 2015 report of smartphone use among millennial mothers born between 1981 and 1996 indicated upwards of 90% owned a smartphone and over 50% owned both a smartphone and a tablet.[193] While accessibility through technology is considered a benefit of electronic health (e-Health) interventions, however, there are concerns regarding the accuracy of information that is freely available through online.[127,194] Mobile apps fail to adhere to guidelines or behavioral components for supporting healthy GWG.[28] There is an opportunity for accessible, research-driven e-Health interventions that provide accurate GWG recommendations and empirically supported behavior change components (i.e., weight tracking) to improve the scalability and sustainability of intervention efforts.[26,27,195]

The primary objective of the Healthy Motivations for Moms-To-Be (HM2B) study was to compare the amount of weight gained during pregnancy among women in a remotely-delivered e-Health intervention targeting healthy eating and PA behaviors versus a comparison condition targeting stress reduction and management. Within the

examination of total GWG, another purpose of the research was to explore the effects of the e-Health intervention on increasing the proportion of women who gained adequate weight according to IOM recommendations for healthy GWG.

METHODS

Participants

Pregnant women were recruited through Facebook and Twitter social networking websites to complete an online screening form (n=761). Interested and initially eligible participants were contacted by phone to confirm eligibility with a series of additional questions regarding health history and current pregnancy (n=280). If eligible, study staff administered an online informed consent and a health history questionnaire. Inclusion criteria were: 1) singleton pregnancy, 2) within the first half of pregnancy (≤20 weeks gestation), 3) ages 20-35 years, 4) pre-pregnancy BMI greater than 18.5 kg/m^2, 5) current resident of the United States, 6) owner of a smartphone, 7) owner of a bathroom scale, 8) able to read and speak English, 9) willing to download and use a mobile app for the duration of the intervention (12 weeks), 10) access to regular and consistent Wi-Fi or a data plan. Exclusion criteria included recent (within past six months) hospitalization for a mental health or substance abuse disorder, persistent bleeding in the first trimester, history of three or more miscarriages, history of incompetent cervix, prior eating disorder or malnutrition, presence of physical disabilities that prevent exercise, physician restricted exercise guidance during pregnancy), or a medical condition that may impact pregnancy outcomes or one's ability to engage in physical activity (i.e., preexisting or uncontrolled hypertension).

Once enrolled, participants were emailed a link to complete an informed consent form and baseline survey. After completion of the survey, participants were randomized to an intervention (n=77) or comparison condition (n=63). Randomization was stratified by self-reported pre-pregnancy BMI to ensure equal distribution of BMI across study conditions and led to slightly greater randomization to the intervention group. After randomization, participants were emailed a set of tailored instructions for their assigned intervention condition for the formal orientation to the study.

Orientation included downloading the mobile app and study website, engaging in a practice challenge with the research staff to address any issues with the mobile app functions, and uploading a photo of their current weight displayed on their bathroom scale to verify their baseline weight. If a participant submitted a photo-verified weight during orientation that was vastly different from the self-reported pre-pregnancy weight on the baseline survey, the study team contacted the participant to confirm pre-pregnancy weight. If the confirmed pre-pregnancy weight classified the participant as underweight, they were removed from the sample. Nine participants failed to complete the orientation tasks. Participant weight photos were only shared with members of the research staff for data collection purposes. The study protocol was approved by the Institutional Review Board at the University of South Carolina.

Study Design

HM2B used digital technologies for all study procedures (e.g., recruitment, enrollment, data collection, intervention delivery, and incentives). Guided by the Unified Theory of Acceptance and Use of Technology,[30] which draws on Social Cognitive Theory[31] and the Theory of Planned Behavior,[33] the HM2B study addressed social

support and self-monitoring constructs for healthy behavior change. The study was a two-armed randomized controlled trial in which the primary intervention group received educational materials targeting healthy eating and physical activity (HEPA), while the comparison group received materials focused on stress reduction and management (SRAM) during pregnancy. Both HM2B conditions received the same dose of content and tested the same mobile platform (one mobile app used for both conditions).

The HM2B study used a free, commercially available mobile app, called MakeMe™, to connect participants in virtual teams of 6-10 other pregnant women. The MakeMe™ app provides a means for connecting individual users into a team setting to host behavioral challenges. For 12 consecutive weeks, teams were asked to complete a daily behavioral challenge on 5 of the 7 days of the week that aligned with their respective intervention target (HEPA vs. SRAM). For example, a group-based behavioral challenge for the HEPA condition was to "Eat five servings of fruits and veggies" on any 5 of the 7 days during the assigned week. An example of a challenge for the SRAM condition was to "Share a gratitude journal entry" on 5 of the 7 days. The challenges were developed by the PI, based on theoretical constructs such as behavioral capability, social support, and validation. Table 4.9 outlines the challenges included in the HM2B intervention. Participants were only able to view the interactions within their assigned team and they were unable to access the other conditions' challenges.

In addition to the group-based mobile app component, participants were also instructed to log onto a personalized profile on the HM2B study website from randomization until delivery to self-monitor their health and access pregnancy-related resources. The website contained content related to participants' respective intervention

conditions (HEPA vs. SRAM), and participants were unable to access the other group's content. Website content included: individual health outcome monitoring features (i.e., tracking weekly weight gain or recording perceived stress levels), informational podcasts (approximately 15-30 minutes in length), and weekly informational tips linked to outside resources for HEPA or SRAM during pregnancy. The podcasts used for the HEPA group focused on increasing knowledge and behavioral strategies tied to healthy weight management during pregnancy (i.e., reading nutrition labels, the importance of vegetable consumption).[133] The SRAM condition had access to podcasts that were guided relaxation and meditation focused.

The GWG graph for participants in the HEPA condition was individualized by pre-pregnancy BMI data providing upper and lower IOM recommendation graph lines for reference, total weight gained to date, and an indicator of weekly weight gain rate based on IOM guidelines.[196] Given the participants were using two intervention tools, weekly reminders were sent via email to encourage participants to join the team challenge in the MakeMe app and to use the HM2B website to track their weight or stress levels, respective of their group assignment, and access study resources.

Key Measurements

To evaluate the effects of the behavioral intervention, study participants completed online surveys at two time points: baseline ($\leq$20 weeks gestation) and upon completion of the group-based segment of the intervention (32-34 weeks gestation). Questions regarding demographic data were adapted from the Pregnancy Risk Assessment Monitoring Surveillance Survey and included health history, pregnancy status, education level, income level, employment status, and relationship status.[152] The

primary outcome of interest was GWG, and the secondary outcomes included the proportion of women with adequate GWG according to IOM recommendations (i.e., inadequate, adequate, or excessive GWG), healthy eating behaviors, and physical activity behaviors.

Total gestational weight gain

Pre-pregnancy weight was self-reported on the online screening form. To control for misreporting throughout the study, participants were asked to verify their pregnancy weight during baseline orientation and 32-weeks gestation by uploading a photo of their bathroom scale display. Participants were asked to self-report their final pregnancy weight before delivery through a delivery outcomes survey completed between weeks 1-4 postpartum. Photo-verified postpartum weight at the time of the delivery outcomes survey was used as a validation measure to confirm self-reported weight on the survey was accurate. Total GWG was calculated by self-reported final pregnancy weight before delivery minus pre-pregnancy weight.

IOM guideline adherence

Total GWG was used to determine if participants met IOM guidelines based on their pre-pregnancy BMI and gestational age at delivery (reported 1-4 weeks after delivery).[179,197] The ratio of observed GWG to expected weight gain for gestational age was calculated for each participant, and values were classified as inadequate, adequate, and excessive in relation to the IOM range for healthy GWG.[3,39] For example, a participant with normal weight delivering at 40 weeks has an expected total weight gain of 11.84 kg (0.5 kg in the first trimester + 0.42 kg/week x 27 weeks). This value would be used to define the lower (11.5/11.84*100=97%) and upper range values

(16/11.84*100=135%) of the IOM recommendation. The observed weight in proportion to the expected weight would be adequately met if the participants' value falls between 97-135% for women who were normal weight before pregnancy.

Healthy Eating Behaviors

Dietary patterns were assessed using the Rapid Eating and Activity Assessment for Participants Short (REAP-S) Scale.[154] Items on the REAP-S measure meal behaviors (i.e., skipping breakfast) and serving frequency (i.e., how often do you drink less than 2 servings of milk, yogurt, or cheese a day). Response options were "usually/often (score=3)", "sometimes (2)", "rarely/never (1)", or "does not apply (0)". The thirteen items for the REAP-S were scored on a 0-3 scale, with a greater score indicating healthier eating practices (i.e., responding "sometimes" or "usually/often").[154]

Physical Activity

The 4-item Godin Leisure-Time Exercise Questionnaire was used to assess participants' level of physical activity during a typical 7-day period.[153] Participants reported the number of times per week each level of physical activity (i.e., strenuous, moderate, or mild) was performed for more than 15 minutes.

Statistical Analysis

Sample size calculations (α=0.05 and power 1-β=80%) were based on a previous randomized controlled trial with normal and overweight/obese pregnant women[48] in order to detect a significant between group difference in GWG. In that study, participants in the intensive counseling behavioral intervention (n=57) gained a mean weight of 13.0$\pm$5.7 kg, compared to a routine care group (n=43), who gained a mean of 16.1$\pm$7.0 kg (p=0.01), corresponding to an effect size of 0.49 and 67 participants needed per group.

Assuming 20% attrition, the recruitment goal of about 80 participants was set for each group. This sample size may have been unrealistic given the minimal effects of most studies combined. Combined with attrition, the study may be underpowered.

Due to the online nature of the study and anticipation of a potential lower effect on GWG outcomes due to study design differences, we used a second sample size calculation model based on IOM adherence cited in the literature.[48,85] National data indicates 32% of women gain adequate weight during pregnancy.[198] Using this as the basis for the comparison condition, we estimated a clinically significant increase of 25% of participants who will adequately gain within recommendations for the intervention condition (57%) resulting in a required 61 participants in each treatment arm. Allowing for 20% attrition, recruitment aims were approximately 145-158 (73-79 per group) for a medium effect size.

Descriptive characteristics of the sample were explained using frequencies, percentages, medians, means, and standard deviations. Comparisons of the baseline characteristics across the two groups were conducted with independent samples *t* or Chi-square tests, and any significant outcomes were included as covariates in the statistical models.

The primary dependent variable for this study was total GWG. To examine group differences in total GWG, ANOVA tests were conducted. Secondary outcomes included the proportion of women who gained adequate weight within the IOM recommendation. Multinomial logistic regression was used to analyze the effect of intervention condition (HEPA vs. SRAM) and BMI group on IOM GWG classification (inadequate, adequate, or excessive). Additionally, changes in HEPA behaviors were examined by intervention

condition and BMI group using ANCOVA tests. Pre-pregnancy BMI, parity, and gestational age (weeks) at delivery were used as covariates for analyses.

Only completers of self-reported weight at delivery and postpartum (photo verified) were used in the primary outcome analyses, since weight data at delivery was a critical value for calculating total GWG and identifying whether IOM recommendations were met. A *p*-value of less than 0.05 was established to define statistical significance in all cases. All analyses were performed with IBM SPSS 25 Statistical Software (IBM Corp, 2013).

RESULTS

The participation flow diagram is presented in Figure 4.6. A total of 140 participants were randomized between January 2017 and September 2017. After removing participants due to ineligibility or missed virtual orientation, a total of 122 participants received the allocated interventions. Of the active sample, 87 (71.3%) women completed the weight-related measurements and were included in this primary data analysis (attrition from active participants=28.7%). Of the completers, 47 (54.0%) were assigned to the HEPA condition and 40 (46.0%) received the SRAM treatment. The distribution of pre-pregnancy BMI of completers was balanced across treatment groups due to the stratified randomization approach. Forty-two participants (48.3%) reported a pre-pregnancy BMI of normal weight while 45 (51.7%) reported overweight or obesity. Demographic data of the analytic sample are presented in Table 4.10. A majority of the sample was white (n=71, 81.6%), educated beyond high school (n=85, 97.7%), married (n=79, 90.8%), and employed full-time for wages during pregnancy (n=60, 69%). There were no significant group differences observed across baseline demographic variables (*p*

values>0.05). However, when observed by intervention condition, parity differed between HEPA and SRAM groups. Significantly more women in the HEPA condition were nulliparous (n=37, 72.3%) compared to the SRAM condition (n=23, 42.5%, $p<0.01$). Therefore, parity was used as a covariate in the statistical models.

Gestational Weight Gain

Summary statistics for weight outcomes are provided in Tables 4.11 and 4.3.12 Mean GWG was higher among normal weight participants (15.4 $\pm$ 4.3 kg) than overweight/obese (10.8 $\pm$ 7.4 kg, F (1,87)=11.614, p=0.001). There were no significant differences observed in GWG between intervention (13.3 $\pm$ 6.4 kg) and comparison participants (12.7 $\pm$ 6.6 kg, p=0.72) after adjusting for covariates. Multinomial logistic regression was performed to determine the effects of the intervention condition on IOM GWG classification (inadequate, adequate, or excessive); however, the model was not statistically significant (χ^2(1,87)=63.4, p=0.45).

Healthy Eating Behavior Change

Regarding healthy eating and moderate physical activity, there was a significantly positive difference observed in post-intervention REAP-S scores between groups (F (1, 87)=4.07, p=0.047) when adjusted for baseline REAP-S. Participants in the HEPA intervention group reported higher healthy eating practices (32.9, SE=0.45 out of 39) compared to the SRAM group (31.5, SE=0.47). Pre-pregnancy BMI classification was not a significant predictor of healthy eating behavior change (p=0.82).

Physical Activity Behavior Change

Regarding physical activity post-intervention, there were no observed intervention effects on mild (p=0.42), moderate (p=0.38), or strenuous (p=0.38) physical activity

during leisure time after adjusting for baseline self-reported activity levels. Although non-significant (*p*'s>0.05), participants in the HEPA condition reported a higher mean frequency of mild physical activity (5.7 $\pm$ 9.9 times/week) compared to the SRAM condition (3.6 $\pm$ 2.9 times/week).

Program Feedback

Overall, participants rated the HM2B program as favorable. Participants rated the group-based behavioral challenges as "very good (47.5%)" or "good (25.0%)" and "very useful (28.8)" and "somewhat useful (53.8%)". The MakeMe app was "very easy (40.0%)" or "somewhat easy (50.0%)" for participants to use.

CONCLUSIONS FOR PRACTICE

The primary aim of the Healthy Motivations for Moms-To-Be study was to reduce total GWG and increase the proportion of women within IOM recommendations for healthy GWG. The secondary aim was to improve HEPA behaviors. To our knowledge, this is the first remotely delivered intervention using a mobile app to facilitate a group-based intervention for promoting adequate GWG where participants are connected through virtual networks and therefore not limited by geographical location.[26,27] Although participants in the intervention and control group showed similar GWG, there was no statistically significant effect observed on the prevention of excessive GWG, there were several descriptive differences of proportions in favor of the intervention group versus the comparison group, indicating the potential for large effect in a fully-powered sample. The direction of the results, overall, favored the intervention group for several outcome variables related to healthy eating behaviors. For instance, there was a higher proportion of women gaining adequate weight in the intervention

versus comparison group (36% vs. 25%) while more women in the comparison group exceeded IOM guidelines compared to the intervention group (53% vs. 43%, p=0.42).

The HM2B intervention showed initial evidence in facilitating healthy eating behavior change through an e-Health intervention for pregnant women. Participants who received the intervention targeting HEPA behavioral challenges showed significant improvements in their reported dietary behaviors versus the comparison condition, consistent with in-person behavioral interventions.[22,23,174,199] The positive dietary behavior changes facilitated through the virtual groups in this e-Health intervention demonstrates the potential to supplement existing behavioral interventions aimed at reducing excessive GWG with online elements, consistent with studies aimed at weight loss efforts.[34,200] Furthermore, the self-monitoring of weekly behavioral challenges through virtual teams may hold potential for reducing researcher burden associated with traditional health coaching and weekly telephone call methods.

Regarding physical activity, we did not find significant differences by intervention condition or BMI group. Overall, physical activity was moderate after the intervention which may reflect the physical changes experienced in later weeks of pregnancy (i.e., swelling, bedrest) rather than an effect of the intervention.[201] Future intervention methods may benefit from incorporating a self-monitoring device for physical activity throughout pregnancy, such as a wearable fitness tracker or pedometer to provide women with more concrete goals around increasing physical activity.[133]

This study has several limitations. Most importantly, the sample size calculation may have been unrealistic given the minimal effects of most studies combined with the attrition rate experienced in this study. The sample of completers fell short of the

expected goal for recruitment and retention and therefore may have limited our power to detect significant effects of the intervention. Of the 140 women who were randomized in our study, 122 received the allocated intervention, and only 87 completed the weight measurements post-delivery (attrition rate of 28.7%). Remotely delivered interventions commonly report high attrition rates above 20%.[202–204] Additionally, some studies targeting GWG have reported high attrition rates among their pregnant samples.[23,89,98,139,174] Given the online nature of the HM2B intervention and typically high drop-out rates among young, pregnant samples, we believe that the completion rate was moderate and additional research is needed to understand the feasibility for delivering a mobile health intervention to this population. Additionally, this type of intervention may be more appropriate for certain population subgroups and warrants additional efforts to improve retention.

There are several potential explanations for the high attrition rate of participants including, but not limited to, our inability to reach the participants after several attempts, potential complications with their pregnancy, cell phone service cancellation, or lack of external motivation to participate given the online nature of the study. Additionally, drop-out may have been due to lack of interest or engagement with the intervention post-randomization, specifically for the participants assigned to the Stress Reduction and Management comparison condition. The majority of participants (57.5%) reported low perceived stress at baseline, followed by medium perceived stress (41.4%). Only one participant indicated high stress at the beginning of the study (1.1%). The baseline stress levels may have contributed to higher drop-out among the SRAM participants, given the lack of need for a stress management program.

To reduce participant dropout, one proposed consideration for future e-Health interventions for GWG is the engagement of health care providers in the recruitment and intervention delivery to increase participants' confidence in the credibility of the study as well as increase accessibility of prenatal providers,[122,192] or to identify "high engagers" to incentivize as team leaders to facilitate the virtual group challenges within the mobile app component.[100]

Pre-pregnancy weight data was collected via self-report for the HM2B study. To reduce recall bias, participants were asked to provide photo evidence of their baseline weight by uploading a photo of their bathroom scale display prior to BMI stratification and intervention randomization. During the remaining data collection points, participants were asked to provide another weight photo. While this strategy helped to reduce the limitation of not having a standardized objective weight measure, this photo-verification process may have potentially led to participant attrition if women felt they were not doing as well in the program as they expected or if they were dissatisfied with their pregnancy weight status. A potential solution for future studies would be the use of a Bluetooth or Wi-Fi scale provided to participants that remotely sends weight data to the study team. Partnerships with OB/GYN clinics to conduct medical abstractions on weight data and birth outcomes may be another solution that is traditionally used in behavioral interventions delivered locally.[133]

Consistent with the literature, another limitation of the study is the lack of diversity in the sample, which we attempted to address with remotely delivered intervention methods. Previous studies examining diet and exercise interventions for the prevention of excessive GWG report recruiting mostly highly educated and

predominately white samples.[23,26] Despite our efforts to expand the reach and scope of in-person interventions through electronic delivery methods and the recruitment of women through social media networks and targeted, paid promotional posts online, our sample was not diverse in several demographic characteristics (i.e., race, income, education, relationship status). Additional focused methods are needed to recruit and test the intervention among a more diverse sample to improve generalizability of findings to the larger population of pregnant women living in the United States.

The strengths of this study include the innovative and novel use of virtual teams to facilitate healthy behavior change. The positive healthy eating behaviors reported by the intervention group after participation in the group-based component of the study indicate potential for applying e-Health methods to health behavior change interventions. Moreover, the virtual teams reduced several participation burdens such as geographical location, childcare needs, transportation to and from the study site, and provided flexibility in participation. As stated earlier, it is plausible that the online nature of the intervention contributed to participant drop-off. Furthermore, by recruiting, obtaining measurements, and delivering the intervention solely through electronic platforms, this study demonstrated environmentally and socially relevant approaches to behavioral interventions.

Increasing the reach and accessibility of behavioral intervention efforts is an important consideration for researchers. The Healthy Motivations for Moms-To-Be study was an innovative attempt at delivering a theory-based behavioral lifestyle intervention program targeting healthy GWG among pregnant women living in the United States. Due to the small effect size observed by the HM2B intervention, this project served as an

informative pilot study for a fully-powered sample with greater considerations for attrition due to the online nature of the study.

Table 4.9. List of the group-based behavioral challenges for participants

HEPA weekly challenges	Example daily subtext for group discussion
Prepare a healthy dinner	What choices did you make to have a healthy dinner?
Engage in intentional physical activity for 20+ minutes	Tell the group what activity you did and how many minutes you were active!
Check out the nutrition label on your food	Measure out one serving size of a food item and upload a picture. Do you usually eat less or more than this serving?
Engage in intentional stretching for 20+ minutes	Focus on stretching your muscles daily. Tell the group where you feel the most aches and pains.
Prepare a healthy lunch	Here's the MyPlate guide for a balanced meal. How does your lunch compare?
Aim for 20+ minutes of physical activity	What are some of the challenges you're experiencing with staying physically active during pregnancy?
Eat the most colorful meal you can today	Fruits and veggies are a quick way to add color to your meal! What colors do you need to add in from the rainbow?
Engage in cardio exercise	What are some ways you can add in more steps during the day?

Prepare a healthy breakfast	Fiber is an important nutrient and can help relieve constipation during pregnancy. What breakfast foods do you enjoy that are high in fiber?
Set a HEPA goal for yourself	Are your goals S.M.A.R.T? (Specific, measurable, achievable, realistic, and timely)
Aim for 5 servings of fruits/veggies	What ideas can you share for adding in more fruits or vegetables during the day?
Aim for 12 cups of water	What strategies do you use to replace sugary sweetened beverages with healthier choices?
SRAM weekly challenges	**Example daily subtext for group discussion**
Share a gratitude journal entry	Tell us something you're thankful for today.
Phone a friend	Who do you rely on for emotional support?
Prepare for tomorrow	Share a method you use to keep track of the things you need to get done each day.
Declutter a space you've been avoiding	It can be your email, a junk drawer, a closet, etc! We love before and after pics!
Take a mindful moment and reflect on your day	Focus on something good that came out of your day and share with the group!
Be helpful to someone else	What are some things you anticipate needing help with once the baby arrives?

Take a 20-minute technology break	Tell the group what you did with your 20 minutes of technology free time!
Set a bedtime and track your sleep	Tell your group about the quality of sleep you've had lately
Stressed out? Tell us about it.	Talk about your stressors and how you've been handling the stress during your pregnancy.
Set a healthy goal for yourself.	Share a short-term health goal with the group!
Treat Yo'Self!	Self-care is important. Share some ideas with the group for reserving “me time” when the baby arrives.
Listen to music/podcasts	Have you listened to the HM2B podcasts on the website?

Table 4.10. Baseline demographic characteristics of the analyzed sample (n=87)

	Intervention (HEPA n=47)	**Comparison (SRAM n=40)**	*p*-value
Demographics Mean (SD)			
Age (years)	30.2 (3.6)	29.9 (3.1)	0.60
Gestational age at baseline (weeks)	15.9 (5.4)	14.7 (4.4)	0.29
Gestational age at delivery (weeks)	384 (2.0)	39.1 (1.5)	0.11
Gestational time in the study (weeks)	22.6 (5.9)	24.4 (4.9)	0.13
Pre-pregnancy BMI (kg/m^2)	26.1 (5.3)	27.0 (5.5)	0.45
Pre-pregnancy BMI classification n (%)			0.36
Normal weight	24 (51.1)	18 (45.0)	
Overweight/Obese	23 (48.9)	22 (55.0)	
Race n (%)			0.86
White	38 (80.9)	33 (82.5)	
Black/African American	4 (8.5)	2 (5.0)	
Asian	3 (6.4)	4 (10.0)	
Multiracial	2 (4.3)	1 (2.5)	
Parity n (%)			<0.01
Nulliparous	34 (72.3)	17 (42.5)	
Multiparous	13 (27.7)	23 (57.5)	
Educational level n (%)			0.69
Advanced Degree	27 (57.4)	23 (57.5)	
College Graduate (4-year)	13 (27.7)	11 (27.5)	

Table 4.11. GWG outcomes by intervention condition

	Intervention (N=47)	**Control (N=40)**	**p-value**
Total GWG (kg), mean (SE)	11.34 (1.19)	10.46 (1.19)	0.46
Adjusted total GWG (kg), mean (SE)	11.37 (0.74)	10.43 (0.80)	0.39
Meeting IOM guidelines, n (%)			0.51
Below recommendations	10 (21.3)	9 (22.5)	
Met recommendations	17 (36.2)	10 (25.0)	
Exceeded recommendations	20 (42.6)	21 (52.5)	

Table 4.12 GWG outcomes by BMI group and intervention condition

	Normal weight (n=42)			Overweight/obese (n=45)		
	Intervention (n=24)	Control (n=18)	p-value	Intervention (n=23)	Control (n=22)	p-value
Total GWG (kg), mean (SE)	12.8 (0.7)	13.1 (1.2)	0.83	9.8 (1.4)	8.3 (1.2)	0.41
Adjusted total GWG (kg), mean (SE)	12.7 (0.7)	13.3 (0.9)	0.65	9.2 (1.3)	8.9 (1.4)	0.88
Meeting IOM guidelines, n (%)			0.64			0.75
Below recommendations	4 (16.7)	4 (22.2)		6 (26.1)	5 (22.7)	
Met recommendations	10 (41.7)	5 (27.8)		7 (30.4)	5 (22.7)	
Exceeded recommendations	10 (41.7)	9 (50.0)		10 (43.5)	12 (54.4)	

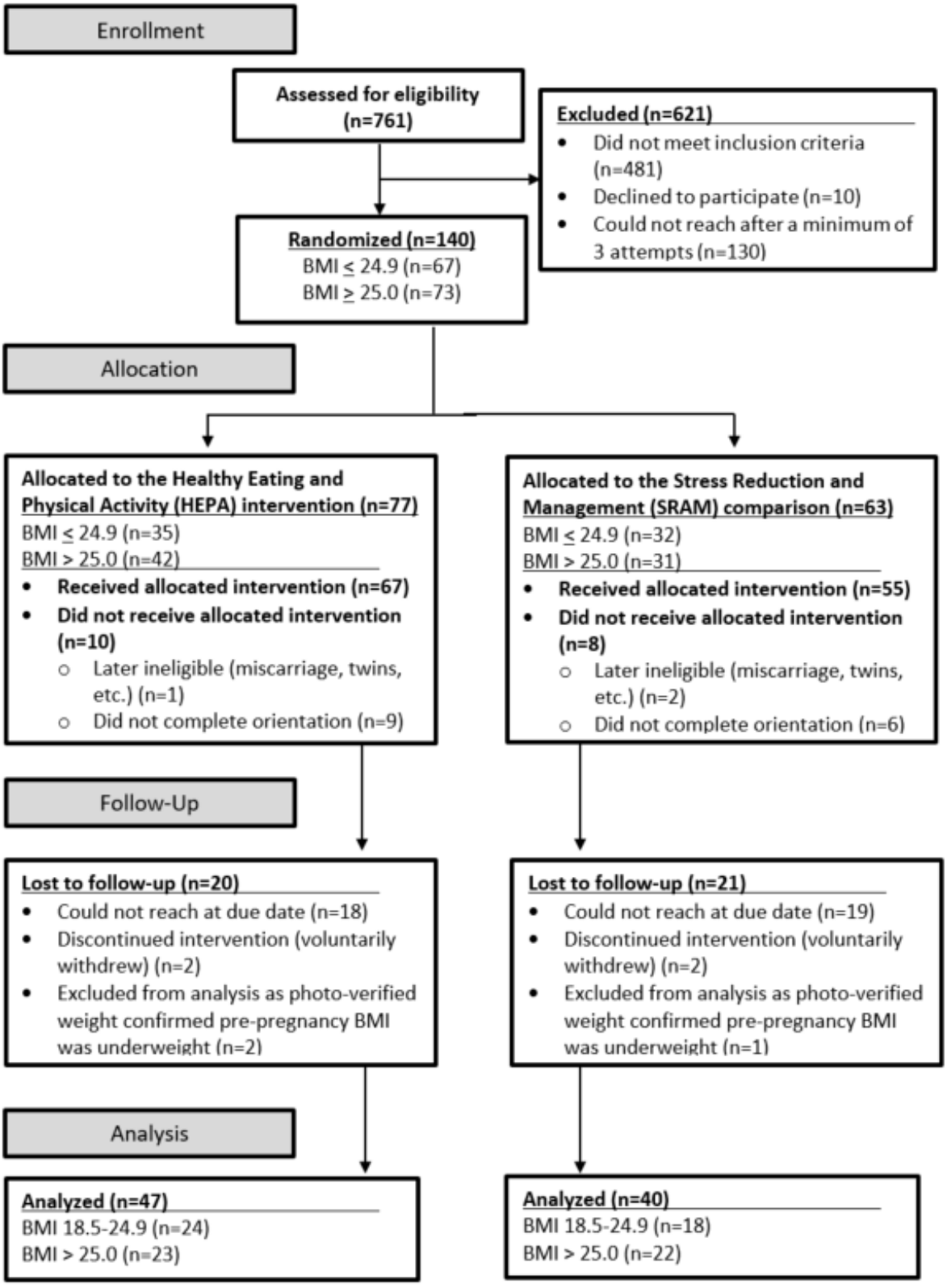

Figure 4.6. Flow chart of participant recruitment and randomization

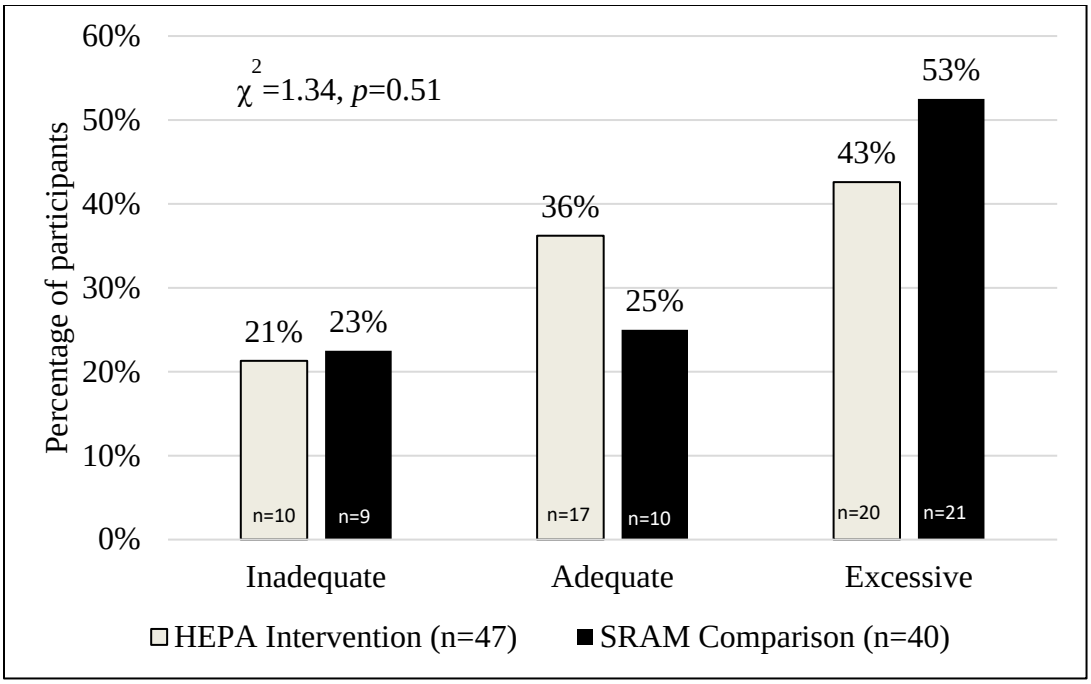

Figure 4.7. Proportions of GWG according to IOM recommendations by intervention condition (n=87)

Chapter 5: Discussion

5.1. Major Findings and Implications

Excessive weight gained during pregnancy is a major public health concern given the associated risks for adverse health outcomes for both the mother and offspring.[5] With about half (48.3%) of U.S. women exceeding 2009 IOM recommendations for healthy GWG,[205] there is a critical need to focus theory-based behavioral interventions on the prevention of excessive GWG. Research has found promising, yet modest, effects of behavioral interventions on reducing the proportion of women with excessive GWG by an average of 20% when diet, exercise, or a combination is the primary focus.[22,23]

The field of eHealth/mHealth is expanding as technology has become ubiquitous. Technology-mediated behavioral interventions (i.e., eHealth and mHealth) have become increasingly popular in public health practice due to the availability of technologies, the ability to expand the reach and scope of intervention efforts, and the potential reduction of researcher and participant burden (i.e., travel to in-person sessions and cost-effectiveness).[29,134,136,140,206] However, the effects of technology-mediated intervention components targeting GWG are inconclusive.[26,27] The types of technologies are changing rapidly and presents a challenge for researchers to identify which types are best for different behavior change applications, topics, or activities. Moreover, as demonstrated by the BMI group-specific intervention effects observed in the studies of the systematic review aim, certain e-Health intervention components may not be as effective across all

subgroups within a given sample. Identifying the e-Health intervention components (i.e., GWG tracking, health coaching) that are more effective for different groups may be an advantageous strategy for moving the field of technology-based interventions forward.

The use of technology for intervention delivery was a primary focus of the Healthy Motivations for Moms-To-Be Study. This study 1) systematically reviewed existing literature of behavioral intervention strategies supported by technology in the prevention of excessive GWG, 2) assessed the informational needs and preferences of pregnant women to inform the intervention design and tools, and 3) examined the effects of a remotely-delivered behavioral intervention targeting GWG among pregnant women in the U.S. The target audience of pregnant women in the HM2B study were aged 20-35 and fell within the millennial generation (born between 1981 and 1996). A 2015 report found that 80% of millennial moms reported owning a smartphone, with over 50% owning a smartphone and tablet.[193] Studies targeting women of childbearing age report high feasibility for eHealth interventions.[72,98,137] However, there is a need for exploring effective intervention methods and scalable approaches through technology for the prevention of excessive GWG and the reduction of GWG overall.

The HM2B study aimed to test the feasibility and effects of a randomized controlled trial in which the two conditions simultaneously used an online, personalized study website with information and theory-based podcasts, pregnancy health-related resources, and a tracking feature (i.e., GWG or stress), in addition to a mobile app for engaging in virtual teams working towards a common behavioral goal for 12 consecutive weeks. The HM2B intervention components and dose were informed by the previous literature reviewed as Aim 1. Several of the studies included in the systematic review

were ongoing and did not yet report effectiveness data; however, the methods and technology components were used to guide the HM2B intervention. Although the systematic review did not produce a clear recommendation on best practices for technology-mediated interventions examining GWG due to the varying methods, outcome variables, and technologies used, the review was informative about the feasibility of eHealth implementation among a pregnancy population. With the growing interest around technology-based interventions, there is a need for establishing rigorous methods for the development and testing of eHealth tools or intervention strategies.

Furthermore, appropriately classifying interventions as technology-mediated or eHealth based on the tools used and delivery mode is critical in establishing an evidence-base for best practices.[26,195,207] For instance, an in-person, group-based intervention study that uses email only to remind participants about upcoming measurement visits may not be considered an eHealth intervention, since the intervention components and channels are not tech-based, whereas an intervention testing the use of daily YouTube exercise videos for increasing physical activity during pregnancy may fit the eHealth category.

In addition to the systematic review, additional formative research was needed to guide HM2B intervention components. Aim 2 of this dissertation focused on conducting a needs assessment of health information needs and preferences for an eHealth intervention among pregnant women in the U.S. This needs assessment found that, during pregnancy, most women report seeking information related to nutrition and physical activity from websites, followed by doctors. Overall, participants indicated high levels of interest in different eHealth intervention components (i.e., podcasts and group-based behavioral challenges), with a mobile app GWG tracking feature as the most desired.

First-time moms expressed greater interest in the proposed intervention features that were information based (i.e., podcasts) and supported physical activity, compared to multiparous women. An implication for public health research and practice is to consider parity-specific intervention designs as an effective approach for group cohesion and participant engagement.[120]

The HM2B intervention was limited in statistical power due to attrition and did not yield a significant reduction on GWG or the proportion of women who exceeded IOM guidelines. However, the e-Health intervention showed promise in facilitating healthy eating behavior change (i.e., reduction of fast food consumption) in pregnant women. Participants showed significant improvements in their reported dietary behaviors after receiving the HEPA intervention versus the comparison condition, consistent with in-person behavioral interventions.[22,23,174,199] The positive dietary behavior changes facilitated through the virtual groups in this e-Health intervention demonstrates the potential to supplement existing behavioral interventions aimed at reducing excessive GWG with online elements, consistent with studies aimed at weight loss efforts.[34,200]

Overall, participants rated the HM2B program as favorable. Participants rated the group-based behavioral challenges as “very good (47.5%)” or “good (25.0%)” and “very useful (28.8)” and “somewhat useful (53.8%)”. The MakeMe app was “very easy (40.0%)” or “somewhat easy (50.0%)” for participants to use. Unfortunately, participants did not find their virtual groups to be interactive, helpful, or providing social support. Due to the lack of interaction within the groups, most participants reported little motivation from group members for meeting the weekly challenges. The frequency of participant posts (daily on 5 of 7 days in a week) did not generate much discussion

between members, except for one study team. A major implication for public health research and practice is to consider how design elements for social interactions or the use of social networks in an intervention does not guarantee group cohesion or feelings of social support. For example, daily prompts or polls to encourage participants to post within the virtual group may be a potential strategy to elicit participant interactions. Technology is advancing at a rapid rate, making communication opportunities more accessible and diverse. Video calling and conferencing allows an opportunity for participants to virtually connect and interact in a face-to-face platform, while reducing participation barriers like transportation to the intervention meetings or restricting the sample to a specific geographical area. Further exploration of how to engage online users or virtual teams effectively should be considered.[32,100]

5.2. Limitations

This study was subject to several limitations and results should be interpreted with consideration. For Aim 1, the systematic review of technology-mediated interventions for healthy GWG, the variations in sample size, intervention design, methodologies, and technologies used across the studies presented a limitation for pooling results and conducting a meta-analysis. There were also several studies included in the review that were ongoing and did not have GWG outcomes published yet. Due to these limitations, a recommendation for best intervention practices using technology for GWG efforts could not be established. The intention of Aim 1 was to guide the development of the intervention methods, however, the systematic review yielded little direction for ideal approach and behavioral strategies. The review was informative for understanding the feasibility and barriers of technology-mediated interventions.

The intentional design for remote-delivery of the HM2B study presented a few limitations, specifically for Aims 2 and 3. The samples for both the needs assessment and the intervention were not diverse in several demographic characteristics (i.e., race, income, education, relationship status). This is potentially a fault of the online recruitment methods design using social media networks. By design, the recruitment text was meant to be organically shared through social networks but also strategically targeted to specific user profile interests (i.e., pregnancy blogs and baby products) and identifiers (i.e., geographical location and age). Previous studies examining diet and exercise interventions for the prevention of excessive GWG report recruiting mostly highly educated and predominately white samples.[23,26] Despite our efforts to use social media networks for targeted, paid promotional posts online, additional focused methods are needed to recruit and test the intervention among a more diverse sample to improve generalizability of findings to the larger population of pregnant women living in the United States.

While this study was aimed at smartphone users, a significant portion of users may not have an active presence on social media and therefore were not recruited for participation. A broader limitation of this approach to online recruitment and intervention methods was a potentially skewed sample of high online engagers with greater interest in eHealth features than the general population. Similarly, one of the goals for this eHealth intervention was to increase the accessibility of the intervention to hard-to-reach populations, based on the ubiquitous use of smartphones and social media among millennial mothers.[193] Recruitment through online-only methods may have inadvertently excluded potential participants who do not have Wi-Fi service or data plans for their

smartphones, or simply lack a presence on social media, therefore undermining the goal of accessing hard-to-reach population subgroups.

While the HM2B intervention in Aim 3 alleviated a few barriers to participation associated with traditional in-person intervention methods, such as childcare or scheduling conflicts, the online nature of the intervention presented new challenges that are important to consider for future eHealth interventions. A major limitation was the lack of face-to-face interaction for participants to connect with their assigned group members. Traditional in-person methods may help to establish rapport with group members that can then be maintained by online interactions like the MakeMe app challenges used in this study. Participants rated the interactions between group members on the mobile app to be relatively poor. Since the women in this study ranged in geographical region, a potential solution to this limitation would be to host online group orientations or a video introduction of team members.

An associated barrier to the online-only methods used in Aims 2 and 3 was the lack of objective anthropometric measures of height and weight, dietary intake, and physical activity. Self-reported measures were used and subjected the data to error; however, a validation study found high correlation (r=0.99) between self-reported pre-pregnancy and clinically measured weight.[13] Moreover, health care providers and prenatal clinics were not involved in the study, and therefore could not verify respondents' information related to their pregnancies. In an effort to reduce said error for the intervention, Aim 3 included photo-verified weigh-ins at three time-points. As part of the orientation process, participants were asked to download the app and verify their

starting weight with a photo. Fifteen participants did not complete the weight-verification during orientation and therefore could not move further along in the study (10.7%).

An additional major limitation of the HM2B study was the use of a commercially available, free mobile app. While this platform prevented the need to design an app for the study, the research team did not have control over all the features available in the app. A few participants had trouble logging into the app on multiple occasions, could not use all the functions of the app correctly (i.e., photo uploads), and expressed compatibility issues. Since the HM2B study did not develop the MakeMe app, troubleshooting these issues was time consuming and a barrier for participants. Near the end of the HM2B study, the mobile app was removed from the marketplace and no longer available for public use. This did not affect the participation or data collection for HM2B, but could have been a foreseeable limitation if our group-based intervention efforts were extended past December 2017.

Lastly, the small sample size, high attrition rate, and lack of statistical power may have limited the ability to detect significant findings. These factors may have individually and/or collectively impacted the internal and external validity of results. HM2B used a per-protocol approach since the data collection relied on self-reported weight, and therefore non-completers were not included in the primary analysis on GWG. A potential solution to this limitation would have been a partnership with health care providers and clinics to conduct medical abstractions for all data to provide an objective measure of maternal weight status and delivery outcomes. In regards to the high attrition rate, an in-person meeting or virtual video conference to allow participants to meet and interact prior to the group-based behavioral challenges may have established group cohesion. Another

potential solution to the high attrition rate may be a comparison group that strictly served as a control, with no SRAM intervention. For this sample, the perceived stress level of participants was relatively low and therefore the SRAM-focused intervention may not have felt necessary or important to the participants with low stress at the beginning of the study.

5.3. Future Directions

Technology offers innovative solutions to repeated barriers of traditional public health interventions and prenatal care.[114,140,207] For example, the use of mobile apps or wearable devices to track individual behaviors (i.e., steps per day) have become increasingly popular as mobile phones became ubiquitous. However, the literature examining the effects of behavioral interventions on GWG mediated by technology is limited. The studies synthesized in the Aim 1 systematic review used varying methods and rarely tested the effect of delivery modes or behavioral tools. There is a growing demand for evidence-based, rigorous studies that mobilize effective intervention strategies with technology. More research is needed to empirically test the effects of eHealth intervention components to identify best practices in this field. In regard to pregnant women, there is resounding support for eHealth as an accessible and feasible approach to intervention delivery for women of childbearing age.[99,136,137,193,208] The development of theory- and evidence-based intervention components is essential in moving this area of eHealth research forward.[28]

The HM2B study was an attempt at providing participants with an opportunity to connect virtually with other participants working towards a common goal while also using a personalized website for monitoring pregnancy health-related outcomes (i.e., weight or stress). A next iteration of the HM2B study might include a merged platform

for participants to engage with group members but also access the personalized profile. Participants in the HM2B study repeatedly suggested having a single mobile app or website that included the group-based challenges and informational content (i.e., podcasts, GWG graphs, and external resources) so they did not have to switch back and forth. A single HM2B app or website may have reduced drop-out among participants who found the two-platform system confusing or burdensome.

Additional testing of the HM2B intervention materials and website design may be advantageous for a next iteration as well. Specifically, testing the podcasts and group-based behavioral challenges among different population subgroups (i.e., racial or age), by parity or pre-pregnancy BMI may provide a more targeted intervention that addresses the specific health information needs of the sample. Given the results of the needs assessment in Aim 2, parity may play an important role in interest and retention of participants enrolled in a behavioral intervention targeting GWG.

In the context of future interventions, there are four main recommendations from lessons learned in the HM2B study. The first recommendation is to revisit the intervention design to enhance the statistical power of the analyses and the ability to detect differences between groups and understand the effects of the intervention over time. One suggestion to address this recommendation would be to test a standard care control group compared to an eHealth intervention using both group-based and individualized behavioral strategies, like the HM2B intervention condition. Using an intent-to-treat design with dependent variables obtained from medical records would additionally enable the assessment of feasibility in terms of how many people would participate in a typical intervention. Another option is to employ a SMART design, as

people who stop participating and/or are not engaging with the eHealth intervention may respond better to an in-person or telephone-based intervention that adds in more interpersonal contact and accountability. Another potential suggestion for intervention design would include testing the effectiveness of an in-person intervention compared with a virtual setting condition, where the content and materials are the same but offered across two different platforms. Within this recommendation, a cost-effectiveness analysis would be beneficial to better understand the trade-offs between intervention delivery modes and provide justification for future eHealth interventions.

Second, the integration of health care providers in the intervention design and delivery methods may fill the critical gaps found in this study regarding providers' perceived barriers to counseling women on GWG and related behaviors.[16,17,21,92,138,184] Previous research has shown greater reduction of GWG when providers are involved in the intervention delivery.[192] The third recommendation would be to understand the impacts of this HM2B behavioral intervention on postpartum health outcomes to contribute to the growing body of evidence examining the role of the gestational environment on postpartum weight retention and childhood adiposity.[8,11,13] Obesity prevention is at the forefront of public health efforts, as rates in the US exceed two-thirds of the population.[132] To do this, researchers may extend the data collection into the postpartum period.

Lastly, in terms of future study populations to work with, there are important considerations for determining the target sample and tailoring the intervention materials to specific cultural and linguistic norms. While the HM2B study recruited a predominately white, highly educated sample, the intervention podcasts were originally

written to address social norms of white and African American women living in the southeastern region of the United States.[133] Despite the push for increasing the reach and scope of public health intervention efforts, intervention materials should be tested among population subgroups for cultural appropriateness, otherwise scaling up may not be effective. In a future iteration of the HM2B study, input from population subgroups on the mobile app design, elements within the app, and accessibility to the intervention would be important to consider. For instance, if working with a sample that has low literacy, it may be advantageous to use simple icons and images within the mobile app and keep medical jargon to a simpler form.

Related to tailored intervention materials, there are important considerations for recruiting hard-to-reach and more diverse samples. A tech-based intervention may not be ideal for all population subgroups due to accessibility issues like inconsistent telephone service. When recruiting participants for an e-Health intervention, it is important to consider participation barriers and provide solutions. For instance, an incentive for participating in the research study could be pre-paid calling cards or data plans. A more feasible approach may be coupling e-Health components with in-person and non-tech dependent intervention components so that a disruption in technology access does not eliminate the opportunity to participate.

5.4. Concluding Remarks

Pregnancy presents a critical window of opportunity for maternal and child health, specifically regarding metabolic programming[189] and weight status.[36] Developing and testing scalable approaches to pregnancy health promotion and excessive GWG prevention is necessary to reduce the prevalence of women who exceed IOM guidelines. The HM2B study tested a remotely delivered intervention targeting GWG. Although the

intervention was not successful at significantly reducing the proportion of women who exceeded IOM guidelines, the intervention group yielded several favorable improvements in dietary behavior changes. Overall, the results of the HM2B study demonstrate promise in eHealth interventions for healthy eating behavior change but warrants additional modifications to test the effectiveness of this model on GWG outcomes.

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Appendix A: Needs Assessment IRB Approval Letter

INSTITUTIONAL REVIEW BOARD FOR HUMAN RESEARCH
APPROVAL LETTER for EXEMPT REVIEW

This is to certify that the research proposal: **Pro00054713**

Entitled: *Pregnancy Health-Related App Motivations & Experiences Survey*

Submitted by:

Principal Investigator: Alicia Dahl
College/Department: Arnold School of Public Health
Health Promotion, Education, and Behavior
915 Greene Street
Columbia, SC 29208

was reviewed in accordance with 45 CFR 46.101(b)(**2**), the referenced study received an exemption from Human Research Subject Regulations on **4/15/2016.** No further action or Institutional Review Board (IRB) oversight is required, as long as the project remains the same. However, the Principal Investigator must inform the Office of Research Compliance of any changes in procedures involving human subjects. Changes to the current research protocol could result in a reclassification of the study and further review by the IRB.

Because this project was determined to be exempt from further IRB oversight, consent document(s), if applicable, are not stamped with an expiration date.

Research related records should be retained for a minimum of three (3) years after termination of the study.

The Office of Research Compliance is an administrative office that supports the University of South Carolina Institutional Review Board (USC IRB). If you have questions, contact Arlene McWhorter at arlenem@sc.edu or (803) 777-7095.

Sincerely,

Lisa M. Johnson
IRB Manager

Appendix B: Needs Assessment Survey

Welcome to the Pregnancy Health-Related App Motivations & Experiences Survey (PHRAMES)!

Thank you for participating in this online survey. We are researchers at the University of South Carolina and we are conducting a brief survey of **currently pregnant women living in the United States**. ***If you are not currently pregnant, we appreciate your interest but ask that you do not provide feedback at this time.*** This survey will help inform researchers about the needs and interests of current pregnant women to guide the development of an electronically delivered health intervention.

As a thank you for your participation, you will be entered into a drawing for $25 Amazon gift cards for completing the survey (odds of winning depend on the number of participants who complete the survey but are estimated at 1 in 50). Winners will be notified by email at the end of data collection (estimated end date: 5/31/2016).

Please feel free to contact me with any questions. Thank you in advance for your time and honest responses.

Alicia A. Dahl, M.S.
Doctoral Student
Department of Health Promotion, Education, and Behavior
Arnold School of Public Health
University of South Carolina
Phone: 803-777-9905
Email: adahl@email.sc.edu

Screening Questions

1) Are you currently pregnant?*

- ○ Yes
- ○ No

2) Do you currently live in the United States?*

- ○ Yes
- ○ No

3) Do you own a smartphone?*

- ○ Yes
- ○ No

4) Would you like to continue to the survey?*

- ○ Yes
- ○ No

Current Pregnancy Information

For each of the following questions, please select or enter the best response regarding your current pregnancy:

5) When is your due date?*

6) Are you expecting multiples?

- Yes
- No
- Not sure

7) Are you a first time mother?

- Yes
- No

8) When you got pregnant with your new baby, were you trying to get pregnant?

- Yes
- No

Respondent's Demographic Information

For each of the following questions, please select or enter the response that best describes you:

9) How many other children do you have?

10) How would you describe your current relationship status? (You may select more than one response.)

- Single
- In a relationship
- Married
- Separated
- Divorced
- Widowed
- Other

11) Are you Hispanic or Latina?

- Yes
- No

12) What is your racial background? (Check all that apply.)

- American Indian or Alaskan Native
- Asian
- Black or African American
- Native Hawaiian or Other Pacific Islander
- White
- Other - Please describe::

13) What is your age? (Please answer in years.)

14) What is your highest level of education? (Please choose only **one** of the following.)

- 8th grade or less

- ○ Some high school
- ○ High school graduate or equivalent
- ○ Some college or Associate's degree
- ○ College graduate (4 year)
- ○ Advanced degree (Masters, doctoral, or other post-college degree)

15) What is your current employment status? (Please select all that apply.)

- ☐ Employed for wages full time (30 hours or more per week)
- ☐ Employed for wages part time (less than 30 hours per week)
- ☐ Self-employed
- ☐ Unemployed
- ☐ A homemaker
- ☐ A student
- ☐ Retired

16) What zip code do you currently live in? (Example: 98765)

Respondent's Height and Weight Characteristics

For each of the following questions, please select or enter the response that best describes you:

17) How tall are you without shoes?

Feet:

Inches:

18) Just before you got pregnant with your new baby, how much did you weigh? (Please answer in pounds).

19) What is your current weight? (Please answer in pounds.)

20) In the past year, how often did you weigh yourself on a scale?

- ○ Daily
- ○ Weekly
- ○ Monthly
- ○ Every few months
- ○ Yearly
- ○ Never

Current Pregnancy Health Status

For each of the following questions, please select or enter the best response regarding your current pregnancy:

21) How much weight do **you** believe would be a healthy amount to gain over the course of your current pregnancy? There is no right or wrong answer. (Please answer in pounds.)

22) During your current pregnancy, has a physician (Primary Care Provider or Obstetrician) discuss weight gain recommendations with you?

- Yes
- No

23) At any time during the ***12 months before*** your current pregnancy, did you do any of the following things? For each item, check **Yes** if you did do it or **No** if you did not do it.

	Yes	No
I was dieting (changing my eating habits to lose weight).		
I was exercising 3 or more days of the week.		
I was regularly taking prescription medicines other than birth control.		
I visited a health care worker and was checked for diabetes.		
I visited a health care worker and was checked for high blood pressure.		
I visited a health care worker and was checked for depression or anxiety.		
I talked to a health care worker about my family medical history.		
I had my teeth cleaned by a dentist or dental hygienist.		

24) ***Before*** your current pregnancy, did a doctor, nurse, or other health care worker tell you that you had any of the following health conditions? For each one, check **Yes** if you did have the condition or **No** if you did not have the condition.

	Yes	No
Type 1 or Type 2 diabetes (NOT the same as gestational diabetes or diabetes that starts during pregnancy)	○	○
High blood pressure or hypertension	○	○
Depression	○	○

Current Pregnancy Health Topics for Discussion

For each of the following questions, please select or enter the best response regarding your current pregnancy:

25) During your current pregnancy, did your doctor, nurse, or other health care worker discuss or provide information or recommendations on any of the following topics? For each item, check **Yes** if you did discuss it or **No** if you did not discuss it.

	Yes	No
Barriers to healthy eating	○	○
Barriers to physical activity	○	○
Breastfeeding	○	○
Calcium	○	○
Daily calorie recommendation	○	○
Infant development	○	○
Infant nutrition	○	○

Foods to avoid	○	○
Folic acid	○	○
Formula feeding	○	○
Fruits and vegetables	○	○
Gestational diabetes	○	○
Nutrition guidelines	○	○
Meal planning	○	○
Physical activity guidelines	○	○
Physical activity safety	○	○
Postpartum depression	○	○
Prenatal vitamins	○	○
Preparing for delivery	○	○
Social support	○	○
Stress management	○	○
Weight counseling	○	○

26) What types of information were/are you interested in learning about during this pregnancy? For each item, check **Yes** if you were/are interested in learning about it or **No** if you're not interested.

	Yes	No
Barriers to healthy eating	○	○
Barriers to physical activity	○	○
Breastfeeding	○	○
Calcium	○	○
Daily calorie recommendation	○	○
Infant development	○	○
Infant nutrition	○	○
Foods to avoid	○	○
Folic acid	○	○
Formula feeding	○	○
Fruits and vegetables	○	○
Gestational diabetes	○	○
Nutrition guidelines	○	○
Meal planning	○	○
Physical activity guidelines	○	○

Physical activity safety	○	○
Postpartum depression	○	○
Prenatal vitamins	○	○
Preparing for delivery	○	○
Social support	○	○
Stress management	○	○
Weight counseling	○	○

27) During your current pregnancy, where do you get **most** of your information related to nutrition and physical activity? (Please check all that apply)

☐ Doctor
☐ Nurse/Health Care Worker
☐ Friends/Family
☐ Blog posts
☐ Websites
☐ Social media
☐ Cell phone apps
☐ Books/Magazines
☐ Other - Write In: _____

Motivations and Interests

For each of the following questions, please select or enter the best response regarding your current pregnancy:

28) During your current pregnancy, how interested would you be in listening to weekly podcasts (audio recordings of women's pregnancy experiences about 15-20 minutes long) that provide information related to health and pregnancy?

○ Not at all interested ○ Slightly interested ○ Moderately interested ○ Very interested ○ Extremely interested

29) During your current pregnancy, how interested would you be in participating in weekly **online** group-based challenges related to **healthy eating** (you would be assigned

to a group of pregnant women who would try and achieve the same weekly challenge, such as “eat 5 servings of fruits and vegetables a day”)?

Not at all interested Slightly interested Moderately interested Very interested Extremely interested

30) During your current pregnancy, how interested would you be in participating in weekly **online** group-based challenges related to **exercise** (you would be assigned to a group of pregnant women who would try and achieve the same weekly challenge, such as “take a 30 minute walk three times this week”)?

Not at all interested Slightly interested Moderately interested Very interested Extremely interested

31) During your current pregnancy, how interested would you be in communicating with other pregnant women through a mobile app?

Not at all interested Slightly interested Moderately interested Very interested Extremely interested

32) How interested would you be in using a mobile app that allows you to track your current pregnancy weight gain?

Not at all interested Slightly interested Moderately interested Very interested Extremely interested

33) Do you currently participate in any of the following resources related to pregnancy? For each item, check **Yes** if you use the resource or **No** if you do not use the resource.

	Yes	No
Pregnancy-related blogs		
Pregnancy apps on smartphone/tablet		
Websites about pregnancy		
Social networking groups for pregnant women		
In-person education sessions for pregnancy related topics		

34) How did you hear about the survey?

- Blog post
- Facebook
- Twitter
- Printed flyer
- Other - Please describe::

Appendix C: Healthy Motivations for Moms-To-Be IRB Approval Letter

INSTITUTIONAL REVIEW BOARD FOR HUMAN RESEARCH

APPROVAL LETTER for EXPEDITED REVIEW
with WAIVER of SIGNED CONSENT

This is to certify that the following proposal: **Pro00061320**

Entitled: *Healthy Motivations for Moms-to-be Study*

Submitted by:
Principal Investigator: Alicia Dahl
Arnold School of Public Health
Health Promotion, Education, and Behavior
915 Greene Street
Columbia, SC 29208

was reviewed and approved by the University of South Carolina Institutional Review Board (USC IRB) by **Expedited** review on **11/15/2016** (**category 7**). This approval includes a Waiver of Signed Consent.

Approval is for a one-year period from **11/15/2016** to **11/14/2017**. When applicable, approved consent /assent documents are located under the "Stamped ICF" tab on the Study Workspace screen in eIRB.

PRINCIPAL INVESTIGATORS ARE TO ADHERE TO THE FOLLOWING APPROVAL CONDITIONS

- The research must be conducted according to the proposal/protocol that was approved by the USC IRB
- Changes to the procedures, recruitment materials, or consent documents, must be approved by the USC IRB prior to implementation
- *If applicable*, each subject should receive a copy of the approved date stamped consent document
- It is the responsibility of the principal investigator to report promptly to the USC IRB the following:
  - Unanticipated problems and/or unexpected risks to subjects
  - Adverse events effecting the rights or welfare of any human subject participating in the research study
- Research records, including signed consent documents, must be retained for at least (3) three years after the termination of the last IRB approval.
- No subjects may be involved in any research study procedure prior to the IRB approval date, or after the expiration date. For continued approval of the research study, an update of the study is required prior to the expiration date. The PI is responsible for initiating the Continuing Review process. At the time a study is closed, a Continuing Review report form is to be used for the final report to the USC IRB in order to formally close the research study.

The Office of Research Compliance is an administrative office that supports the USC IRB. If you have questions, contact Arlene McWhorter at arlenem@sc.edu or (803) 777-7095.

Sincerely,

Lisa M. Johnson
IRB Manager

Appendix D: Healthy Motivations for Moms-To-Be Recruitment Text

Examples of Facebook recruitment text: Healthy MoM2B Study

Pregnant? Congrats! Interested in working towards healthy goals through a smartphone app with other pregnant women? Researchers at the University of South Carolina are looking for PREGNANT women living in the United States, ages 20-35, and in the first half of their pregnancy (<20 weeks) to join a 12-week long research study using smartphones. No travel is required so you can participate from the comfort of your home! Participants in the study can receive up to $35 in incentives for their time. Fill out this interest form and someone from the study will contact you regarding your eligibility to participate! Please feel free to share this post. – THANKS! https://goo.gl/bSN9lj

Are you or someone you know pregnant? Researchers at the University of South Carolina are looking for PREGNANT women ages 20-35 to join a 12-week long research study using smartphones. This study specifically focuses on moms-to-be working towards healthy lifestyle goals like stress reduction, healthy eating, and exercise during pregnancy. We're looking for participants who are within the first 20 weeks of their pregnancy. No travel is required so you can participate from the comfort of your home or on the go! Participants in the study can receive up to $35 in incentives for their time. Fill out this interest form and someone from the study will contact you regarding your eligibility to participate! Please feel free to share this post. – THANKS! https://goo.gl/bSN9lj

Do you want to have a healthy pregnancy? Join our research study through the University of South Carolina and get access to a completely free health program and receive up to $35 in incentives as a thank you for your time! No travel is required so you can participate from the comfort of your home or on the go! We're looking for PREGNANT women living in the US, ages 20-35, within the first 20 weeks of their pregnancy to join a 12-week long research study using smartphones. This study specifically focuses on moms-to-be working towards healthy lifestyle goals like stress reduction, healthy eating, and exercise during pregnancy. Fill out this interest form and someone from the study will contact you regarding your eligibility to participate! Please feel free to share this post. – THANKS! https://goo.gl/bSN9lj

Our research study is now recruiting expectant mommies-to-be for a healthy pregnancy study using a mobile app and website for 12 weeks. Must live in the US and must own a smartphone and bathroom scale. Please share this link with pregnant women you know who may also be interested! https://goo.gl/bSN9lj

Researchers at the University of South Carolina are looking for women who are in early pregnancy to join a 12-week long research study using smartphones. This study specifically focuses on moms-to-be working towards healthy lifestyle goals like stress reduction, healthy eating, and exercise during pregnancy.

No travel is required so you can participate from the comfort of your home or on the go. In addition to a free pregnancy health program, participants in the study can receive up to $35 in incentives for their time. Fill out this interest form and someone from the study will contact you regarding your eligibility to participate! Please feel free to share this post. – THANKS! https://goo.gl/bSN9lj

Examples of Twitter recruitment text: 140 characters

Attn #pregnant women! Join our 12-wk healthy preg study using #mHealth and #socialsupport. Must live in US. https://goo.gl/bSN9lj

Calling all #pregnant women: plz join a 12-wk preg study using #mHealth & #socialsupport.Must live in US. https://goo.gl/bSN9lj

#Pregnant? Congrats! Less than 20 weeks along? Join our study using #mhealth and #social support. Must live in US. https://goo.gl/bSN9lj

Free health program for #pregnant women! Join our research study using #mhealth and #social support. Must live in US. https://goo.gl/bSN9lj

Appendix E: HM2B Eligibility Screener

Eligibility questions

1) Are you currently pregnant?*
( ) Yes
( ) No

2) When is your due date?*
_____
3) How many weeks pregnant are you today?*
_____
4) Are you expecting multiples?*
( ) Yes
( ) No
( ) Not Sure

---

5) Do you currently live in the United States?*
( ) Yes
( ) No

6) Are you able to read and speak English?*
( ) Yes
( ) No

7) Do you own a smartphone?*
( ) Yes
( ) No

8) Do you have regular and consistent access to Wi-Fi or a data plan to use mobile apps on your smartphone?*
( ) Yes
( ) No

---

9) Are you willing to download a mobile app to use on your smartphone for the duration of the research study (three months)?*
( ) Yes
( ) No

10) Do you own a scale to weigh yourself regularly, or would you be willing to purchase or borrow a scale from someone for the duration of the research study (three months)?*
( ) Yes
( ) No

Contact information
11) Is it OK if someone from the study contacts you via phone?*

( ) Yes
( ) No

Logic: Hidden unless: #11 Question "Is it OK if someone from the study contacts you via phone?" is one of the following answers ("Yes")
12) If yes, what is your phone number?*
_____

13) Is it OK if someone from this study contacts you via email?*
( ) Yes
( ) No

14) If yes, what is your email address?*
_____
15) When is the best time to reach you? (Please select all that apply.)*
[ ] Mornings
[ ] Afternoons
[ ] Evenings
[ ] Weekdays
[ ] Weekends
[ ] Anytime

16) What is your first name?*
_____
17) What is your last name?*
_____

Thank You!

Appendix F: HM2B Baseline Survey

Consent to be a Research Participant

Below is the document that provides a description of the research study and the benefits and risks associated with being a research participant. Although this document is lengthy, the content is very important. Please take a moment to review this document and ask any questions you may have. At the bottom of the page, there is a spot for you to enter your name which gives consent for the research team to begin data collection. After signing, you'll be directed to the baseline survey where you'll answer questions about your health and pregnancy.

PURPOSE & BACKGROUND:

You are being asked to volunteer for a research study conducted by Alicia A. Dahl, MS. I am a doctoral candidate in the Health Promotion, Education, and Behavior Department at the University of South Carolina. This research is sponsored in part by the Prevention Research Center, The Technology Center to Promote Healthy Lifestyles (TecHealth), and the University of South Carolina. You are being asked to participate in this study because you are currently a U.S. resident within early pregnancy (≤20 weeks) interested in having a healthy pregnancy and you own a smartphone device.

The purpose of this study is to examine the use of a mobile application (mobile app) and mobile website for encouraging and maintaining healthy behaviors such as healthy eating, regular exercise, and stress management and reduction during pregnancy. The study will include collaborative group-based health behavior challenges for pregnant women living in the United States. The study will test the effectiveness of the intervention on improving maternal health behaviors.

PROCEDURES:

Participation in this research study requires the use of a commercially available free mobile app that you will be asked to download on your smartphone. The study will be done remotely through emails, phone calls, online surveys, a mobile app, and a study website. On the study website you will create a private user account to upload study-related forms, listen to 10 podcasts, and view weekly tips for having a healthy pregnancy. We expect this study to involve approximately 120 volunteers.

If you agree to participate, you will be randomly assigned to one of two health-related intervention conditions for the duration of your pregnancy. Random assignment means that you are put into a group by chance. A computer program will place you in one of the two conditions. Neither you nor the study investigators can choose what condition you will be in. Your chances of being in one condition or another condition are equal. Below is a description of the two intervention conditions.

Healthy eating/physical activity (HEPA) condition: The goals of the HEPA condition are to encourage healthy eating and physical activity behaviors for gaining a healthy amount of weight during pregnancy and to provide motivation and social support to help overcome challenges to eating healthier and becoming more physically active while pregnant.

Behavior Tracking: You will be assigned to a group of 8-10 other pregnant women to work towards the same healthy eating or physical activity behavior challenge each week for a total of 12 weeks. The challenges will not require travel or financial support, but will focus on modifying or encouraging daily lifestyle activities, such as "drink 8 full glasses of water 3 times this week." You will track your healthy eating and physical activity behaviors in a mobile app. When you enter that you've completed the healthy eating or physical activity behavior challenge, a post will show up in a group newsfeed and other participants can comment or provide a "bump" (thumbs up) to your activity. If you fail to meet the healthy behavior challenge of the week, the app will prompt you to share with the group why you were unable to meet the goal as an exercise to address barriers and/or difficulties when making healthy lifestyle changes. In addition, the HEPA condition will have access to podcasts and informational tips for having a healthy pregnancy through the study website. Lastly, the HEPA condition will be able to log their weight on a daily basis and track their overall weight gain on a chart through the study website.

Stress reduction and management (SRAM) condition: The goals of the SRAM condition are to encourage stress reduction and management techniques as well as to provide motivation and social support to reduce stress levels during pregnancy.

Behavior Tracking: Just like the HEPA condition, if you are randomly assigned to the SRAM condition, you will be put into a group of 8-10 other pregnant women to work towards the same stress reduction and management goal each week for a total of 12 weeks. The challenges will not require travel or financial support, but will focus on modifying or encouraging daily lifestyle activities, such as "take a 15 minute technology break each day this week." You will track your stress reduction and management behaviors in a mobile app. When you enter that you've completed the behavioral challenge, a post will show up in a group newsfeed and other participants can comment or provide a "bump" (thumbs up) to your activity. If you fail to meet the stress reduction and management behavior challenge of the week, the app will prompt you to share with the group why you were unable to meet the goal as an exercise to address barriers and/or difficulties when making healthy lifestyle changes. In addition, the SRAM condition will have access to meditation podcasts and informational tips for having a healthy pregnancy through the study website. Lastly, the SRAM condition will be able to rate their stress level on a daily basis and track their stress on a graph.

<u>Below are the steps in the study:</u>
Consent form

After reading and signing this online consent form, you will be directed to a baseline survey link.

Baseline survey
You will be sent a link to complete an online survey that will ask questions about your health behaviors, health knowledge, diet, physical activity levels, perceived stress, sleep duration, and social support. The survey will take approximately 15 minutes to complete.

Mobile app & study website orientation
When the survey is completed, you will receive an email with information on how to download a free mobile app that we will use for the duration of the study and instructions on how to set up a profile. A practice challenge code will be provided for you and you will be asked to take a photo of your weight on a scale within one week of receiving the challenge code to help orient you to the features of the mobile app. You will not receive an intervention challenge code until you're assigned to a group for the study. If you experience any problems, our research staff will be able to talk through your concerns over the phone – 803-777-9905.

You will also receive an email providing instructions for accessing your user profile on the study website and how to track your weight or stress levels, depending on group assignment. Instructions for listening to the podcasts and viewing the weekly tips on the website will be described in detail as well.

Begin the study
Once 8-10 new participants have been randomized to one of the two conditions in the study, a group will be formed and you will receive a notification from the mobile app as well as through email providing you with a challenge code to enter into the mobile app. At this point, you will begin tracking specific health behaviors through the mobile app. You will receive a new challenge code every week for 12 weeks. You will have control over what personal information you choose to share with the other members in the group. We will request that you log your weight or stress levels through the study website, depending on group assignment. Podcasts and weekly tips will be available through the website for you to access at your convenience.

There will be three time points where you are asked to verify your current weight. We will ask you to take a photo of your scale display with you standing on it and then upload it to the mobile app. This information will not be visible to the other participants in the study. Only the research staff will have access to see and download the image of your verified weight.

Final survey
After 12 weeks of challenges, you will be asked to complete an online survey that will ask similar health-related questions as the baseline survey, with an additional section on program feedback. The survey should take 15-20 minutes to complete.

Delivery outcomes survey

After your due date has passed, you will receive a link to a brief online survey that will ask you about your delivery and infant birth outcomes (such as baby's length and weight). This survey will take less than 5 minutes to complete and you will be entered to win a raffle gift valued at $20.

PARTICIPATION TIMELINE

All tasks and activities related to this research study will be remotely delivered through email, phone calls, a mobile app, a study website, and online surveys. There will be no travel required for this study. Personal cell phones, tablets, or computers will be required to complete the study tasks. It is possible that duration of the study may range from 12-15 weeks, depending on when tasks are completed by the participant and pace of enrollment of other participants to form a group for the challenges. After the 12 weeks of challenges and final survey are completed, your group participation in the study will be over but you will still have access to the study website to track weight and stress levels through delivery if you'd like, as a thank you for your participation.

Time	Task
Week 1-3: Pre-randomization	Informed consent form, baseline survey, mobile app orientation and set up, randomization to a group
Weeks 3-15: Intervention	Health behavior challenges tracked through the mobile app; weight gain or stress levels tracked through the study website
Week 15: Post-intervention	Final survey; option to continue tracking health related behaviors through the study website; delivery outcomes survey

RISKS/DISCOMFORTS

This study poses minimal risk for participants. Participants will be assigned a unique identification number (ID) and may use a pseudonym in the group challenges if desired. Sharing of personal information within the assigned group is at the discretion of the participant. Survey items may ask about your health and habits, which may be uncomfortable to share. However, all survey responses will remain confidential using unique participant ID numbers and data will be stored on a secure server. Study website profiles will be created by individual users using the unique participant ID numbers and personalized passwords for entering weight information to the website. Only study team members will be able to see and access your weight or stress level entries on the study website.

BENEFITS

Taking part in this research study may benefit your health through encouraging behavior change or maintenance of living a healthy lifestyle. You may gain a healthy amount of weight during your pregnancy which may help reduce your risk of developing gestational diabetes, preeclampsia, or eclampsia. You may also learn new ways to eat healthy, exercise, reduce stress, and improve sleep. This study may benefit society by gaining new knowledge about the use of mobile tracking devices for health behaviors and social support interactions among pregnant women.

COSTS
It will not cost you anything to be in this study. Travel is not required for participation. The mobile app used for this study is commercially available and free on Android and Apple stores.

PAYMENTS TO PARTICIPANTS
As a thank you for your participation, you will receive an incentive for your time once all study-related activities are completed. Incentives will be based on study-related activities that you complete throughout the 12 weeks. Below is a description of how the points determine the incentive value.

Points will be tallied as follows:

Study activity	Points for activity	Total points available
Completion of the baseline and final surveys	5 points each	10
Completion of weekly behavioral challenges	1 point each	12
Tracking weight/stress info on study website	1 point per weekly entry	12
Uploading a completed Health Care Practitioner verification form or photo of your weight on a scale	3 points each time point (baseline, 32-weeks, delivery)	9

Points will be converted as follows:
10-15 total points = $5 gift
16-20 total points = $10 gift
20-25 total points = $15 gift
26-30 total points =$20 gift
31 or greater total points = $25 gift

Additionally, you may be entered to win one of several raffle gifts valued at $20 upon completion of the delivery outcomes survey (odds of winning depend on the number of participants who complete the study but are estimated at 1 in 10). Winners will be notified by email at the end of data collection (estimated end date: 5/30/2018).

CIRCUMSTANCES FOR DISMISSAL FROM THIS STUDY
You may be dismissed from the study without your consent for various reasons including the following:

If you miscarry at any point during the study;
If you deliver your baby prior to completing the 12 weeks of challenges;
If you do not follow the instructions that you are given;
If the investigator believes that it is not in your best interest to continue in the study; and
If you fail to complete study activities (e.g. failure to complete forms/surveys).

CONFIDENTIALITY OF RECORDS

Participation will be confidential. Each participant will receive a unique identification number at the beginning of the project. This number will be used on project records rather than your name, and no one other than the researchers will be able to link your information with your name. All surveys and emails will be maintained by the Principal Investigator, Alicia A. Dahl, using a password-protected account, on a secure Internet connection, on a password-protected computer. Any paper forms will be filed in a locked office on the University of South Carolina campus. All electronic databases will be stored on secured university network servers and on password protected computers. Data will be reported at the group level to reduce the risks of sharing personal health information. The results of this study may be published or presented at professional meetings, but your identity will not be revealed and no identifying information about you will be shared.

While we make every effort to protect your privacy, it cannot be absolutely guaranteed. In rare cases, a research study may be evaluated by an oversight agency, such as the U.S. Office for Human Research Protections. If this occurs, records that identify you and the consent form signed by you may be inspected so that they may evaluate whether the study is properly conducted and the rights of participants were adequately protected.

VOLUNTARY PARTICIPATION
Participation in this study is voluntary. You are free not to participate, or to stop participating at any time, for any reason without negative consequences. In the event that you do withdraw from the study, the information you have already provided will be kept in a confidential manner. If you wish to withdraw from the study, please call or email the Principal Investigator.

The Office of Research Compliance is an administrative office that supports the USC Institutional Review Board (IRB). If you have any questions about your rights as a research subject contact, Lisa Marie Johnson, IRB Manager, Office of Research Compliance, University of South Carolina by phone: (803) 777-7095 or email: LisaJ@mailbox.sc.edu. The IRB consists of representatives from a variety of scientific disciplines, non-scientists, and community members for the primary purpose of protecting the rights and welfare of human subjects enrolled in research studies.

SIGNATURE OF PARTICIPANT
I have been given a chance to ask questions about this research study. These questions have been answered to my satisfaction. If I have additional questions about my participation in this study or study related injury, I may contact Alicia A. Dahl at 803-777-9905 or email healthymom2b@gmail.com. By typing my name below, I agree to participate in this study.
1) Full Name:*

_____

2) Today's Date*

_____

Survey Follows:

Thank you for your participation in the Healthy Motivations for Moms-to-be (Healthy MoM2B) research study! The purpose of this study is to examine the use of a mobile application (mobile app) and mobile website for encouraging and maintaining healthy behaviors such as healthy eating, regular exercise, and stress management and reduction during pregnancy. You will now be asked a series of questions to provide baseline information regarding personal demographics, your health knowledge, health behaviors, perceived stress, and social support.

As a thank you for your participation in this study, you may receive up to $35 in Amazon gift cards. All participants who complete the required components of the study will receive a $25 Amazon gift card at the end of the study. Participants will also be entered to win several $10 Amazon gift card drawings throughout the study (odds of winning depend on the number of participants who complete the study but are estimated at 1 in 10). Winners will be notified by email at the end of data collection (estimated end date: 05/30/2018).

Please feel free to contact me with any questions. Thank you in advance for your time and honest responses.

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Demographics

For each of the following questions, please select or enter the response that best describes you:

3) When you got pregnant with your new baby, were you trying to get pregnant?*
( ) Yes
( ) No

4) Are you a first-time mom?*
( ) Yes
( ) No

5) How would you describe your current relationship status?*
( ) Single
( ) In a relationship
( ) Married
( ) Widowed
( ) Divorced
( ) Other - Write In: _____

6) Are you Hispanic or Latina?*
( ) Yes
( ) No

7) What is your racial background? (Check all that apply):*
[ ] American Indian or Alaskan Native
[ ] Asian
[ ] Black or African American
[ ] Native Hawaiian or Other Pacific Islander
[ ] White
[ ] Other - Write In: _____
8) What is your date of birth?*
_____
9) What is your **highest** level of education you've **completed**? Please choose only **one** of the following:*
( ) 8th grade or less
( ) Some high school
( ) High school graduate or equivalent
( ) Vocational school (technical or trade)
( ) Some college or associate's degree (2 year)
( ) College graduate (4 year)
( ) Advanced degree (Masters, doctoral, or other post-college degree)
10) What is your current and **primary** employment status? Please select all that apply:*
[ ] Employed for wages full time (30 hours or more per week)
[ ] Employed for wages part time (less than 30 hours per week)
[ ] Unemployed
[ ] A homemaker
[ ] A student
[ ] Retired
[ ] Self-employed
11) During the **month before you got pregnant** with your new baby, what kind of health insurance did you have? Check all that apply.*
[ ] Private health insurance from my job or the job of my husband, partner, or parents
[ ] Private health insurance purchased directly from an insurance company
[ ] Medicaid
[ ] Some other kind of health insurance. Please describe: (Required):
_____*
[ ] I did not have any health insurance during the month before I got pregnant.
12) What zip code do you currently live in? (Example: 98765)
_____
13) How did you hear about this study? (Check all that apply.)
[ ] Blog post
[ ] Facebook
[ ] Google ad
[ ] Twitter
[ ] Printed flyer
[ ] Friend/Family member
[ ] Other - Write In (Required):
_____*

Perceived stress scale

For each of the following questions, please select or enter the response that best describes you during the last month:

14) In the **last month**, how often have you...*

	Never	Almost Never	Sometimes	Fairly Often	Very Often
been upset because of something that happened unexpectedly?	( )	( )	( )	( )	( )
felt that you were unable to control the important things in life?	( )	( )	( )	( )	( )
felt nervous and "stressed"?	( )	( )	( )	( )	( )
felt confident about your ability to handle your personal problems?	( )	( )	( )	( )	( )
felt that things were going your way?	( )	( )	( )	( )	( )
been able to control irritations in your life?	( )	( )	( )	( )	( )
felt that you were on top of things?	( )	( )	( )	( )	( )
been angered because of things that were outside of your control?	( )	( )	( )	( )	( )

felt difficulties were piling up so high that you could not overcome them?	( )	( )	( )	( )	( )

Weight-Related Knowledge and Behaviors

For each of the following questions, please select or enter the response that best describes you:

15) How tall are you without shoes?*

Feet: _____

Inches: _____

16) Just before you got pregnant with your new baby, how much did you weigh? (Please answer in pounds.)*

_____

17) What is your current weight? (Please answer in pounds.) *

_____

18) Before joining this study, how often did you weigh yourself on a scale?*

( ) Never
( ) Daily
( ) Weekly
( ) Monthly
( ) Every few months
( ) Yearly

Health Knowledge and Behaviors

For each of the following questions, please select or enter the best response regarding your current pregnancy:

19) During your current pregnancy, did your health care practitioner (nurse, midwife, physician) discuss weight gain recommendations with you?*

( ) Yes
( ) No

20) How much weight do you believe would be a healthy amount to gain over the course of your current pregnancy? There is no right or wrong answer. (Please answer in pounds.)*

_____

21) During your most current pregnancy, did your health care practitioner (nurse, midwife, physician) discuss or provide information or recommendations on any of the following topics? For each item, check **Yes** if you did discuss it or **No** if you did not discuss it.*

	Yes	No
Healthy eating	( )	( )

Physical activity	( )	( )
Breastfeeding	( )	( )
Calcium	( )	( )
Daily caloric recommendation	( )	( )
Infant development	( )	( )
Infant nutrition	( )	( )
Foods to avoid	( )	( )
Folic acid	( )	( )
Formula feeding	( )	( )
Fruits and vegetables	( )	( )
Gestational diabetes	( )	( )

22) Do you plan to breastfeed your baby?*
( ) Yes
( ) No

Health Behaviors
23) Do you **regularly** do any of the following meal-related activities? For each item, check **Yes** if you do it or **No** if you do not do it.*

	Yes	No
Shop with a grocery list	( )	( )
Budget for groceries	( )	( )
Build a grocery list around meal recipes	( )	( )
Prepare meals in advance	( )	( )
Portion out meals	( )	( )

Measure ingredients when following a recipe	( )	( )
Read nutrition facts labels	( )	( )
Compare brands when making food choices	( )	( )
Participate in WIC	( )	( )

24) **In the past month**, about <u>how many times a week</u> did you do the following activities?*

	0	1	2	3	4	5	6	7	8 or more times
Ate fast food	( )	( )	( )	( )	( )	( )	( )	( )	( )
Ate at a restaurant (not fast food)	( )	( )	( )	( )	( )	( )	( )	( )	( )
Ate alone	( )	( )	( )	( )	( )	( )	( )	( )	( )
Made a main dish from scratch	( )	( )	( )	( )	( )	( )	( )	( )	( )
Made a purchase at a grocery store	( )	( )	( )	( )	( )	( )	( )	( )	( )
Wrote a to-do list	( )	( )	( )	( )	( )	( )	( )	( )	( )
Slept LESS than 6 hours a night	( )	( )	( )	( )	( )	( )	( )	( )	( )

Slept 6 OR MORE hours a night	( )	( )	( )	( )	( )	( )	( )	( )	( )

25) Do you use low-fat (2%), very low-fat (1%), or nonfat milk?*
( ) Yes
( ) No
26) Do you consider your eating patterns to be vegetarian or vegan?*
( ) Yes
( ) No

Health Behaviors
For each of the following questions, please select or enter the response that best describes you:
27) Thinking about the **past month**, how often did you:*

	Usually/Often	Sometimes	Rarely/Never	Does not apply to me
a. Skip breakfast?	( )	( )	( )	( )
b. Eat 4 or more meals from sit-down or take out restaurants?	( )	( )	( )	( )

c. Eat less than 2 servings of whole grain products or high fiber starches a day? (serving =1 slice of 100% whole grain bread; 1 cup whole grain cereal/oatmeal, 3-4 whole grain crackers, 1/2 cup brown rice or whole wheat pasta, boiled or baked potatoes, yuca, yams or plantain	( )	( )	( )	( )
d. Eat less than 2 servings of fruit a day? (serving=1/2 cup or 1 medium fruit or 3/4 cup 100% fruit juice)	( )	( )	( )	( )
e. Eat less than 2 servings of vegetables a day?(serving=1/2 cup vegetables, or 1 cup leafy raw vegetables)	( )	( )	( )	( )

f. Eat or drink less than 2 servings of milk, yogurt, or cheese a day? (serving=1 cup milk or yogurt; 1 1/2-2 ounces of cheese)	( )	( )	( )	( )
g. Eat more than 8 ounces (see sizes below) of meat, chicken, turkey or fish per day? Note: 3 ounces of meat or chicken is the size of a deck of cards or ONE of the following: 1 regular hamburger, 1 chicken breast or leg (thigh and drumstick), or 1 pork chop.	( )	( )	( )	( )

28) Thinking about the **past month**, how often did you:*

	Usually/ Often	Sometimes	Rarely/ Never	Does not apply to me
h. Use regular processed meats (like bologna, salami, corned beef, hotdogs, sausage or bacon) instead of low fat processed meats (like roast beef, turkey, lean	( )	( )	( )	( )

ham; low-fat cold cuts/hotdogs)?				
i. Eat fried foods such as fried chicken, fried fish, French fries, fried plantains, tostones or fried yuca?	( )	( )	( )	( )
j. Eat regular potato chips, nacho chips, corn chips, crackers, regular popcorn, nuts instead of pretzels, low-fat chips or low-fat crackers, air-popped popcorn?	( )	( )	( )	( )
k. Add butter, margarine or oil to bread, potatoes, rice or vegetables at the table?	( )	( )	( )	( )
l. Eat sweets like cake, cookies, pastries, donuts, muffins, chocolate and candies more than 2 times per day.	( )	( )	( )	( )
m. Drink 16 ounces or more of non-diet soda, fruit drink/punch or Kool-Aid a day? (Note: 1 can of soda=12 ounces)	( )	( )	( )	( )

29) In the past month, did you or a member of your family usually shop and cook rather than eating sit-down or take-out restaurant food?*

( ) Yes

( ) No

30) In the past month, did you usually feel well enough to grocery shop or cook?*
( ) Yes
( ) No
31) How willing are you to make changes in your eating habits in order to be healthier?*
( ) 1- Not at all willing
( ) 2
( ) 3
( ) 4
( ) 5-Very willing

Physical Activity Behaviors
For each of the following questions, please select or enter the response that best describes you:
32) Do you currently have a gym or fitness center membership?*
( ) Yes
( ) No
33) Do you currently use a physical activity tracker? (Fitbit, My Fitness Pal, Garmin watch, Apple watch, pedometer, etc.)*
( ) Yes
( ) No
34) During a typical **7-Day period** (a week), how many **times per week** on the average do you do the following kinds of exercise for **more than 15 minutes** during your free time *
STRENUOUS EXERCISE (HEART BEATS RAPIDLY) (e.g., running, jogging, hockey, football, soccer, squash, basketball, cross country skiing, judo, roller skating, vigorous swimming, vigorous long distance bicycling):
_____
MODERATE EXERCISE (NOT EXHAUSTING) (e.g., fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, alpine skiing, popular and folk dancing): _____
MILD EXERCISE (MINIMAL EFFORT) (e.g., yoga, archery, fishing from river bank, bowling, horseshoes, golf, snow-mobiling, easy walking)
_____
35) During this past month, how much time did you spend…*

	None	Less than 1/2 hour per week	1/2 to almost 1 hour per week	1 to 2 hours per week	2 to 3 hours per week	3 or more hours per week
walking slowly for fun or exercise	( )	( )	( )	( )	( )	( )

walking more quickly for fun or exercise	( )	( )	( )	( )	( )	( )
walking quickly up hills for fun or exercise	( )	( )	( )	( )	( )	( )

36) The next question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. *Do not include the time you were asleep.* This may include time spent sitting at a desk, commuting, visiting friends, reading, or sitting or lying down to watch television or before falling asleep.

During the **last 7 days**, about how much time did you spend **sitting per day**?
Monday (hours): _____
Tuesday (hours): _____
Wednesday (hours): _____
Thursday (hours): _____
Friday (hours): _____
Saturday (hours): _____
Sunday (hours): _____

Social Support
Please rate each question twice. Under family, rate how often anyone living in your household has said or done what is described during the last three months. Under friends, rate how often your friends, acquaintances, or coworkers have said or done what is described during the last three months.
37) During the **past three months**, my family or friends...*
Response options for each column: NONE; RARELY; A FEW TIMES; OFTEN; VERY OFTEN; DOES NOT APPLY

	FAMILY	FRIENDS
Exercised with me.		
Offered to exercise with me.		
Gave me helpful reminders to exercise ("Are you going to exercise tonight?").		
Gave me encouragement to stick with my exercise program.		

Changed their schedule so we could exercise together.		
Discussed exercise with me.		
Complained about the time I spend exercising.		
Criticized me or made fun of me for exercising.		
Gave me rewards for exercising (bought me something or gave me something I like).		
Planned for exercise on recreational outings.		
Helped plan activities around my exercise.		

38) During the **past three months**, my family or friends...*
Response options for each column: NONE; RARELY; A FEW TIMES; OFTEN; VERY OFTEN; DOES NOT APPLY

	FAMILY	FRIENDS
Asked me for ideas on how they can get more exercise.		
Talked about how much they like to exercise.		
Encouraged me not to eat "unhealthy foods" (cake, salted chips) when I'm tempted to do so.		
Discussed my eating habit changes with me (asked me how I'm doing with my eating changes).		
Reminded me not to eat high fat, high salt foods.		

Complimented me on changing my eating habits ("Keep it up", "We are proud of you ").		
Commented if I went back to my old eating habits.		
Ate high fat or high salt foods in front of me.		
Refused to eat the same foods I eat.		
Brought home foods I'm trying not to eat.		
Got angry when I encouraged them to eat low salt, low fat foods.		
Offered me food I'm trying not to eat.		

Motivation to Change

For each of the following questions, please select or enter the response that best describes you:

39) **I am willing to make changes so that I can…***

	Strongly Disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree
eat healthy food more often.	( )	( )	( )	( )	( )
eat vegetables more often.	( )	( )	( )	( )	( )
enjoy eating a variety of healthy food.	( )	( )	( )	( )	( )
eat fruit more often.	( )	( )	( )	( )	( )

prepare healthy meals more often.	( )	( )	( )	( )	( )
eat healthy snacks more often.	( )	( )	( )	( )	( )
eat whole grain food more often.	( )	( )	( )	( )	( )
eat more slowly to determine whether I am hungry or full.	( )	( )	( )	( )	( )
exercise regularly.	( )	( )	( )	( )	( )
feel less stressed.	( )	( )	( )	( )	( )
sleep better.	( )	( )	( )	( )	( )
feel more in control of my daily tasks.	( )	( )	( )	( )	( )
physically relax.	( )	( )	( )	( )	( )

Self-Efficacy

40) Below is a list of things people might do while trying to change their eating habits. Whether you are trying to change your eating habits or not, please rate how confident you are that you could really motivate yourself to do things like these consistently. Please check the most appropriate response for you next to each item.

How sure are you that you can do these things?

	1= I know I cannot	2	3= Maybe I can	4	5=I know I can	Does not apply
Stick to your low fat, low salt foods when you feel depressed, bored, or tense.	( )	( )	( )	( )	( )	( )

Stick to your low fat, low salt foods when there is high fat, high salt food readily available at a party.	( )	( )	( )	( )	( )	( )
Stick to your low fat, low salt foods when dining with friends or co-workers.	( )	( )	( )	( )	( )	( )
Stick to your low fat, low salt foods when the only snack close by is available from a vending machine.	( )	( )	( )	( )	( )	( )
Stick to your low fat, low salt foods when you are alone, and there is no one to watch you.	( )	( )	( )	( )	( )	( )
Eat smaller portions at dinner.	( )	( )	( )	( )	( )	( )
Cook smaller portions so there are no leftovers.	( )	( )	( )	( )	( )	( )
Eat lunch as your main meal of the day, rather than dinner.	( )	( )	( )	( )	( )	( )
Eat smaller portions of food at a party.	( )	( )	( )	( )	( )	( )
Eat salads for lunch.	( )	( )	( )	( )	( )	( )

41) **How sure are you that you can do these things?**

	1= I know I cannot	2	3= Maybe I can	4	5=I know I can	Does not apply

Add less salt than the recipe calls for.	( )	( )	( )	( )	( )	( )
Eat unsalted peanuts, chips, crackers, and pretzels.	( )	( )	( )	( )	( )	( )
Avoid adding salt at the table.	( )	( )	( )	( )	( )	( )
Eat unsalted, unbuttered popcorn.	( )	( )	( )	( )	( )	( )
Keep the salt shaker off the kitchen table.	( )	( )	( )	( )	( )	( )
Eat meatless (vegetarian) entrees for dinner.	( )	( )	( )	( )	( )	( )
Substitute low or non-fat milk for whole milk at dinner.	( )	( )	( )	( )	( )	( )
Cut down on gravies and cream sauce.	( )	( )	( )	( )	( )	( )
Eat poultry and fish instead of red meat at dinner.	( )	( )	( )	( )	( )	( )
Avoid ordering red meat (beef, pork, ham, lamb) at restaurants.	( )	( )	( )	( )	( )	( )

42) Below is a list of things people might do while trying to **increase or continue regular exercise**. We are interested in physical activities like running, swimming, brisk walking, bicycle riding, or aerobics classes. Whether you exercise or not, please rate how confident you are that you could really motivate yourself to do things like these consistently. Please check the most appropriate response for you next to each item.

How sure are you that you can do these things?*

	1=I know I cannot	2	3=Maybe I can	4	5=I know I can	Does not apply

Get up early, even on weekends, to exercise.	( )	( )	( )	( )	( )	( )
Stick to your exercise program after a long, tiring day at work.	( )	( )	( )	( )	( )	( )
Exercise even though you are feeling depressed.	( )	( )	( )	( )	( )	( )
Set aside time for a physical activity program; that is, walking, jogging, swimming, biking, or other continuous activities for at least 30 minutes, 3 times per week.	( )	( )	( )	( )	( )	( )
Continue to exercise with others even though they seem too fast or too slow for you.	( )	( )	( )	( )	( )	( )
Stick to your exercise program when undergoing a stressful life change (e.g., divorce, death in the family, moving).	( )	( )	( )	( )	( )	( )

43) **How sure are you that you can do these things?***

	1=I know I cannot	2	3=Maybe I can	4	5=I know I can	Does not apply
Attend a party only after exercising.	( )	( )	( )	( )	( )	( )
Stick to your exercise program when your family is demanding more time from you.	( )	( )	( )	( )	( )	( )

Stick to your exercise program when you have household chores to attend to.	( )	( )	( )	( )	( )	( )
Stick to your exercise program even when you have excessive demands at work.	( )	( )	( )	( )	( )	( )
Stick to your exercise program when social obligations are very time consuming.	( )	( )	( )	( )	( )	( )
Read or study less in order to exercise more.	( )	( )	( )	( )	( )	( )

Thank you for completing the HM2B baseline survey. You will receive an email from our research team within the next week with directions on how to get started in the HM2B study activities! Please feel free to contact us if you have any questions in the meantime.

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Appendix G: HM2B Orientation Instructions

Dear Participant,

We are so excited to have you on board for the Healthy Motivations for Moms-to-be Study (HealthyMoM2B). To get started, we will need you to download an app on your smartphone as soon as possible. Please follow the directions below for the phone type that you have and if you need assistance, we're here to help you! You may email or call us at any time (details below).

Sincerely,

Alicia A. Dahl, MS
PhD candidate
University of South Carolina
Arnold School of Public Health
803-777-9905
healthymom2b@gmail.com

Getting started: Please follow the directions below for the smartphone that you'll be using for the duration of this study.

Android users

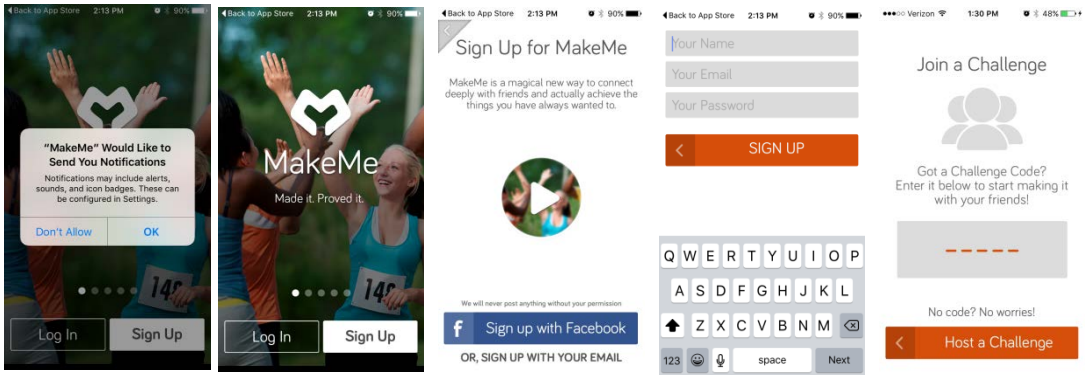
Step 1: Find and click the "GooglePlay" icon on your home screen
Step 2: Click the "Search" option.
Step 3: Type "MakeMe" in the search bar.
Step 4: The app we'll be using for this study should be the first to appear if you typed MakeMe in correctly. The icon circled in red in the photo below is the app we'll need you to download. The app is called MakeMe - Group Challenges for Fitness, Health, Learning.
Step 5: Click on the icon and then select "Install" to download the app. This download will work best if you are connected to WiFi, but will work if you use a data plan as well. This download may take a few minutes.
Step 6: When the MakeMe app has completed downloading, you can click "Open" in the App Store, or open the app from your home screen. It's possible the app downloaded to a secondary home screen, so when you press the home button, be sure to swipe the screen to the left until you see the MakeMe icon circled in red below. Click to open the MakeMe app.
Step 7: When MakeMe first opens, a white window will pop up asking if MakeMe can send you notifications. Please click OK for this option so that you will be notified when a new study task is waiting for you in the app.
Step 8: Click SignUp. In the next window, please choose "sign up with your email" so that your participation in the study is not connected to your personal Facebook page.
Step 9: Please enter your name (other participants in the study will only see your first name and last initial - (example: Alicia D.) - but if you do not want to use your real name, please use your HM2B study ID number as your name - (example: HM2B 0000), enter your personal email address so that you can receive email notifications throughout the

study, and your password should match the HM2B password we provided with your HM2B study ID number.

- The reason that we ask you to use your HM2B password for the app is so we can help with technical support if you forget your login information, or if you're experiencing a problem accessing the study challenges.
- If you do not know your HM2B study ID number or password, please contact our office and we'll be happy to provide it to you again.
- You can also add a photo, if you want to!

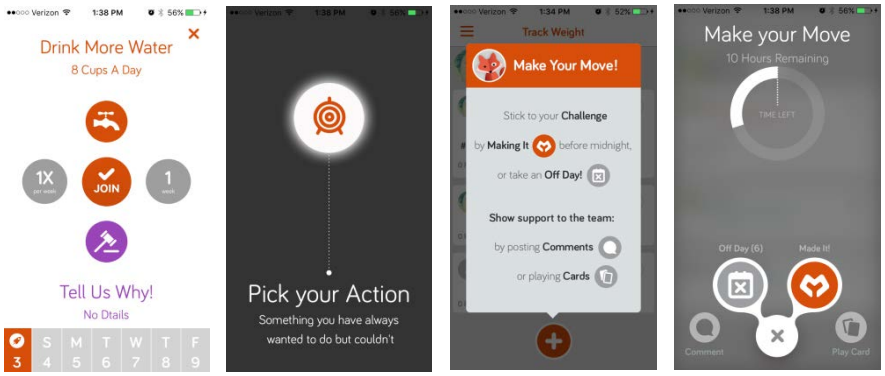
Step 10: Once you've registered, a new screen will come up welcoming you to the app. Click "Let's get started".

Step 11: We're going to practice what will happen when we send out a new challenge code each week during the study. Click on the 5 orange dashes on the let's get started page. Then enter challenge code **XXXXX**. This is a practice challenge code, so no other group members will be assigned yet!

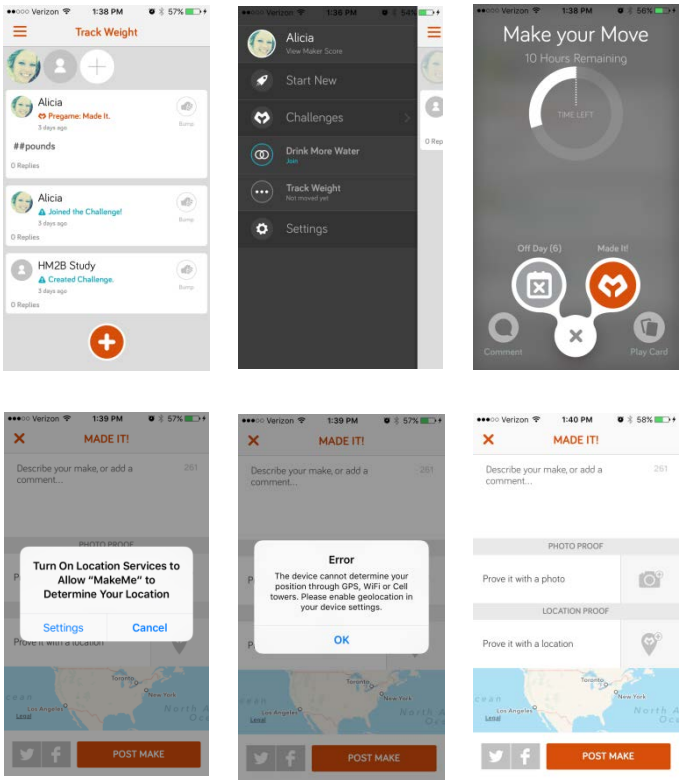


Step 12: Click "Join" and the next screen will give you a description of this week's challenge. You can click on each icon to see what our challenge entails. The details of the challenge will be the same for all group members each week. The action is what the challenge will ask you to do, the frequency is the number of times a week we'll ask you to do the action, and the consequence throughout the study is that we'll ask you to share with the group what struggles or barriers got in your way if you aren't able to meet the challenge (such as "didn't have enough time" or "had morning sickness" so that your group members will be able to provide social support and suggestions). **Please do not change any of the actions, frequency, consequence, or duration settings as we would like everyone to work towards the same assigned goal.** Click Join again when you're done reviewing the challenge details.

Step 13: The next window will tell you how to "Make your move" and enter when you've completed the challenge. During each weekly challenge, you'll be allowed to take a certain number of "off days" so if you aren't able to make the challenge, just select "off day", but you can certainly meet the challenge every day if you'd like to! Click X for now.



Step 14: Let's practice how to log the challenges. The practice challenge is for you to track your weight. In the top left corner of your screen, there are three orange lines. Click on those lines and you'll see a challenge that says "Track Weight". This is where your current challenge will be displayed so that you can easily find it and log when you make a challenge. Click "Track Weight" and the challenge page will open.

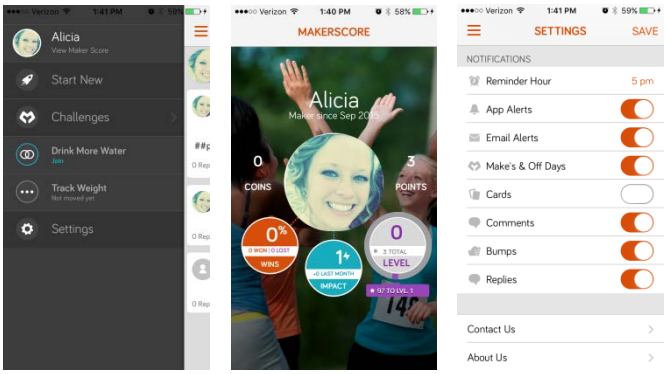


Please press the orange icon with the plus sign at the bottom of the screen. Press the MakeMe icon next. The app will try to pinpoint your location for when you log the challenge. You may choose to share this information by going into your iPhone settings and turning location services on, or you can select Cancel. The choice is yours! If you select cancel, the next window will read "Error. The device cannot determine your position through GPS…", just select OK.

For practice, let's describe your Make by entering the weight you are today. We will never ask you to share weight information in a group with other participants, this will only be shared with the research staff in this particular challenge to get you familiar with the app. No one else will see this information. For this challenge, please step on your scale. In the top section of the MakeMe app page, type in the weight you are today in pounds. Then, "Prove it with a photo" by taking a picture of the scale while you're stepping on it so that the research team can see the amount of weight displayed on the scale. Click the camera icon, select "Take a new photo" and your camera will open, allowing you to take a picture of the scale's display screen. You can also pinpoint your location if you choose to, but that will be optional for this study. Once you've typed in your weight and uploaded a photo of the scale's display screen, please click "Post Make".

Each time you make a challenge, you'll get points and you'll earn play cards. We will not use the play cards in this study, but feel free to collect them! After you post that you've made the challenge, please click "not right now" to the next screen that asks if you want to invite friends. *We want to keep this group closed.* After the study, you can feel free to use this app to work towards goals with other friends.

Step 15: Let's look at our profile page. Click those three orange lines at the left top of the screen. Click on your name. This will show you how many points you've collected through the challenges. Swipe left to get back to the menu.



Step 16: Click on the three orange lines again to take us to the menu. Click on "Settings". Scroll down and please turn "Cards" off. We will not be using play cards during the study.

Step 17: If you go into the challenge again by clicking on the orange lines and clicking the challenges tab, you'll see a newsfeed of when group members logged their challenge. You can give a "bump" to a group member for their good efforts! You can also click on a newsfeed post and comment on the post.

Step 18: That's about it… but if you have any other questions, please let us know as you go along. Once your group is formed, you'll receive an invitation to join a challenge in the next week or two through the MakeMe app and we'll send the challenge code to your email address as well. The group will be made up of 8-10 other pregnant women in early pregnancy working towards the same health goals! **Have fun!**

<u>Study Website Orientation</u>

1. Open the Internet browser (Safari, Chrome, etc.) on your computer, laptop or tablet.

2. Go to http://web.asph.sc.edu/mom2b
3. If you are using a tablet or cell phone, you can save this website as an app.
    a. Apple Users: with the HM2B log-in page open in Safari, you'll see an icon that looks like a piece of paper with an upward arrow at the bottom of this screen. It's the "send to" icon. Click this and a few options come up. Click "Add to Home screen" and then close out of the browser and you'll see the HM2B website will appear on your phone just like an app! Cool, right?
    b. Android users: with the HM2B log-in page open in your browser, you'll see three dots at the top right of the screen, next to where you typed our website address. Click these three dots and a few options come up. Click "Add to Home screen" and then close out of the browser and you'll see the HM2B website will appear on your phone just like an app! Cool, right?

4. Open our website from the app on your home screen or your browser. Log in with your study ID and password provided to you in the email. The study ID is four digits, and the password should be the name of a color or fruit with a number following, no spaces, no CAPS! Click "Remember me" if you don't want to have to enter your username and password every time. Log in.
5. You'll be taken to the study website Homepage, where you can navigate all of our resources.

6. **Healthy Eating/Physical Activity Condition:** Click "Weigh-in" to log your weight using the date of measurement, time of day you weighed yourself, and your current weight in pounds. Then click "Weigh-in" or you can skip logging your weight and go straight to your weight gain graph.
7. **Stress Reduction/Management Condition:** Click "Stress Scale" to track your stress levels. Move the slider from "No stress" to "Extremely stressed" with the level of stress you're feeling today. Then click "Record." You can skip the log and view your stress graph here too!
8. **All participants:**
9. Under "Weekly Tips" we will post an informational tip for having a healthy pregnancy with a link to additional resources related to the topic.

10. The “Study Forms” page will be where you can upload screenshots of any issues you’re experiencing with the mobile app. We will also provide a copy of the Informed Consent on the website so that you can access this form at any time to review the participation timeline and expectations. When a new survey link is available to you at 32-weeks and your delivery, we will post a link here for you as well.
11. “Podcasts” will be uploaded to the study website for you to listen to whenever you’d like! There are 10 total and you can listen to these as often or as little as you’d like to.
12. We have a “Leaderboard” that will be updated each Saturday so that you can see how your team is doing compared to the other teams in the study. We calculate points based on how many group members “Make” their challenge each week! Remember to motivate your team to be the top scorers of the week!!
13. The “Contact Us” page will have information for you to reach us at any time.

A few final reminders:

- The study website is INDIVIDUAL-user based, meaning your group members will not be able to see what you post or access in this website. Weight and stress information will never be shared with your group members, unless you personally choose to share that information.
- Our study team manages this website daily. If you have ANY issues, please contact us immediately and we’ll be happy to assist and troubleshoot.
- At any time while using the study website, you may click our logo at the top to get back to the homepage.

Appendix H: HM2B Final Survey

Healthy Motivations for Moms-to-be Study: Final Survey

HM2B Final Survey

1) What is your four digit HM2B participant ID number?
_____

2) Please enter your current email address.*
_____

Logic: Show/hide trigger exists.
3) In the past 3 months, have you moved to a different zip code?*
( ) Yes
( ) No

Logic: Hidden unless: #3 Question "In the past 3 months, have you moved to a different zip code?" is one of the following answers ("Yes")
4) What is your new zip code?*
_____

5) How would you describe your current relationship status? *
( ) Single
( ) In a relationship
( ) Married
( ) Widowed
( ) Divorced
( ) Other - Write In: _____

6) What is your current and primary employment status? Please select all that apply:*
[ ] Employed for wages full time (30 hours or more per week)
[ ] Employed for wages part time (less than 30 hours per week)
[ ] Unemployed
[ ] A homemaker
[ ] A student
[ ] Retired
[ ] Self-employed

7) When is your baby due?*
_____

8) During your current pregnancy, were you on WIC (the Special Supplemental Nutrition Program for Women, Infants, and Children)?*
( ) Yes
( ) No

9) During your current pregnancy, were you told by a doctor, nurse or other health care worker that you had gestational diabetes (diabetes that started during pregnancy)? *
( ) Yes
( ) No

10) During your current pregnancy, were you told by a doctor, nurse, or other health care worker that you had preeclampsia?*
( ) Yes
( ) No

11) During your current pregnancy, were you told by a doctor, nurse, or other health care worker that you had anemia or an iron deficiency?*
( ) Yes
( ) No

12) During the past 12 months, what was your yearly total household income before taxes? Include your income, your partner's income, and any other income you may have received. (All information will be kept private and will not affect any services you are now getting.)*
( ) Less than $10,000
( ) $10,000 to $14,999
( ) $15,000 to $19,999
( ) $20,000 to $24,999
( ) $25,000 to $34,999
( ) $35,000 to $49,999
( ) $50,000 to $69,999
( ) $70,000 or more

13) How many people, including yourself, depended on the income selected above (e.g. you and your partner=2)?*
# of people:: _____

Logic: Show/hide trigger exists.
14) Do you plan to work for pay during your baby's first year?*
( ) Yes
( ) No
( ) Not sure

Logic: Hidden unless: #14 Question "Do you plan to work for pay during your baby's first year?" is one of the following answers ("Yes")
15) How many weeks after the baby is born do you plan to get back to work?*
( ) Fewer than 4 weeks
( ) 4-6 weeks
( ) 7-9 weeks
( ) 10-12 weeks

( ) 13-16 weeks
( ) 17-20 weeks
( ) 21-30 weeks
( ) More than 30 weeks
( ) I have not decided yet.

Logic: Hidden unless: #14 Question "Do you plan to work for pay during your baby's first year?" is one of the following answers ("Yes")
16) What will you do with your baby while you are working? (Please select all that apply.)*
[ ] My baby will be cared for by a family member.
[ ] My baby will be cared for by someone not in my family.
[ ] I will keep my baby with me while I work outside my home.
[ ] I will keep my baby with me while I work at home.
[ ] I have not decided yet.

17) What method do you plan to use to feed your new baby in the first few weeks?*
( ) Breastfeed only (baby will not be given formula)
( ) Formula feed only
( ) Both breast and formula feed
( ) Don't know yet

Perceived Stress Scale

18) In the last month how often have you...*

	Never	**Almost Never**	**Sometimes**	**Fairly Often**	**Very Often**
been upset because of something that happened unexpectedly?	( )	( )	( )	( )	( )
felt that you were unable to control the important things in life?	( )	( )	( )	( )	( )
felt nervous and "stressed"?	( )	( )	( )	( )	( )

felt confident about your ability to handle your personal problems?	( )	( )	( )	( )	( )
felt that things were going your way?	( )	( )	( )	( )	( )
have you been able to control irritations in your life?	( )	( )	( )	( )	( )
felt that you were on top of things?	( )	( )	( )	( )	( )
been angered because of things that were outside of your control?	( )	( )	( )	( )	( )
felt difficulties were piling up so high that you could not overcome them?	( )	( )	( )	( )	( )

Weight-Related Knowledge and Behaviors

19) What is your current weight? (Please answer in pounds.)*

_____

20) Since joining this study, how often did you weigh yourself on a scale?*

( ) Never

( ) Daily
( ) Weekly
( ) Monthly

21) Since joining the study, do you regularly do any of the following meal-related activities? For each item, check Yes if you do it or No if you do not do it.*

	Yes	**No**
Shop with a grocery list	( )	( )
Budget for groceries	( )	( )
Build a grocery list around meal recipes	( )	( )
Prepare meals in advance	( )	( )
Portion out meals	( )	( )
Measure ingredients when following a recipe	( )	( )
Read nutrition facts labels	( )	( )
Compare brands when making	( )	( )

food choices		
Participate in WIC	( )	( )

22) In the past month, about how many times a week did you do the following activities *

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**or more times**
Ate fast food	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Ate at a restaurant (not fast food)	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Ate alone	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Made a main dish from scratch	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Made a purchase at a grocery store	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Wrote a to-do list	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Slept LESS than 6 hours a night	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )

Slept 6 OR MORE hours a night	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )

23) Do you use low-fat (2%), very low-fat (1%), or nonfat milk?*
( ) Yes
( ) No

24) Do you consider your eating patterns to be vegetarian or vegan?*
( ) Yes
( ) No

Health Behaviors

25) Thinking about the past month, how often did you:*

	Usually/Often	**Sometimes**	**Rarely/Never**	**Does not apply to me**
a. Skip breakfast?	( )	( )	( )	( )
b. Eat 4 or more meals from sit-down or take out restaurants?	( )	( )	( )	( )
c. Eat less than 2 servings of whole grain products or high fiber starches a day? Serving = 1 slice of	( )	( )	( )	( )

100% whole grain bread; 1 cup whole grain cereal like Shredded Wheat, Wheaties, Grape Nuts, high fiber cereals, oatmeal, 3-4 whole grain crackers, 1⁄2 cup brown rice or whole wheat pasta, boiled or baked potatoes, yuca, yams or plantain.				
d. Eat less than 2 servings of fruit a day? Serving = 1⁄2 cup or 1 med. fruit or 3⁄4 cup 100% fruit juice.	( )	( )	( )	( )
e. Eat less than 2 servings of vegetables a day? Serving =	( )	( )	( )	( )

1⁄2 cup vegetables, or 1 cup leafy raw vegetables.				
f. Eat or drink less than 2 servings of milk, yogurt, or cheese a day? Serving = 1 cup milk or yogurt; 1 1⁄2 - 2 ounces cheese.	( )	( )	( )	( )
g. Eat more than 8 ounces (see sizes below) of meat, chicken, turkey or fish per day? Note: 3 ounces of meat or chicken is the size of a deck of cards or ONE of the following: 1 regular hamburger, 1 chicken breast or leg (thigh and	( )	( )	( )	( )

drumstick), or 1 pork chop.				

26) Thinking about the past month, how often did you:*

	Usually/Often	**Sometimes**	**Rarely/Never**	**Does not apply to me**
h. Use regular processed meats (like bologna, salami, corned beef, hotdogs, sausage or bacon) instead of low fat processed meats (like roast beef, turkey, lean ham; low-fat cold cuts/hotdogs)?	( )	( )	( )	( )
i. Eat fried foods such as fried chicken, fried fish, French fries, fried plantains, tostones or fried yuca?	( )	( )	( )	( )
j. Eat regular potato chips, nacho chips, corn chips, crackers, regular	( )	( )	( )	( )

popcorn, nuts instead of pretzels, low-fat chips or low- fat crackers, air-popped popcorn?				
k. Add butter, margarine or oil to bread, potatoes, rice or vegetables at the table?	( )	( )	( )	( )
l. Eat sweets like cake, cookies, pastries, donuts, muffins, chocolate and candies more than 2 times per day.	( )	( )	( )	( )
m. Drink 16 ounces or more of non-diet soda, fruit drink/punch or Kool-Aid a day? Note: 1 can of soda = 12 ounces	( )	( )	( )	( )

27) In the past month, did you or a member of your family usually shop and cook rather than eating sit-down or take-out restaurant food?*
( ) Yes
( ) No

28) In the past month, did you usually feel well enough to shop or cook?*
( ) Yes
( ) No

29) How willing are you to make changes in your eating habits in order to be healthier? *

( ) 1 - Not at all willing ( ) 2 ( ) 3 ( ) 4 ( ) 5 - Very willing

---

Physical Activity Barriers

30) Do you currently have a gym or fitness center membership?*
( ) Yes
( ) No

31) Do you currently use a physical activity tracker (Fitbit, My Fitness Pal, Garmin watch, Apple watch, Pedometer, etc.)*
( ) Yes
( ) No

32) During a typical 7-Day period (a week), how many times on the average do you do the following kinds of exercise for more than 15 minutes during your free time (fill in each box with the appropriate number).*
STRENUOUS EXERCISE (HEART BEATS RAPIDLY) (e.g., running, jogging, hockey, football, soccer, squash, basketball, cross country skiing, judo, roller skating, vigorous swimming, vigorous long distance bicycling):
_____
MODERATE EXERCISE (NOT EXHAUSTING) (e.g., fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, alpine skiing, popular and folk dancing): _____
MILD EXERCISE (MINIMAL EFFORT) (e.g., yoga, archery, fishing from river bank, bowling, horseshoes, golf, snow-mobiling, easy walking) :
_____

33) During the past month, how much time did you spend....*

	None	**Less than a 1/2 hour per week**	**1/2 to almost 1 hour per week**	**1 to 2 hour per week**	**2 to 3 hours per week**	**3 or more hours per week**
...walking slowly for fun or exercise	( )	( )	( )	( )	( )	( )

...walking more quickly for fun or exercise	( )	( )	( )	( )	( )	( )
...walking quickly up hills for fun or exercise	( )	( )	( )	( )	( )	( )

34) The next question is about the time you spent sitting on weekdays during the last 7 days. Include time spent at work, at home, while doing course work and during leisure time. *Do not include the time you were asleep.* This may include time spent sitting at a desk, commuting, visiting friends, reading, or sitting or lying down to watch television or before falling asleep.

During the last 7 days, about how much time did you spend sitting per day?*
Monday (hours): _____
Tuesday (hours): _____
Wednesday (hours): _____
Thursday (hours): _____
Friday (hours): _____
Saturday (hours): _____
Sunday (hours): _____

Social Support

35) During the past three months, my family, friends, or HM2B group...*

	Family	**Friends**	**My HM2B Group**
Exercised with me.	_____ _____ _____	_____ _____ _____	_____ _____ _____
Offered to exercise	_____ _____ _____	_____ _____ _____	_____ _____ _____

with me.			
Gave me helpful reminders to exercise ("Are you going to exercise tonight?").	_____ _____ _____	_____ _____ _____	_____ _____ _____
Gave me encouragement to stick with my exercise program.	_____ _____ _____	_____ _____ _____	_____ _____ _____
Changed their schedule so we could exercise together.	_____ _____ _____	_____ _____ _____	_____ _____ _____

Discussed exercise with me.	_____ _____ _____	_____ _____ _____	_____ _____ _____
Complained about the time I spend exercising.	_____ _____ _____	_____ _____ _____	_____ _____ _____
Criticized me or made fun of me for exercising.	_____ _____ _____	_____ _____ _____	_____ _____ _____
Gave me rewards for exercise (bought me something or gave me something I like).	_____ _____ _____	_____ _____ _____	_____ _____ _____
Planned for exerci	_____ _____ _____	_____ _____ _____	_____ _____ _____

se on recreational outings.			
Helped plan activities around my exercise.	_____ _____ _____	_____ _____ _____	_____ _____ _____

36) During the past three months, my family, friends, or HM2B group...*

	Family	**Friends**	**My HM2B Group**
Asked me for ideas on how they can get more exercise.	_____ _____ _____	_____ _____ _____	_____ _____ _____
Talked about how much they like to exercise.	_____ _____ _____	_____ _____ _____	_____ _____ _____

Encouraged me not to eat "unhealthy foods " (Cakes, salted chips) when I'm tempted to do so.	_____ _____ _____	_____ _____ _____	_____ _____ _____
Discussed my eating habit changes with me (asked me how I'm doing with my eating changes).	_____ _____ _____	_____ _____ _____	_____ _____ _____
Reminded me not to eat high	_____ _____ _____	_____ _____ _____	_____ _____ _____

fat, high salt foods.			
Complimented me on changing my eating habits ("Keep it up", "We are proud of you").	_____ _____ _____	_____ _____ _____	_____ _____ _____
Commented if I went back to my old eating habits.	_____ _____ _____	_____ _____ _____	_____ _____ _____
Ate high fat or high salt foods in front of me.	_____ _____ _____	_____ _____ _____	_____ _____ _____

Refused to eat the same foods I eat.	_____ _____ _____	_____ _____ _____	_____ _____ _____
Brought home foods I'm trying not to eat.	_____ _____ _____	_____ _____ _____	_____ _____ _____
Got angry when I encouraged them to eat low salt, low fat foods.	_____ _____ _____	_____ _____ _____	_____ _____ _____
Offered me food I'm trying not to eat.	_____ _____ _____	_____ _____ _____	_____ _____ _____

Motivation to Change

37) I am willing to make changes so that I can...*

	1. Strongly Disagree	**2. Disagree**	**3. Neither Disagree nor Agree**	**4. Agree**	**5. Strongly Agree**
eat healthy food more often.	( )	( )	( )	( )	( )
eat vegetables more often.	( )	( )	( )	( )	( )
enjoy eating a variety of healthy food.	( )	( )	( )	( )	( )
eat fruit more often.	( )	( )	( )	( )	( )
prepare healthy meals more often.	( )	( )	( )	( )	( )
eat healthy snacks more often.	( )	( )	( )	( )	( )
eat whole grain food more often.	( )	( )	( )	( )	( )

eat more slowly to determine whether I am hungry or full.	( )	( )	( )	( )	( )
exercise regularly.	( )	( )	( )	( )	( )
feel less stressed.	( )	( )	( )	( )	( )
sleep better.	( )	( )	( )	( )	( )
feel more in control of my daily tasks.	( )	( )	( )	( )	( )
physically relax.	( )	( )	( )	( )	( )

Self-Efficacy

38) Below is a list of things people might do while trying to change their eating habits. Whether you are trying to change your eating habits or not, please rate how confident you are that you could really motivate yourself to do things like these consistently. Please select one number for each item:

How sure are you that you can do these things?*

	1=I know I cannot	**2**	**3=Maybe I can**	**4**	**5=I know I can**	**Does not apply**
Stick to your low fat, low	( )	( )	( )	( )	( )	( )

salt foods when you feel depressed, bored, or tense.						
Stick to your low fat, low salt foods when there is high fat, high salt food readily available at a party.	( )	( )	( )	( )	( )	( )
Stick to your low fat, low salt foods when dining with friends or co-workers.	( )	( )	( )	( )	( )	( )
Stick to your low fat, low salt foods when the only snack close by is available from a vending machine.	( )	( )	( )	( )	( )	( )

Stick to your low fat, low salt foods when you are alone, and there is no one to watch you.	( )	( )	( )	( )	( )	( )
Eat smaller portions at dinner.	( )	( )	( )	( )	( )	( )
Cook smaller portions so there are no leftovers.	( )	( )	( )	( )	( )	( )
Eat lunch as your main meal of the day, rather than dinner.	( )	( )	( )	( )	( )	( )
Eat smaller portions of food at a party.	( )	( )	( )	( )	( )	( )
Eat salads for lunch.	( )	( )	( )	( )	( )	( )

39) How sure are you that you can do these things?*

	1=I know I cannot	2	3=Maybe I can	4	5=I know I can	Does not apply
Add less salt than the recipe calls for.	( )	( )	( )	( )	( )	( )
Eat unsalted peanuts, chips, crackers, and pretzels.	( )	( )	( )	( )	( )	( )
Avoid adding salt at the table.	( )	( )	( )	( )	( )	( )
Eat unsalted, unbuttered popcorn.	( )	( )	( )	( )	( )	( )
Keep the salt shaker off the kitchen table.	( )	( )	( )	( )	( )	( )
Eat meatless (vegetarian) entrees for dinner.	( )	( )	( )	( )	( )	( )
Substitute low or non-fat milk for whole milk at dinner.	( )	( )	( )	( )	( )	( )

Cut down on gravies and cream sauce.	( )	( )	( )	( )	( )	( )
Eat poultry and fish instead of red meat at dinner.	( )	( )	( )	( )	( )	( )
Avoid ordering red meat (beef, pork, ham, lamb) at restaurants.	( )	( )	( )	( )	( )	( )

40) Below is a list of things people might do while trying to increase or continue regular exercise. We are interested in physical activities like running, swimming, brisk walking, bicycle riding, or aerobics classes. Whether you exercise or not, please rate how confident you are that you could really motivate yourself to do things like these consistently. Please select one number for each item:

How sure are you that you can do these things?*

	1=I know I cannot	**2**	**3=Maybe I can**	**4**	**5= I know I can**	**Does not apply**
Get up early, even on weekends, to exercise.	( )	( )	( )	( )	( )	( )
Stick to your exercise program after a long, tiring	( )	( )	( )	( )	( )	( )

day at work.						
Exercise even though you are feeling depressed.	( )	( )	( )	( )	( )	( )
Set aside time for a physical activity program; that is, walking, jogging, swimming, biking, or other continuous activities for at least 30 minutes, 3 times per week.	( )	( )	( )	( )	( )	( )
Continue to exercise with others even though they seem too fast or too slow for you.	( )	( )	( )	( )	( )	( )
Stick to your exercise program when undergoing a stressful	( )	( )	( )	( )	( )	( )

life change (e.g., divorce, death in the family, moving).						

41) How sure are you that you can do these things?*

	1=I know I cannot	**2**	**3=Maybe I can**	**4**	**5= I know I can**	**Does not apply**
Attend a party only after exercising.	( )	( )	( )	( )	( )	( )
Stick to your exercise program when your family is demanding more time from you.	( )	( )	( )	( )	( )	( )
Stick to your exercise program when you have household chores to attend to.	( )	( )	( )	( )	( )	( )
Stick to your exercise program even when	( )	( )	( )	( )	( )	( )

you have excessive demands at work.						
Stick to your exercise program when social obligations are very time consuming.	( )	( )	( )	( )	( )	( )
Read or study less in order to exercise more.	( )	( )	( )	( )	( )	( )

Pregnancy Resources Used

42) During your current pregnancy, where did you get most of your information related to nutrition and physical activity? (Please check all that apply.)*
[ ] Doctor/Nurse/Midwife
[ ] Friends/Family
[ ] Education classes
[ ] Blog posts
[ ] Podcasts
[ ] Websites
[ ] Social media (Facebook, Twitter, Instagram, Pinterest)
[ ] Cell phone apps
[ ] Books/Magazines
[ ] Other - Write In: _____

HM2B Program Feedback

Logic: Show/hide trigger exists.
43) Which HM2B condition were you assigned to? *
( ) Healthy Eating and Physical Activity (HEPA)
( ) Stress Reduction and Management (SRAM)

44) Since joining this program, have you/do you...*

	Yes	**No**
a. Tried different ways of preparing fruits and vegetables?	( )	( )
b. Increased fruit and vegetable consumption?	( )	( )
c. Eat more dark green vegetables than before?	( )	( )
d. Tried a fruit or vegetable that you didn't like before, but now like?	( )	( )
e. Eat more fruits and vegetables because you think they are good for you?	( )	( )
f. Tried to follow a healthier diet?	( )	( )
g. Reduced fast food intake?	( )	( )

h. Reduced sugary-sweetened beverage consumption (soda, sweet tea, etc.)?	( )	( )
i. Measure out portions when preparing a meal?	( )	( )
j. Increased moderate physical activity?	( )	( )
k. Increased the average amount of sleep you get each night?	( )	( )
l. Tried new ways to de-stress?	( )	( )
m. Increased the amount of time spent doing things you enjoy?	( )	( )

HM2B Challenges: Feedback

45) How would you rate the overall quality of the group challenges?*
( ) Very poor ( ) Poor ( ) Fair ( ) Good ( ) Very good

46) How useful were the group challenges to you?*
( ) Not at all useful ( ) Not very useful ( ) Somewhat useful ( ) Very useful

Logic: Hidden unless: #43 Question "Which HM2B condition were you assigned to? " is one of the following answers ("Healthy Eating and Physical Activity (HEPA)")

47) Please rate your level of enjoyment with the weekly challenges, with 0 being “did not enjoy the challenge at all” to 10 being “extremely enjoyed the challenge”. If you did not participate in the challenge, please select N/A.*

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**N/A**
Share a photo and description of your meals.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Engage in intentional physical activity.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Check out the nutrition label on your foods.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Aim for 20 minutes of physical activity.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Eat the most colorful meal you can today.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Engage in intentional stretching.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Listen to music while you exercise.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )

Set a healthy goal for yourself.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Count the number of times you eat fruits/veggies.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Drink more water.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )

Logic: Hidden unless: #43 Question "Which HM2B condition were you assigned to? " is one of the following answers ("Stress Reduction and Management (SRAM)")

48) Please rate your level of enjoyment with the weekly challenges, with 0 being “did not enjoy the challenge at all” to 10 being “extremely enjoyed the challenge”. If you did not participate in the challenge, please select N/A.*

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**N/A**
Share a gratitude journal entry.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Phone a friend.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Prepare for tomorrow.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Declutter a space you've been avoiding.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Take a mindful moment	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )

and reflect on your day.												
Be helpful to someone else.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Take a 20-minute technology break.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Set a healthy goal for yourself.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Set a bedtime and track your sleep.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Stressed out? Tell us about it.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Treat Yo'Self.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
Listen to music for at least 30 minutes.	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )

49) What improvements would you suggest for the weekly challenges?*

_____
_____
_____
_____

50) Do you have suggestions for other challenges we could include in the future?*

_____

_____
_____
_____

51) Each challenge that was not met prompted a “consequence” feature, where the app would ask you to share with the group why you weren’t able to make the challenge. Did you have to participate in a consequence at any point in the study?*
( ) Yes
( ) No

52) How motivated were you to avoid the consequence in the app?*
( ) Not at all motivated ( ) Not very motivated ( ) Somewhat motivated
( ) Very motivated

53) Do you have any feedback about the consequence feature of the app?*
_____
_____
_____
_____

54) How easy was it for you to use the MakeMe app?*
( ) Not at all easy ( ) Not very easy ( ) Somewhat easy ( ) Very easy

55) Did you experience any technical difficulties with the MakeMe app during the study?*
( ) Yes. Please describe the problem::
_____
( ) No

56) Please rate your overall level of enjoyment with the MakeMe app, with 0 being “did not enjoy using the MakeMe app at all” to 10 being “extremely enjoyed using the MakeMe app”.*
( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10

HM2B Study Groups: Feedback

57) How would you rate the overall social support provided in your group?*
( ) Very poor ( ) Poor ( ) Fair ( ) Good ( ) Very good

58) How interactive were your group members?*
( ) Not at all interactive ( ) Not very interactive ( ) Somewhat interactive
( ) Very interactive

59) How helpful were your group members?*
( ) Not at all helpful ( ) Not very helpful ( ) Somewhat helpful ( ) Very helpful

60) How motivated were you to meet the challenge by your group members?*
( ) Not at all motivated ( ) Not very motivated ( ) Somewhat motivated
( ) Very motivated

61) Please rate your level of enjoyment with your group members, with 0 being "did not enjoy being part of this group" to 10 being "extremely enjoyed being part of this group".*
( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10

62) Do you have any suggestions for improving the group/social support elements of this study?*
_____

HM2B Study Website: Feedback

63) How would you rate the overall quality of the study website?*
( ) Very poor ( ) Poor ( ) Fair ( ) Good ( ) Very good ( ) N/A - I did not use

64) How useful were the podcasts to you?*
( ) Not at all useful ( ) Not very useful ( ) Somewhat useful ( ) Very useful
( ) N/A - I did not use

65) How useful were the website's weekly tips to you?*
( ) Not at all useful ( ) Not very useful ( ) Somewhat useful ( ) Very useful
( ) N/A - I did not use

66) How useful were the website graphs to you?*
( ) Not at all useful ( ) Not very useful ( ) Somewhat useful ( ) Very useful
( ) N/A - I did not use

67) Please rate your overall level of enjoyment with the website features, with 0 being "did not enjoy the features on the wesbite" to 10 being "extremely enjoyed the features". If you did not participate in ANY features of the website such as weight or stress graphs, podcasts, weekly tips, or study forms, please select N/A.*
( ) 0 ( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10 ( ) N/A

68) What did you like MOST about the study website?*
_____

69) What did you like LEAST about the study website?*
_____

70) What improvements would you suggest for the website?*

_____
_____
_____
_____

HM2B Study: Overall Feedback

71) What improvements would you suggest for the study?*

_____
_____
_____
_____

72) What else would have motivated you to meet the weekly challenges?*

_____
_____
_____
_____

73) We understand that this was a lengthy survey! THANK YOU for your time. If you would like to be entered into a drawing for a HM2B package of prizes, please enter your mailing address below. We will draw a winner once a month, through December 2017.

_____
_____
_____
_____

Thank You!

Appendix I: Delivery Outcomes Survey

Healthy Motivations for Moms-to-be Study: Delivery Form

Delivery Information

1) What is your four digit HM2B ID number?*
_____

2) Your current height:*
Feet: _____
Inches: _____

3) What is your current weight? (Please answer in pounds.)*
_____

4) Just before giving birth to your baby, what was your final pregnancy weight? (Please answer in pounds.)*
_____

5) Delivery Date:*
_____

6) Gestational Age at Delivery:*
_____

Infant Outcomes

7) Infant's full name:*
_____

8) Infant's Sex:*
( ) Male
( ) Female

9) Delivery Type:*
( ) Vaginal
( ) Cesarean

10) Infant's Length at Delivery:*
_____

11) Infant's Weight at Delivery:*
pounds: _____
ounces: _____

Delivery Outcomes

12) Check if any of the following birth outcomes were present with your infant:*
[ ] Macrosomia
[ ] Large-for-Gestational Age
[ ] Preterm Delivery
[ ] Low Birth Weight
[ ] None of the above

13) Was your labor induced?*
( ) Yes
( ) No

14) Were there any complications during labor and delivery?*
( ) Yes, and please describe:
_____*
( ) No

15) What method are you currently using to feed your baby?*
( ) Breastfeed only (baby will not be given formula)
( ) Formula feed only
( ) Both breast and formula feed

16) What method do you plan to use to feed your baby over the next 6 months?*
( ) Breastfeed only (no formula)
( ) Formula feed only
( ) Both breast and formula feed
( ) Don't know yet

Contact information

17) Please enter your current mailing address below. We will be mailing you a final document to thank you for your participation in and completion of our study.*
_____
_____
_____
_____

18) Would you like to be contacted regarding future studies about:*

	Yes	**No**
Pregnancy	( )	( )

Postpartum	( )	( )
Exercise	( )	( )
Stress Reduction	( )	( )
Weight Maintenance	( )	( )
Healthy Eating	( )	( )

19) Thank you for your time. If you would like to be entered into a drawing for a HM2B package of prizes, please enter your email address below. We will draw a winner once a month, through December 2017.

_____

Thank You!