A Mobile Health Intervention to Sustain Recent Weight loss

by

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Nursing
Duke University

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Linda L. Davis

Dissertation submitted in partial fulfillment of
the requirements for the degree of Doctor of Philosophy
in Nursing
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ABSTRACT

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Abstract

Background: Obesity is the number one health risk facing Americans. The obesity epidemic in America is attributed to physical inactivity, unhealthy food choices, and excessive food intake. Structured weight loss programs have been successful in initiating behavior change and weight loss; however, weight is almost always regained over time. The rate of weight gain is highest immediately after cessation of a structured weight loss program. Thus, effective interventions are needed that can successfully be used following a structured weight loss program to sustain weight loss and prevent weight relapse. Due to low cost, ubiquity, and ease of use, healthcare communicated through mobile technology, or "mHealth", may be able to serve as an effective medium to reach a large number of people to facilitate weight loss behaviors. Short message service (SMS), also known as text messaging, is easy to use, ubiquitous, affordable, and can target people directly where they are regardless of geographic location, socioeconomic status, or demographic factors. A review of the literature demonstrated limited information regarding message content, timing and frequency of message delivery and only 3 of 14 SMS-related interventions reviewed demonstrated a statistically significant effect on weight loss, diet or exercise. Additionally, information on how to integrate and leverage SMS as a health promotion tool for weight loss was also limited in the literature.

The Behavior Change Process model was used as a guide to understand how to develop an intervention to help people sustain recent weight loss. Furthermore, research

suggests interventions that target and frame messages about how people reach goals in their life through either a prevention or promotion focus may be beneficial at motivating people to self-regulate and sustain recent behavioral changes. The goal of this study was to design an intervention that would help people stay in the continued response phase of the Behavior Change Process and help prevent weight relapse. Using the Behavior Change Process and regulatory focus theory, an intervention was developed that leveraged short message service (SMS) to deliver messages to people who have recently lost weight in attempt to help them sustain weight loss and prevent relapse.

Methods: First, a pilot study was conducted to inform the development of a SMS software application, the development of message content and the frequency and timing of message delivery. Second, an exploratory 3-arm mixed methods randomized controlled trial was conducted to test the feasibility, acceptability, perception of the usefulness, and efficacy of a weight loss sustaining mHealth SMS intervention among people with obesity. Participants (N=120) were randomized to a promotion message group, a prevention message group, or an attention-control general health message group. Participants completed baseline assessments, and reported their weight at 1 and 3 months post-baseline to assess efficacy of the intervention on sustaining weight loss. In addition, participants partook in a phone interview follow completion of the intervention to assess acceptability and usefulness.

Results: Participants found the message content and intervention acceptable and a majority perceived value in receiving messages via SMS that promote weight loss

sustaining behaviors. Interview data implied that the intervention served as a reminder and daily cue to action. Participants were favorable towards receiving a daily reminder, which they noted helped them to stay focused, and in some cases to keep them motivated to continue losing weight. And a majority, 42 (91%) who participated in a telephone interview said that they preferred to get messages on their cell phone due to accessibility and convenience. A minimum of one message per day delivered at approximately 8:00 A.M. was deemed the optimal delivery time and frequency. This was particularly true for weight loss, which many participants reported as a daily struggle that begins every morning. With regards to sustaining weight loss, there was a statistical trend in sustained weight loss at months 1 and 3 in the promotion and prevention framed message groups compared to the control group in both the intent-to-treat and evaluable case analyses. Clinically, there was a significant decrease in mean weight of approximately 5 pounds at month 3 in the promotion and prevention groups compared to the control. Additionally, effect sizes indicated a large effect of the intervention on sustaining weight loss in the promotion and prevention groups relative to the control group.

Conclusion: Overall results showed that at the continued response phase of the behavioral change process, it was feasible to design an application to deliver promotion and prevention framed weight loss sustaining messages. In particular, prevention framed messages may have been more useful in helping participants sustain weight loss. Though there was less than 80% power to detect a statistically significant difference, the observed effect sizes in this study were significant and demonstrated a large effect of the

promotion and prevention interventions on sustaining weight loss relative to control. Furthermore, there was a clinically significant increase in mean weight loss and in the number of people who sustained weight loss in the promotion and prevention intervention groups compared to control.

These findings may serve as a reference for future interventions designed to help people thwart relapse and transition from a state of sustaining recent weight loss behaviors to a state of maintenance. Technological tools such as this SMS intervention that are constructed and guided by evidence-based content and theoretical constructs show promise in helping people sustain healthy behaviors that can lead to improved health outcomes.

Dedication

I dedicate this dissertation to my Mother for always believing in me.

Contents

List of Tables

List of Figures

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1. Introduction

Obesity is the number one health risk facing Americans (Hoque, McCusker, Murdock, & Perez, 2010; Reuters, 2003; Weight-control Information Network, 2010). Over one-third of American adults are obese (National Center for Health Statistics, 2009). This condition is very costly (Finkelstein, Fiebelkorn, & Wang, 2004; National Center for Chronic Disease Prevention and Health Promotion, 2009) at over $190 billion annually (Cawley & Meyerhoefer, 2012) and is associated with lower self-esteem, depression, discomfort in social situations, and lower quality of life (Obesity in America, 2009) as well as multiple chronic diseases, including type 2 diabetes, cancer, and cardiovascular illnesses (Guh et al., 2009). In particular, minority and low socioeconomic groups are disproportionately affected by obesity (Y. Wang & Beydoun, 2007). The obesity epidemic in America is attributed to physical inactivity, unhealthy food choices, and excessive food intake (Centers for Disease Control and Prevention, 2009; National Heart Lung and Blood Institute & National Institute of Diabetes and Digestive Kidney Diseases, 1998). Sustained public health and clinical-based interventions are needed to increase physical activity (L. H. Anderson et al., 2005; Bijnen et al., 1998; Haskell et al., 2007; Katzmarzyk & Janssen, 2004; I. M. Lee & Skerrett, 2001; National Institute of Diabetes and Digestive and Kidney Diseases, 2003; Paluska & Schwenk, 2000; Perkins & Clark, 2001; Singh, 2002; G. Wang, Helmick, Macera, Zhang, & Pratt, 2001) and decrease caloric intake (Blanck et al., 2006; Kant, Graubard, & Schatzkin, 2004; U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2005; Yancy & Boan, 2006).

Structured weight loss programs have been successful in initiating behavior change and weight loss (Albright et al., 2005; Anderson, King, Stewart, Camacho, & Rejeski, 2005; Diabetes Prevention Program Research Group, 2002; Funk et al., 2008; Lin et al., 2007; Marcus, Lewis, et al., 2007; Marcus, Napolitano, et al., 2007; Pi-Sunyer et al., 2007); however, weight is almost always regained over time (Kramer, Jeffery, Forster, & Snell, 1989; Wadden & Frey, 1997; Wadden, Sternberg, Letizia, Stunkard, & Foster, 1989). The regain of weight is attributable to individuals' failure to self-regulate and sustain weight-control behaviors such as regular physical activity (Baum, Clark, & Sandler, 1991; R.W. Jeffery et al., 1984; Schoeller, Shay, & Kushner, 1997), consumption of a low-fat diet (R.W. Jeffery et al., 1984), and monitoring of body weight (Baum et al., 1991; Klem, Wing, McGuire, Seagle, & Hill, 1997; Kramer et al., 1989; Wadden & Letizia, 1992; Wing & Hill, 2001; Wing & Phelan, 2005). The rate of weight gain is highest immediately after cessation of a structured weight loss program (MacLean et al., 2009). About half of the lost weight is regained within the first year of treatment (Wadden et al., 1989), with 80% of patients returning to or exceeding their previous weight after 3-5 years (M.G. Perri, 1998; Wadden et al., 1989). When weight control behaviors are successfully achieved, weight loss is sustained, operationalized as continuation of the percentage of body weight lost following a weight loss program (Dunn et al., 1999; Pronk & Wing, 1994). Thus, effective interventions are needed that can be used following a structured weight loss program to successfully sustain weight loss and prevent relapse.

Research demonstrates that interventions intended to change unhealthy behaviors are more likely to elicit positive changes and benefit individuals and communities if they are guided by theories of behavior change (Brug, Oenema, & Ferreira, 2005). Theory provides a "road map" for the study of health problems and the design and evaluation of interventions (Glanz, Rimer, & Su, 2005). Of particular importance, the use of theory increases the likelihood to detect why and whether an intervention had its intended effect (Bartholomew, Parcel, Kok, & Gottlieb, 2006; Green & Kreuter, 1999). However, many theory-guided interventions that generate positive rates of initial change fail to facilitate long-term maintenance (Kramer et al., 1989; Rothman, 2000; Wadden & Frey, 1997; Wadden et al., 1989). Little is known about how people sustain health behavior changes.

Many of the traditional theoretical models of behavior change such as the health belief model (Rosenstock, Strecher, & Becker, 1988), and the theory of planned behavior (Ajzen, 1991) fail to make a distinction between initiation of a behavior and maintenance of a behavior. These theories define maintenance as action sustained over time and assume that the processes involved in initiation of a behavior are the same as maintenance. This is at odds with research that demonstrates successful rates of initiation do not translate into maintenance (M. G. Perri & Corsica, 2002; Toobert, Strycker, Barrera, & Glasgow, 2010). The transtheoretical model and stages of change provide a maintenance stage in the theoretical framework (Prochaska & Velicer, 1997). However, the distinction between initiation and maintenance focuses on the length of the time the new behavior has been performed. It doesn't necessarily distinguish between what is important to help people transition from one stage to the next. According to Social

Cognitive Theory (Bandura, 1991), self-efficacy is a critical determinant of both initiation and maintenance of behavior change. Confidence in the ability to make a change serves to sustain that change in the face of barriers and obstacles. However, this does not explain why changes in behavior are not always maintained (Rothman, Baldwin, Hertel, & Fuglestad, 2004).

These dominant health behavior change models are successful at guiding interventions that create short-term behavior change but do little to improve sustained behavior change (Rothman, 2000). Even among intervention strategies that increase the intensity or frequency of a treatment, thus delaying relapse, long-term sustainability and maintenance is not substantially improved (Curry & McBride, 1994; R. W. Jeffery et al., 1993; M. G. Perri, Nezu, Patti, & McCann, 1989). Therefore, it is assumed that there are psychological differences in the processes of initiation and maintenance.

Initiation of a behavior change occurs when people see a greater benefit in a new pattern of behavior than their current pattern of behavior (Weinstein, 1993). The initiation in behavior change is focused on obtaining positive future outcomes. Goal advancement occurs by decreasing the difference between a current state and a desired reference state (Carver & Scheier, 1996). In other words, people strive towards a goal by changing their current behaviors to be aligned with their desired behaviors.

Maintenance and sustainability, however, are thought to be based on whether the outcomes associated with the new behavior are sufficiently desirable to warrant continued action (Rothman, 2000). If people are satisfied with what they have accomplished, they will sustain the change and put forth effort to monitor their behavior

and prevent relapse. Goal advancement occurs by a sustained difference between a current state and an undesired state (Carver & Scheier, 1996). People continue their goals by sustaining their current behaviors, reflecting upon their on-going experience, and steering away from undesired behaviors, also known as self-regulation. This is consistent with Leventhal's self-regulatory model of illness behavior (Leventhal, Benyamini, & Brownlee, 1997; Leventhal & Cameron, 1987). However this model as in the aforementioned makes no formal distinction between initiation and maintenance (Rothman, 2000).

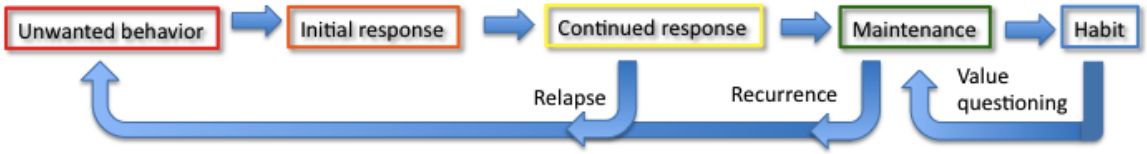

Figure 1: Behavior Change Process

Rothman's Behavior Change Process (Rothman et al., 2004)(Figure 1) can help us understand this process of behavior change and how to develop interventions that help people maintain healthy behaviors. This framework focuses on transitioning from unwanted unhealthy behaviors to healthy behaviors. The Behavior Change Process occurs over the four following phases: an initial response, a continued response, maintenance, and habit formation. In the initial response phase individuals begin to change their behavior. This continues until a significant change is evident. If they fail to achieve the desired behavioral response, the individual is considered to have failed the treatment or intervention and therefore do not transition to the second phase. Transition to the second phase, continued response, occurs once the individual successfully performs

the new behavior. In continued response, people continue the new behavior by evaluating their satisfaction with experiences of engaging in the new behavior (Rothman et al., 2004). A feeling of satisfaction indicates the decision to change was appropriate and provides validation for continued effort. This satisfaction is compared against whether the experiences with engaging in the new behavior meet or exceed their expectations of the outcomes of the behavior change. In addition, people must continue to be confident that they have the ability (self-efficacy) to continue the new behavior. The continued response phase is illustrated as a tension between a person's capability and motivation to consistently perform the new pattern of behavior, and the challenges that lead to lapses and relapses. Transition occurs at the subsequent maintenance phase when an individual no longer struggles to perform the new behavior, has confidence in their ability, and successfully performs it over an extended period of time.

In maintenance, there is a desire to sustain the new successful behavior. In this phase, people no longer have the need to question their ability to perform the new behavior, but continually reevaluate the perceived value. There is an ongoing assessment of the costs and benefits of the new behavior to determine if it is worth continuing. If people are satisfied with the new behavior, benefits outweigh costs, and there is perceived value, they will sustain it. In maintenance, if an individual returns to their previous unwanted behavior it is considered a recurrence. Finally habituation is reached once there is no longer a need to evaluate the behavior; the behavior sustains itself. If the need arises to reevaluate the new behavior, the individual transitions back to

maintenance. For each phase there are specific factors that have strong or moderate effects on transition to the next phase (Figure 2).

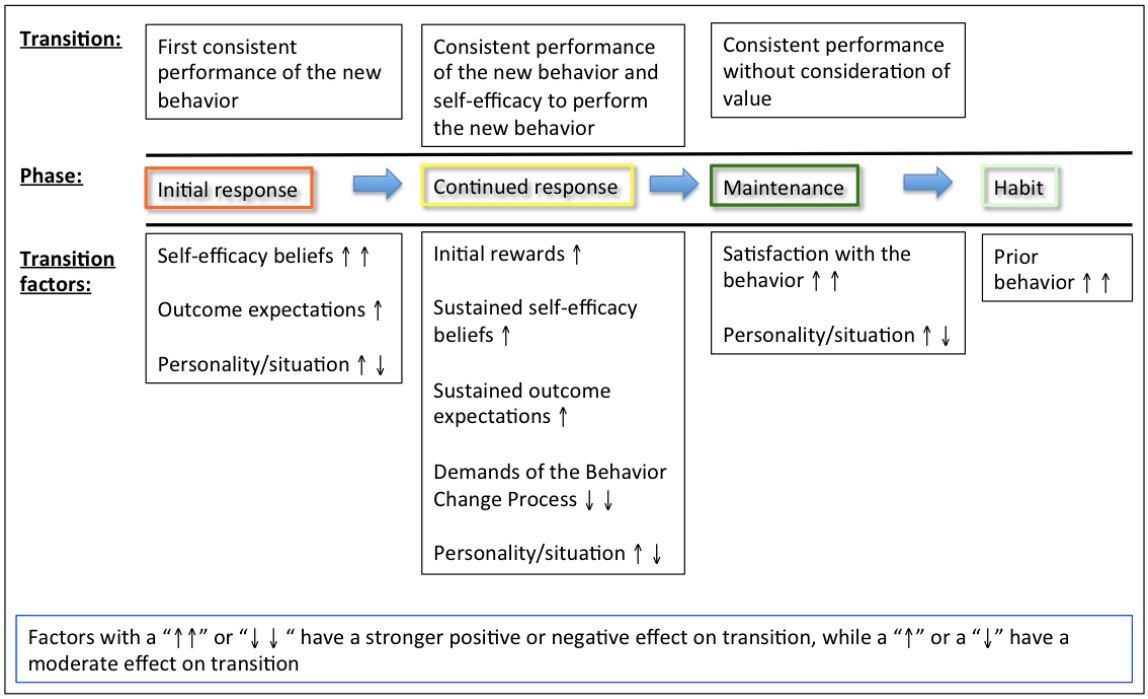

Figure 2: Transition through the Behavior Change Process (Rothman et al., 2004)

Interventions are needed to help people transition from an initial behavior change to a state of maintenance of the new behavior. This is especially true for complex behaviors such as weight loss, where the transition from continued response to maintenance is difficult. The relapse rate from continued response back to the unwanted behavior is high (Kramer et al., 1989; Wadden & Frey, 1997; Wadden et al., 1989). Continued research is needed to understand how to prevent relapse at the phase of continued response.

Due to the obesity epidemic the U.S. faces, obesity reduction is in critical need of research on sustainability and maintenance strategies. However, different processes

govern weight loss initiation versus sustainability (Baldwin et al., 2006; Finch et al., 2005; Rothman, 2000; Rothman et al., 2004; Rothman, Hertel, Baldwin, & Bartels, 2007). Emerging research suggests interventions that target and frame messages about how people reach goals in their life through either a prevention or promotion focus may be beneficial at motivating people to self-regulate and sustain recent behavioral changes (Higgins, 2000) such as weight control behaviors (Fuglestad, Rothman, & Jeffery, 2008).

Regulatory focus theory argues that there are two distinct strategies that people use to reach a goal (Higgins, 1987). People either promote success (promotion) or prevent failure (prevention)(Higgins, 2000). Although any goal can be pursued with either a promotion or prevention focus, some goals are more compatible with an individual's personal regulatory focus of promotion or prevention. When a goal matches a person's regulatory focus it creates a 'fit' (Higgins, 2000; A. Y. Lee & Aaker, 2004). Messages that 'fit' an individual's regulatory focus resonate more with the individual and are more persuasive (Cesario, Grant, & Higgins, 2004; A. Y. Lee & Aaker, 2004). Cesario et al. (2004) demonstrated this by giving a persuasive message about the importance of fruits and vegetables. When the messages matched with participants' regulatory focus, they were rated as being more persuasive. This match with a person's regulatory focus, in turn, may effect initiation and sustainability of behavior (Spiegel, Grant-Pillow, & Higgins, 2004). Motivational strength is enhanced when goals match a person's regulatory focus (Spiegel et al., 2004). Thus, when a 'fit' occurs people are better able to sustain self-regulation and behaviors that allow them to reach their goals such as physical activity, a healthy diet, and weight monitoring.

A limited number of prospective interventions have examined the use of regulatory focus and fit as part of programs to improve health. Spiegel et al. (2004) found that individuals who read either a promotion or prevention framed health promotion message urging them to eat more fruits and vegetables, ate 20% more fruits and vegetables the following week if the messages matched their individual regulatory orientation (promotion or prevention). Tailored messages to individuals' regulatory focus were also been shown to lead to greater physical activity (Latimer et al., 2008). Individual differences in regulatory focus have also been shown to differentially predict the initiation and maintenance of behavioral change in smoking and weight loss (Fuglestad et al., 2008; Kim, 2006). Thus, a prospective intervention is warranted that delivers health promotion framed messages to improve health, and in particular promote weight loss. One way to deliver such framed messages is through mobile phone short-message service (SMS), or text messaging. SMS has the potential to serve as an intervention medium to deliver regulatory focus (promotion and prevention) framed messages that can be easily and affordably used by clinicians and consumers.

SMS is a two-way communication technology that allows brief messages to be sent to and from mobile phones. Mobile phones are the most popular and widespread personal technology in the world with an estimated 5.9 billion subscriptions reaching over 87% of the world (International Telecommunications Union, 2011). In the US alone, more than 88% of the population use a mobile phone (CTIA Wireless Association, 2009), with over one trillion messages sent yearly and over 2.5 billion messages sent daily (CTIA Wireless Association, 2009). Due to widespread use and low cost of SMS, this

technology pervades all age groups (Atun & Sittampalam, 2006; Ling, 2004; Rice & Katz, 2003), many cultures (Goggin, 2006), and socioeconomic backgrounds (Ling, 2004; Rice & Katz, 2003). The nature of this technology allows it to reach across geographic boundaries and reach people directly where they are located.

SMS continues to be more commonly accepted and used as a mode for intervention, particularly related to weight loss (Krishna, Boren, & Balas, 2009). The perception of the "digital divide", the gap between those that have, and do not have, access to information technologies, based on sex, ethnicity, age, and socioeconomic status is rapidly changing as SMS becomes more pervasive. Over 73% of US adults use SMS and 50% of all US text message users are over the age of 35 (dotMobi, 2012). SMS users are 14% more likely to be Hispanic and 24% more likely to be African American than White (Scarborough Research, 2008). Thus, SMS may be an appropriate medium to specifically reach minority populations.

SMS can serve as a platform for persuasive technology (B. Fogg & Eckles, 2007), which is a computing system designed to change people's attitudes and behaviors (B. J. Fogg, 2003). No other medium exists that can reach people as quickly and personally as SMS. These characteristics of SMS make it an ideal tool to aid in chronic illness management and maintenance of healthy behaviors. Preliminary studies suggest that SMS is an affordable health care intervention tool, and has positive short-term behavioral and clinical outcomes when compared to usual care (Anhoj & Moldrup, 2004; Benhamou et al., 2007; Brendryen, Drozd, & Kraft, 2008; Casey et al., 2007; Dunbar et al., 2003; Ferrer-Roca, Cardenas, Diaz-Cardama, & Pulido, 2004; Fjeldsoe, Marshall, & Miller,

2009; Franklin, Waller, Pagliari, & Greene, 2006; Joo & Kim, 2007; Krishna et al., 2009; Lim, Hocking, Hellard, & Aitken, 2008; Patrick et al., 2009; Warwick, Dean, & Carter, 2007). Thus, SMS has the potential to serve as a tool to deliver targeted and framed weight loss-sustaining messages.

Dissertation Questions, Aims, Hypotheses

Researchers have been relatively unsuccessful at helping people sustain behavior changes. This is especially true for people who are obese and have tried to sustain weight loss. Though many interventions have been successful at initiating weight loss, weight is often regained over time. Accessible, easy to use and affordable interventions that focus on sustaining weight loss are needed and the use of newer theoretical models of sustaining behavior change is warranted. To address these research needs, this dissertation had the following five research aims:

The first aim of this dissertation was to review the literature on the relationship between the use of SMS as an intervention medium and weight loss (Chapter 2). The second aim was to develop framed short messages that are deliverable via SMS that promote weight loss among adults with obesity and to design and construct an automated SMS application to deliver these messages (Chapter 3).

The third aim was to assess the feasibility and acceptability of the implementation of two interventions that deliver daily weight loss sustaining messages in comparison to an attention-control group that receives general health messages via SMS over a period of one month to a sample of adults with obesity (BMI>30) who have lost at least 5% of their weight following the completion of a structured weight loss program (Chapter 4). To

address this aim, the following research question was asked: “What is the feasibility and acceptability of conducting a clinical trial with interventions that involve the delivery of daily weight loss sustaining messages via SMS over a period of one month in a sample of adults with obesity who have lost at least 5% of their weight following completion of a structured weight loss program?” More specifically, the following questions were asked, “Is it feasible to recruit a sample of 120 participants from a structured weight loss program who have lost at least 5% of their weight over a period of 9 months? Will the study participants read the messages daily over a period of one month? What is the acceptability, as measured by perceived usefulness, perceived ease of use, and attitudes towards the receipt of the interventions? And what are the technical and pragmatic barriers to the implementation of the interventions?”

The fourth aim of this dissertation was to evaluate the differential effects of daily promotion and prevention weight loss sustaining messages and relative to a control condition of general health messages on sustaining weight loss following the completion of a structured weight loss program in adults with obesity. The outcome was measured by self-reported weight at 1 and 3 months post baseline (Chapter 4). To address this aim, the two following research questions were asked, “Does the delivery of daily promotion or prevention framed weight loss sustaining messages when compared to general health messages increase the likelihood of sustaining weight loss? And does the likelihood of sustaining weight loss differ in the delivery of daily promotion framed weight loss sustaining messages relative to daily prevention framed weight loss sustaining messages?” It was hypothesized that participants randomized to either promotion or

prevention framed message group would have had an increased likelihood of sustaining weight loss compared to a general health message group, and that participants randomized to a prevention framed message group would have an increased likelihood of sustaining weight loss compared to a promotion framed message group.

The fifth and last aim was to determine whether individual promotion or prevention focus (regulatory focus) prior to the start of the interventions moderate the intervention effects on sustaining weight loss following the completion of a structured weight loss program in adults with obesity across 3 months (Chapter 4). To address this aim the following research question was asked, "Does individual differences in regulatory focus moderate the effects of the interventions on sustaining weight loss?" It was hypothesized that participants with a lower regulatory focus score (indicative of greater prevention focus) were more likely to sustain weight loss if they receive prevention messages across three months; whereas, individuals with a higher regulatory focus score (indicative of greater promotion focus) were more likely to sustain weight loss if they receive promotion messages.

The research aims, questions and hypotheses were explored with a review of the literature on SMS as an intervention medium for weight loss; development of an SMS intervention and theoretically framed weight loss messages; and analyses of data from a longitudinal, mixed-methods, randomized controlled trial on sustaining weight loss. The dissertation is organized as follows: Chapter 2 provides a review of the literature on the relationship between the use of SMS as an intervention medium and weight loss. These results were used to guide the initial development of the SMS intervention. Additionally,

recommendations for future research are presented. On the submission date of this dissertation, this chapter is in-press in the *Health Informatics Journal* and the version in this text may be circulated or posted by Ryan J. Shaw without further permission from SAGE publications Ltd. as in concordance with the Journal Contributor's publishing Agreement.

Chapter 3 presents the creation of the weight loss sustaining short messages and a pilot study to inform the development of an SMS software application. This chapter addresses the second aim of this dissertation.

Chapter 4 presents the results of a mixed-methods paradigm that includes a 3-arm randomized controlled trial that examines the efficacy of framed weight loss SMS on two intervention groups in comparison to a control group that receives general health messages. The SMS intervention tool and messages were tested for feasibility, acceptability, usability, message frequency and timing, technical difficulties, patient privacy barriers, perceived usefulness, and attitudes towards the message content. These findings provide preliminary data from which the direction and magnitude of the effects of the prevention and promotion interventions are evaluated. This chapter addresses the third, fourth and fifth aims of the dissertation.

Chapter five provides an overall summary of the dissertation, a discussion on the implications of the research, identifies study limitations, and offers recommendations for future research.

2. Short Message Service (SMS) Text Messaging as an Intervention Medium for Weight Loss: A Literature Review

Introduction

Nearly 68% of American adults are obese or overweight (National Center for Health Statistics, 2009) contributing to chronic disease, mental health problems (Simon et al., 2006), and disability (Obesity in America, 2009). The dramatic increase in the rates of obesity in the last 20 years is due to increases in calorie intake, eating nutrient poor foods, and reductions in physical activity (PA) (Centers for Disease Control and Prevention, 2009; National Heart Lung and Blood Institute & National Institute of Diabetes and Digestive Kidney Diseases, 1998). Weight-loss interventions utilizing a reduced-energy diet and exercise are associated with effective 5 to 8.5 kg (5% to 9%) weight loss that plateaus at approximately 6 months (Franz et al., 2007). Despite the effectiveness of these interventions, people continue to be overweight and obese. Even though we may understand how people lose weight, we must continue to develop effective interventions that people will use and adopt. One potentially effective intervention approach that is easy to use and adopt is the use of mobile devices such as cell phones.

Mobile devices such as cell phones have emerged as a mode of intervention delivery to help people improve their health, particularly related to weight loss (Krishna et al., 2009). In the US alone, more than 87% of the population use a mobile phone (CTIA Wireless Association, 2009). Cell phones as a medium to deliver weight loss interventions has distinct advantages in that it reaches across geographic and economic

boundaries, can be delivered directly to people and is easy to use (Atun & Sittampalam, 2006; Goggin, 2006; Ling, 2004; Rice & Katz, 2003). Furthermore, short message service (SMS) also known as text messaging, has grown in popularity as a way to deliver health information due to it's simplicity, low cost, and ability to serve as a cue to action (Atun & Sittampalam, 2006; Goggin, 2006; Ling, 2004; Rice & Katz, 2003). SMS is a messaging service of up 160 characters in length to and from fixed line and mobile phone devices. SMS text messaging is the most widely used data application in the world with over 2.4 billion users; twice the number of people who use the Internet uses SMS (CTIA Wireless Association, 2009).

Many commercial weight loss programs have adopted SMS as a tool to help clients in their weight loss. A quick web search reveals many online text-based weight loss tools including many "apps" for smart phones that message users about their diet and exercise. Though there is increasing popularity in SMS based weight loss tools, an evaluation of their effectiveness is needed. Thus, the purpose of this review was to answer the following question: what is the relationship between the use of SMS as an intervention medium and weight loss?

The Review

Search methods

A comprehensive search using Medline (PubMed), the Cumulative Index for Nursing and Allied Health Literature (CINAHL), ProQuest, PSYCHINFO and Google Scholar was undertaken. Key words used to search for relevant literature included obese,

overweight AND intervention, AND short message service OR SMS OR text messaging OR mobile health OR mHealth OR multimedia message service OR MMS. In addition, back referencing and citation searching of the selected studies was undertaken. Limits were set at studies published in English or with an English translation.

Inclusion and exclusion criteria

Inclusion criteria required that studies be randomized or quasi-experimental intervention trials of participants who are managing their weight. All interventions had to focus on the use of SMS on reducing obesity, overweight, or promoting weight loss. Studies that used other information technologies such as e-mail, phone calls, and video conferencing, were only included if SMS was a primary mode of communication. Studies were required to measure the impact of SMS on a weight loss related variable post-intervention including body weight, body mass index (BMI), waist circumference, physical activity (PA), or diet. In addition, all studies had to be published in a peer-reviewed journal or similar peer-reviewed process such as a dissertation.

Search outcomes

Using the aforementioned keywords resulted in 205 articles. After screening of titles and abstracts, 43 studies were read entirely. Eleven non-research studies were removed and 6 studies were removed that did not measure a weight loss related outcome post-intervention (i.e. BMI, body fat percentage, exercise, diet). In addition, two studies were removed that were purely qualitative and another was removed that used cell

phones as a portal to a web-based weight management program without SMS (Morak et al., 2008). Fourteen studies were included in the final analysis.

Synthesis

Meta-analysis of the data was not appropriate because there was a great deal of diversity in the interventions and outcomes measures. Many studies had small sample sizes (n<50) and only 5 had a sample size greater than 100. In this review, the main focus was on extracting data on descriptions of interventions (study design, samples, and intervention overviews), outcomes measures, and evaluation of the effectiveness of interventions. Quality of study design was assessed using a scoring system adapted from a review of eHealth interventions (Cole-Lewis & Kershaw, 2010; Norman et al., 2007). Nine methodological characteristics were used to score the studies. These included the following: individual randomization, use of a control group for comparison, isolation of text messaging technology, use of pre-test/post-test design, retention, equivalence of baseline groups, consideration of missing data, power analysis, and validity of measures.

Findings

All 14 studies focused on increasing PA or reducing sedentary behavior, 11 focused on improving dietary habits, 3 measured the effects of SMS on blood pressure (BP) as an outcome from weight loss, and 10 assessed the acceptability or feasibility of SMS as a mode of delivery for weight loss. Studies were conducted across the globe. Although SMS has been used an intervention medium to promote behavior change since 2004 (Fjeldsoe et al., 2009), studies reporting the use of SMS for weight loss were not

found prior to 2007. Mean age ranged from 10 to 65 and in general there were more female participants than male (1863 vs. 385). A clear theoretical or conceptual model was found to guide all but 3 studies (Fukuoka, Vittinghoff, Jong, & Haskell, 2010; Joo & Kim, 2007; Newton, Wiltshire, & Elley, 2009). These included, but were not limited to, social cognitive theory (Bandura, 1986), the self-efficacy construct (Bandura, 1986), the elaboration likelihood model (Petty & Cacioppo, 1986), the theory of planned behavior (Ajzen, 1991) and frameworks of self-monitoring and/or tailoring (Bauer, de Niet, Tinman, & Kordy, 2010; Fukuoka et al., 2010; Morak et al., 2008; Newton et al., 2009; Park, Kim, & Kim, 2009; Patrick et al., 2009; Shapiro et al., 2008).

Randomization was used in 10 studies (Fjeldsoe, Miller, & Marshall, 2010; Haapala, Barengo, Biggs, Surakka, & Manninen, 2009; Hurling et al., 2007; Kornman et al., 2010; Newton et al., 2009; Patrick et al., 2009; Prestwich, Perugini, & Hurling, 2010; Shapiro et al., 2008; Sirriyeh, Lawton, & Ward, 2010; Zuercher, 2009) and a comparison control group was used in 11 (Fjeldsoe et al., 2010; Haapala et al., 2009; Hurling et al., 2007; Kornman et al., 2010; McGraa, 2010; Newton et al., 2009; Patrick et al., 2009; Prestwich et al., 2010; Shapiro et al., 2008; Sirriyeh et al., 2010; Zuercher, 2009). The majority of studies had a single baseline measurement and a single post-intervention measurement. Intervention duration ranged from 2 weeks to 12 months. Only 2 studies intervened greater than 6 months, one for 36 weeks and the other for 12 months. For those studies that had a control group, usual diet and exercise care was the norm. All studies used SMS as an intervention tool, with one adding multimedia messaging service

(MMS) as an intervention tool (Patrick et al., 2009). MMS extends the capability of SMS to include pictures, videos and other multimedia.

Time of delivery of messages was reported in 6 studies and varied among mornings to just before bed. Delivery frequency varied dramatically between 2-5 times per day to once a month. Automation of the SMS was reported in 9 studies. There was limited information reported on the specifics such as software of the SMS programs used for delivery. All of the studies transmitted information from the researchers to the participants. Seven of the studies had two-way communication where participants transmitted information such as weight or PA via SMS to the researchers.

SMS Feasibility and Acceptability

Seven studies measured feasibility and acceptability of SMS as a mode for weight loss interventions (Bauer et al., 2010; Fukuoka et al., 2010; McGraa, 2010; Patrick et al., 2009; Shapiro et al., 2008; Sirriyeh et al., 2010; Zuercher, 2009). Feasibility was defined as the ability to transmit data via SMS to participants, the receipt of information by participants, and the ability to communicate back to the researchers. Acceptability was defined as feeling comfortable with receiving messages to a personal cell phone, feeling that messages were personally relevant, and that they were helpful. SMS was found feasible and acceptable in all 7 studies. Bauer (2010) found it feasible for children (n=40, mean age: 10) to self-report data on eating, exercise and emotions via SMS for 36 weeks. Additionally, several studies reported that people were positive towards the SMS system (Joo & Kim, 2007; Morak et al., 2008; Patrick et al., 2009; Zuercher, 2009).

Self-efficacy and Social Support

Of the three studies that measured the effects of SMS on self-efficacy, two found no significant change in PA self-efficacy (Fukuoka et al., 2010; Zuercher, 2009). One study showed a statistically significant increase ($p < 0.05$) in dietary self-efficacy in comparison to a control group (Haapala et al., 2009). One study measured social support, yet found no change from baseline to post-baseline in comparison to a control group (Zuercher, 2009).

Physical Activity

Three out of six studies that measured PA frequency or duration found a statistically significant difference in PA. All studies reported to use validated PA instruments. Fjeldsoe (2010) found an increase of PA of .74 days/week in a group of post-natal women who received tailored exercise SMS compared to control ($p < .05$). Prestwich (2010) reported participants in the SMS groups increased the number of days on which they met PA daily guidelines, through brisk and fast walking, significantly more ($p < 0.05$) than did the control group. Haapala (2009) found PA increased on average in both the SMS and control groups, from 2–3 times per month to once per week ($p < 0{\cdot}05$); differences between the SMS and control groups were not reported. Hurling (2007) found a significant increase in intent to exercise of .46 ($p < 0.01$) and perceived control of .84 ($p < 0.01$) in the SMS group compared to control. However, McGraa (2010), and Newton (2009) found no significant effect of PA in group of people receiving motivational exercise SMS compared to control.

Diet

Four studies measured the effects of an SMS intervention on dietary habits. Three of the 4 studies used instruments to measure diet specific variables (Haapala et al., 2009; Shapiro et al., 2008; 2009). Of these, only two used validated instruments (Haapala et al., 2009; Zuercher, 2009). Shapiro (2008) found that diet and exercise self-monitoring increased by 43% in the group reporting their behaviors via SMS versus 19% in the paper diary control. However, Zuercher (2009) found no significant difference in the amount of sugar sweetened beverages consumed by a group of women (n=177) receiving SMS tips on improving dietary behavior. Haapala (2009) also found no significant difference in caloric intake in the SMS group receiving tailored dietary feedback compared to a non-intervention control. Joo (2007) found recipients of weekly diet and exercise SMS lost 1.6kg over 12 months ($p < 0.01$), however, diet specific variables were not reported in the outcome measures.

Blood Pressure (BP)

Two of 3 studies that measured the effect of BP from weight loss found SMS statistically, and clinically, significantly reduced BP ($p < 0.05$). Park (2009), for example, found systolic and diastolic BPs significantly decreased by 9.1 and 7.2 mmHg respectively at 8 weeks from baseline (135.7 ± 8.8 mmHg) in the intervention group ($p < 0.05$) with no significant change in BPs in a control group. Joo (2007) found a -4.4mmHg within group decrease in SBP from a baseline of 125.9mmHg ($p < 0.05$) in a 12-week SMS diet and exercise intervention group.

Weight Loss

Overall, 11 (79%) of the 14 studies had a statistically significant effect ($p < 0.05$) on weight loss specific variables (i.e. weight, PA, or diet). Of the 10 studies that measured BMI or weight as an outcome, 5 (50%) demonstrated a statistically, and clinically, significant difference in BMI post-intervention ($p < 0.05$). Hurling (2007) showed an average 2.01% decrease in body fat in the group receiving tailored PA SMS compared to control ($p < 0.05$); however, no significant difference in BMI was found. Compared to a control group, Haapala (2009) found that the exercise SMS group lost 3.4kg over 12 months ($p < 0.01$) and that the percentage of people achieving at least 5% weight loss and keeping it off for 12 months was 25% greater in the intervention than control group. Patrick (2009) found that the experimental group that received tailored SMS and MMS with tips, suggestions, and positive reinforcement over 4 months lost 1.97kg more compared to a control group that received monthly printed materials ($p < 0.01$). In addition, Prestwich (2010) found the group that received goal reminders or plan reminders via SMS lost .39kg more over 1 month compared to a usual care control group ($p<0.05$). From baseline to follow-up, Joo (2007) found recipients of weekly diet and exercise SMS lost 1.6kg over 12 months ($p < 0.01$). Three studies found no significant decrease in BMI or body fat percentage compared to control (McGraa, 2010; Newton et al., 2009; Zuercher, 2009) and one found no significant difference from baseline to follow-up (Bauer et al., 2010).

Design quality

The average quality of the study designs was 66% (Table 2). Ten studies used randomization and a comparison control group. Retention was above 80% for 8 of the 14 studies. Three studies conducted a power analysis and recruited the respective needed sample size. Many of the studies were pilot or feasibility and did not have a power analysis for sample size calculation. All but two studies reported to use validated scales.

Discussion

There is a continuing challenge to develop interventions that successfully help people improve their health and lose weight. Results from this literature review demonstrate that SMS as an intervention tool for weight loss is still in its infancy as indicated by the paucity of randomized clinical trials with limited sample sizes. At the same time, 14 studies within a 4-year time frame demonstrate the increased attention of SMS as an intervention approach to promote weight loss behaviors. SMS was found feasible and acceptable as an intervention medium to transmit and receive diet and exercise messages. Acceptability was determined by people stating they felt comfortable receiving messages, were able to access and receive messages to their cell phone, and felt that the messages were helpful. This is important since mobile phones are a personal entryway into people's lives that provide a direct link of contact at any time and any place.

Of the 14 interventions in this review, 11 showed a statistically significant effect on weight loss, diet or exercise and one study showed a statistically significant effect on

BP. Clinical significance may be garnered from the results that indicated increases in PA, decreases in weight loss and improvement in systolic blood pressure. Nevertheless, 3 of the 14 interventions did not demonstrate a statistically significant effect on weight loss, diet or exercise.

Design of the interventions varied significantly. Notably, timing and frequency of delivery of SMS was inconsistent. Due to the inconsistency of timing and delivery, it is difficult to understand how often and when people should receive diet and exercise SMS. Of the 6 studies that delivered at least one SMS per day, 5 demonstrated significant improvement in weight loss behaviors. From these results, effectiveness and optimal use cannot yet be determined. Nonetheless, at least one SMS per day may be appropriate to help motivate people to engage in weight loss behaviors without generating considerable burden. Two studies used SMS to intervene or measured outcomes for greater than 6 months (Bauer et al., 2010; Haapala et al., 2009) with only one showing a significant difference (Haapala et al., 2009). The effectiveness of SMS longitudinally for weight loss presently remains undetermined.

SMS is often touted as an affordable and low cost method to deliver intervention and communicate between patient and providers. However, among the studies reviewed, there was limited discussion or evaluation on the cost-effectiveness of SMS. One study reported that participants received £140 for mobile phone costs but no specific details (2007). Bauer et al. (2010) spoke about the cost-effectiveness of their SMS messaging intervention and Patrick et al. (2009) reported that costs were low because the tailoring of

the messages was automated and additional users could be added at a low cost. Nevertheless, details were limited.

Continued research is needed on many fronts. Large randomized controlled trials with a significant sample size and longitudinal measurements are needed to understand how to best use and understand the benefits of SMS as an intervention medium. Informative research is needed to know exactly what should be written in a message and to understand the best timing and frequency of message delivery. In addition, it may not be that SMS in unto itself is the most effective intervention approach, but just one of many that should be used in combination to support and help people change their diet and exercise lifestyle.

Recommendations

Based on the findings of this review, the following recommendations for future research are offered:

1. Large randomized controlled trials with a significant sample size that can be used to determine effect sizes and statistical significance.
2. Intervention trials should be longitudinal in nature and evaluate maintenance of weight loss behaviors (12 months or longer).
3. Specific evaluation of cost-effectiveness, frequency, timing and optimal use of SMS.
4. More detailed reporting of intervention content and outcomes with respect to the magnitude of between-groups differences at follow-up and the direction and magnitude of change between end-of-intervention and follow-up.

Conclusion

Text messaging and cellular telephone technology have emerged as an encouraging tool to promote health that can reach people directly where they are, that is affordable, and easy to use. Quickly becoming a popular and major area of focus, SMS is part of a larger field of mobile health, known as mHealth. mHealth is the practice of medicine, nursing and public health supported by mobile devices. The US National Institutes of Health (NIH) alone have a dedicated mHealth research focus which partners with several NIH Institutes. Other public institutes such as the Centers for Disease Control (CDC) offer free mobile tips and alerts through SMS on how to improve individuals' health. Private corporations such as Microsoft have recently held a healthy apps competition where developers compete to create the best health focus application that can be run on a mobile phone. As more sophisticated mobile devices such as smart phones become ubiquitous, SMS will be just a part of a cadre of mHealth technologies that will become available. This affords the opportunity for research applications that were not previously available such as simultaneously assessing behavioral, physiological, and psychological states in the real world and in real-time. The use of mobile technology, including SMS, affords numerous methodological advantages over traditional methods, including "reduced memory bias, the ability to capture time-intensive longitudinal data, date- and time-stamped data, and the potential for personalizing information in real-time" (NIH Office of Behavioral and Social Sciences Research, 2011). However, continued

investigation is needed on how to best leverage this emerging technology to promote lifestyle change towards diet, exercise, and weight loss.

Table 1: Summary of Studies Included in Review

Author/ Date	Behaviors	Sample	Theoretical/ Conceptual model(s)	Research design	Duration	Delivery	Control	Intervention	Outcomes and Measures	Results
Randomized Controlled Trials										
Fjeldsoe, 2010	PA	N = 88, postnatal, 100% female, Australia	Social cognitive theory	2 group RCT, pre-test/post-test at 6 and 13 weeks; total duration: 12 weeks	12 weeks	Timing: not reported; Frequency: 3-5 x week; Automated: no	Usual care	Face-to face PA goal-setting consultation, tailored SMS and a support person who received SMS	Frequency and duration of PA	Primary outcome: Increased PA by 1.82 days/week and walking frequency by 1.08 days/week ($p<0.05$). Positive trends in duration of PA and walking
Haapala, 2009	PA, diet, weight reporting	N = 125, Age mean: 38, BMI mean: 30, 79% women, Finland	Contingency model, self-efficacy theory	2 x 2 RCT, pre-test/post-test at 3, 6, 9, and 12 months; total duration: 12 months	52 weeks	Timing: not reported; Frequency: participant initiated. 8 x week to 3-4 x week by end of 12 months; Automated: yes	No contact	Website tracked diet and weight. Weight sent in via SMS. Tailored diet and PA SMS delivered	Weight, height, waist circumference, perceived usefulness, attitudes of SMS, frequency of use, diet, PA, diet self-efficacy	Primary outcome: 4.5kg lost at 12 months ($p<0.01$) versus 1.1kg in control. Decreased waist circumference ($p<0.01$) Secondary outcome: moderate-high satisfaction, dietary improvements, increased PA, and dietary self-efficacy increased in those who maintained weight loss, but decreased in those who

Author/ Date	Behaviors	Sample	Theoretical/ Conceptual model(s)	Research design	Duration	Delivery	Control	Intervention	Outcomes and Measures	Results
										gained weight back
Hurling, 2007	PA	N = 77, mean age = 40.4, mean BMI: 26, Finland	Social comparison, decisional balance, elaboration likelihood, goal theory	2 group RCT, pre-test/post-test; total duration: 9 weeks	9 weeks	Timing: not reported; Frequency: not reported; Automated: yes	No support	Tailored solutions for perceived barriers, a schedule to plan weekly exercise sessions with SMS and e-mail reminders, message board to share experiences, and feedback on level of PA	Accelerometer, PA, weight, % body fat, height, BP, motivation, perceived control, intent to exercise, exercise knowledge	Primary outcome: significant difference in perceived control and intent to exercise ($p<0.01$). Secondary outcome: significant difference in percent body fat -2.18% in intervention group ($p = 0.04$) versus -0.17% in control; no significant difference in motivation, BMI or BP
Newton, 2009	PA	N = 78, mean age 14, 53% female, type 1 diabetes, New Zealand	Not reported	2 group RCT, pre-test/post-test; total duration: 12 weeks	12 weeks	Timing: not reported; Frequency: weekly; Automated: not reported	Usual care	Wore a pedometer and received motivational SMS	Daily step count, PA, HbA1c, BP, BMI, quality of life, Insulin dose	Primary outcome: no significant changes. At 12 weeks, mean daily step count was not significantly different ($p= 0.4$). Mean self-reported physical activity increased by 38.5 min/week in the control group and by 48.4 in the

Author/ Date	Behaviors	Sample	Theoretical/ Conceptual model(s)	Research design	Duration	Delivery	Control	Intervention	Outcomes and Measures	Results
										intervention group (p=0.9)
Patrick, 2009	PA, diet	N = 65, mean age: 45, mean BMI: 33.2, 80% female, USA	Self-monitoring and tailored messages	2 group RCT, pre-test/post-test; total duration: 4 months	4 months	Timing: varied; Frequency: 2-5 x day; Automated: yes	Monthly printed materials on weight control	SMS and MMS with tips and positive reinforcement. Printed materials and monthly phone calls as well. Participants reported weight via SMS once a week	Weight, adherence, satisfaction, validated self-reported questionnaires	Primary outcome: Intervention lost -1.97kg more than control (p<0.05). Secondary outcome: 67% adherence by week 16, majority of participants would recommend intervention
Prestwich, 2010	PA	N = 149, mean age: 23, female 64%, UK	Implementation intentions	3 group RCT, pre-test/post-test; total duration: 4 weeks	4 weeks	Timing: varied; Frequency: varied; Automated: yes	Usual care and completed a goal recall test at end of study	SMS plan and goal reminders. Completed a goal recall task at the end of the study	PA, implementation intentions, goal recall, weight, waist-to-hip ratio	Primary outcome: Increased brisk walking (p<0.01), goal reminder group lost the most weight (p<0.05) Secondary outcome: Total exercise increased in the implementation goal reminder group compared to control (p<0.05), but no difference in other groups

Author/ Date	Behaviors	Sample	Theoretical/ Conceptual model(s)	Research design	Duration	Delivery	Control	Intervention	Outcomes and Measures	Results
Shapiro, 2008	PA, diet	N = 58, aged: 5-13, 91% female, BMI mean 27, USA	Self-monitoring	3 group RCT, pre-test/post-test; total duration: 8 weeks	8 weeks	Timing: varied; Frequency: 2 x day; Automated: yes	Group 1: Paper diaries, Group 2: monitoring control	3 educational sessions per week for 3 weeks on pedometers, beverage serving sizes and screen time. Parent and child texted behaviors in. Automated text was sent in return. SMS used as a diary tool	Acceptability, self-monitoring adherence	Primary outcome: increase in self-monitoring in SMS group (43%) versus control (19%). Secondary outcome: reduction in screen-time in SMS group
Sirriyeh, 2010	PA	N = 120, aged: 16-19, 70% female, UK	Theory of planned behavior	4 group RCT, pre-test/post-test; total duration: 2 weeks	2 weeks	Timing: 4pm; Frequency: 1 x day; Automated: not reported	2 text messages total with a neutral message	Daily SMS of either affective beliefs, instrumental beliefs, or a combinations	PA	Primary outcome: 31.5 min. increase in PA across all groups ($p<0.05$). Inactive participants at baseline increased activity levels significantly more ($p<0.05$).
Zuercher, 2009	PA, diet, sedentary behavior	N = 177, aged: 18-30, female, USA	Social cognitive theory, elaboration likelihood, and social support theory	randomized pre-test/post-test; total duration: 1 month	1 month	Timing: before bed; Frequency: daily; Automated: yes	Stress management, pedometer, called on 5 random days and asked questions about previous day behavior	Monitored behaviors daily, inputting answers to 3 questions into their phones and received automated feedback to answers based on how close they were to achieving a daily goal	Weight/BMI, daily steps, sugar sweetened beverages, screen time, self-directedness, self-efficacy, social support, elaboration likelihood,	Primary outcome: No significant changes in PA Secondary outcome: Decrease in screen time in both groups. SMS was viewed as acceptable

Author/ Date	Behaviors	Sample	Theoretical/ Conceptual model(s)	Research design	Duration	Delivery	Controls	Intervention	Outcomes and Measures	Results
									self-monitoring, acceptance	
Quasi-experimental										
Bauer, 2010	PA, diet, emotions	N = 40, mean age: 10, 58% female, BMI-SDS mean: 2.62, Germany	Self-monitoring and tailored feedback	pre-test/post-test; total duration: 36 weeks	36 weeks	Timing: not reported; Frequency: weekly; Automated: yes	N/A	Self-monitoring of diet, exercise, and emotions via SMS following a cognitive behavioral therapy group. Tailored feedback was given after each response	Adherence, BMI	Primary outcome: feasible for children to self-report eating and exercise behaviors, 67% of the weekly SMS were submitted. Secondary outcome: no significant difference in BMI
Fukuoka, 2010	PA	N = 41, mean age: 48, BMI: 33, 100% female, USA	Not reported	pre-test/post-test; total duration: 3 weeks	3 weeks	Timing: not reported; Frequency: daily; Automated: yes	N/A	SMS encouraged participants to increase steps by 20% from the previous week	Total steps, self-efficacy, overall barriers, social support	Primary outcome: total steps increased by 15% over three weeks ($p<0.001$) and will-power improved ($p<0.001$). Secondary outcome: no change in self-efficacy, overall barriers, and social support

Author/ Date	Behaviors	Sample	Theoretical/ Conceptual model(s)	Research design	Duration	Delivery	Control	Intervention	Outcomes and Measures	Results
Joo, 2007	PA, diet	N = 927, 89% women, BMI mean: 25.7, South Korea	Not reported	Quasi-experimental pre-test/post-test	2 weeks	Timing: not reported; Frequency: weekly; Automated: not reported	N/A	SMS on behavior modification on exercise, diet and information brochures by post	Weight, waist circumference, BMI, BP, satisfaction	Primary outcome: significant weight loss of 1.6kg, waist circumference of 4.3 cm and BMI -0.6kg/m^2 ($p<0.01$), Secondary outcome: majority were satisfied with intervention
McGraa, 2010	PA, diet	N = 65, age range: 18-70+, 80% female USA	Captology, cognitive theory, social learning theory, persuasive tactics	two arms, pre-test/post-test; total duration: 5 weeks	5 weeks	Timing: 8 a.m.; Frequency: varied up to 3 x day; Automated: yes	Already on a diet and exercise program and did not receive SMS	Daily SMS log of diet, exercise, levels of motivation and stress, and weight. Weekly e-mail asking how often they exercised, logged diet, and level of stress and motivation.	Personality traits on using cell phone as intervention coach, adherence, exercise frequency, weight	Primary outcome: no significant effects on exercise frequency or weight
Park, 2009	PA, diet, medication	N = 49, mean age: 54, 57% female, BMI mean: 26.6, hypertensive, South Korea	Self-monitoring and tailored feedback	Quasi-experimental post-test evaluation	8 weeks	Timing: not reported; Frequency: weekly; Automated: no	N/A	Recorded BP and body weight via a website or cell phone. Tailored recommendations via the Internet and SMS were sent	BP, weight, waist circumference	Primary outcome: significant changes in SBP of -9.1 mmHg, DBP of -7.2 mmHg, weight of -1.7kg, and waist circumference 2.8cm ($p<0.05$)

Table 2: Quality of Study Design and Scoring Criteria

Author, Year	Individual randomization	Control group	Isolate technology	Pre-test/post-test	Retention ≥ 80%	Baseline groups equivalent	Missing data	Sample size calculation	Validated measures	Score (% of maximum)
Bauer, 2010	N	N	Y	Y	Y	N/A	N	N/A	Y	44
Fjeldsoe, 2010	Y	Y	Y	Y	N	Y	Y	N	Y	78
Fukuoka, 2010	N	N	Y	Y	Y	N/A	N	N/A	Y	44
Haapala, 2009	Y	Y	N	Y	N	Y	Y	Y	Y	78
Hurling, 2007	Y	Y	N	Y	N	Y	N	N	Y	56
Joo, 2007	N	N	Y	Y	N	Y	N	N	N	33
McGraa, 2010	Y	Y	Y	Y	N	Y	N	N/A	Y	67
Newton, 2009	Y	Y	N	Y	Y	N	Y	N	Y	67
Park, 2009	N	N	Y	Y	Y	Y	N	Y	Y	67
Patrick, 2009	Y	Y	N	Y	Y	N	Y	N/A	Y	67
Prestwich, 2010	Y	Y	Y	Y	Y	Y	Y	Y	Y	100
Shapiro, 2008	Y	Y	Y	Y	N	Y	N	N/A	N	56
Sirriyeh, 2010	Y	Y	Y	Y	Y	Y	N	N/A	Y	78
Zuercher, 2009	Y	Y	Y	Y	Y	Y	Y	N/A	Y	89

Table heading	Scoring criteria
Individual randomization	Were participants randomly assigned to study conditions? If so, was randomization at the individual level? Stratified and blocked randomization is acceptable. Studies that used individual randomization combined with a small proportion of randomized matched pairs are also considered Y. Appropriately designed and powered group randomization would also be acceptable if group was also unit of analysis. Individual randomization is N when the authors fail to mention randomization, specify that another method of assigning group status was used, or randomize at the group level and analyze at the individual level.
Control group	Did the study include a comparison group? Comparison group could be a no treatment, treatment as usual, or alternate treatment

	group.
Isolate technology	Did study design allow for test of effectiveness of the technology (e.g., Web-based delivery vs. no treatment)? To isolate the technology, the authors had to test the technology alone and compare with a group with no technology (Y). Packaged interventions in which the technological components cannot be parsed out are coded as not isolating the technology (N).
Pre-test/post-test design	Was assessment of behavior completed pre-intervention and post-intervention?
Retention	Was study retention at least 80% of subjects who initially agreed to participate in the study? Retention is calculated for the entire sample and not by group. For studies that did not report retention or dropout rates, retention can be calculated by using the sample sizes used for analyses (e.g., 300 randomized but only 250 included in analyses = 83.3% retention).
Baseline groups equivalent	Were tests conducted to determine whether groups were equivalent at baseline regarding important variables (e.g., gender, age, weight)? If no tests mentioned, then = unknown/unclear. If subset of tests indicated any group differences at baseline, then = N
Missing data	Were analyses conducted with consideration for missing data that maintain the fidelity of the randomization (e.g., intent to treat, imputation)? List wise, case deletion (completer analysis) = N if only analysis conducted. If 100% retention, then completer analysis is appropriate = Y. If authors compared the "dropped subgroup" with the selected or randomized sample but did not consider the impact of the dropped subgroup on randomization (e.g., intent to treat or imputation), then code as N.
Sample size calculation	Was power analysis reported to determine study sample size? If a feasibility or exploratory study for which sample size cannot be calculated beforehand, then N/A.
Validated measures	Did description of measures include reliability and validity information? If reference or coefficients, then Y. If well established measure known to be validated, then Y. For objective measures without validity evidence, if the objective measure is used as a proxy (e.g., food receipts for nutrition intake), then N. If the objective measure is used as a direct measure of behavior (e.g., food receipts for food purchase), then Y. If validity not reported and measure unknown, then unknown/unclear.
Total	Sum of Y's
Abbreviations: N, no; N/A, not applicable; Y, yes	

3. Development of a Theoretically Driven mHealth Short Message Service (SMS) Intervention to Sustain Recent Weight Loss

Introduction

Nearly 2/3 of the American population is overweight (BMI > 25) and 1/3 has obesity (BMI > 30). Obesity is costly on our healthcare system (Finkelstein et al., 2004; National Center for Chronic Disease Prevention and Health Promotion, 2009) and associated with multiple chronic illnesses (Guh et al., 2009). Though people are successful at initial weight loss, only one in six people successfully sustain weight loss (Bray, 2009; Kraschnewski et al., 2010). What is needed are easy and affordable intervention tools that promote sustainability and maintenance of weight loss (National Center for Chronic Disease Prevention and Health Promotion, 2009; National Heart Lung and Blood Institute & National Institute of Diabetes and Digestive Kidney Diseases, 1998).

Mobile phone short-message service (SMS), or text messaging has the potential to serve as an intervention medium to promote sustainability of weight loss that can be easily and affordably used by clinicians and consumers. SMS is a two-way communication technology that allows brief messages to be sent to and from mobile phones. Mobile phones are the most popular and widespread personal technology in the world with an estimated 5.9 billion subscriptions (International Telecommunications Union, 2011). In the U.S. alone more than 88% of the population use a mobile phone (CTIA Wireless Association, 2009), with over one trillion messages sent yearly and over

2.5 billion messages sent daily (CTIA Wireless Association, 2009). Due to widespread use and low cost of SMS, this technology pervades all age groups (Atun & Sittampalam, 2006; Ling, 2004; Rice & Katz, 2003), many cultures (Goggin, 2006), and socioeconomic backgrounds (Ling, 2004; Rice & Katz, 2003). The nature of this technology allows it to reach across geographic boundaries and reach people directly where they are located; and thus is increasingly accepted and used as a mode for health behavior change interventions rather than traditional mediums such as the Internet (Krishna et al., 2009). With over 73% of U.S. adults using SMS (dotMobi, 2012), no other medium exists that can reach people as quickly and personally as SMS. The perception of the "digital divide", the gap between those that have, and do not have access to information technologies based on sex, ethnicity, age, and socioeconomic status is rapidly decreasing as SMS becomes more pervasive.

SMS can serve as a platform for persuasive technology (B. Fogg & Eckles, 2007), which is a computing system designed to change people's attitudes and behaviors (B. J. Fogg, 2003). Preliminary studies suggest that SMS is an affordable mobile health (mHealth) intervention tool, and has positive short-term behavioral and clinical outcomes when compared to usual care (Anhoj & Moldrup, 2004; Benhamou et al., 2007; Brendryen et al., 2008; Casey et al., 2007; Dunbar et al., 2003; Ferrer-Roca et al., 2004; Fjeldsoe et al., 2009; Franklin et al., 2006; Joo & Kim, 2007; Krishna et al., 2009; Lim et al., 2008; Patrick et al., 2009; Warwick et al., 2007). However, a review of the literature by Shaw and Bosworth (in press) of SMS as an intervention medium for weight-loss, revealed that of the 14 SMS-related interventions reviewed, only 3 demonstrated a

statistically significant effect on weight loss, diet or exercise. There was limited information regarding message content, and timing and frequency of message delivery.

In order to leverage SMS as a tool to promote behavior change and sustain weight loss, we must match effective content with effective delivery. We must understand how much information to deliver, the frequency and timing of delivery, maintain compliance with patient privacy laws, and most importantly, understand how to deliver targeted weight loss sustaining specific information to motivate and promote self-regulation of weight loss behaviors; the ability to monitor one's own behavior, evaluate its effects, and adjust behavior as needed to continue and sustain progress towards a goal.

Weight loss is a complex behavioral process that involves many factors. The Behavior Change Process (Rothman et al., 2004) can be used as a guide to understand how to develop an mHealth intervention to help people sustain recent weight loss. This framework focuses on transitioning from unhealthy behaviors to healthy behaviors through a four-step process. The first step is an initial change, where for example, people with obesity begin an exercise program and healthy eating. That is followed by a sustained or continued response where people must overcome challenges and barriers to continuing the new exercise and diet behaviors. Ultimately, people move from the sustained response to a state of maintenance and then habit, where they have integrated the weight loss behaviors into their daily lives. However, for complex behaviors such as weight loss, the transition from continued response to maintenance is challenging (Kramer et al., 1989; Wadden & Frey, 1997; Wadden et al., 1989). People often relapse, revert back to their old behaviors and regain lost weight. In fact, many people revert back

to their old unwanted behaviors within the first month of a structured weight loss program (MacLean et al., 2009). Therefore, a mHealth intervention and application using SMS was developed to help motivate people to continue their weight loss behaviors within the first month of completing a structured weight loss program. The goal was to design a mHealth SMS intervention that would help people stay in the continued response phase of the Behavior Change Process and help prevent relapse.

Furthermore as a caveat, we sought to examine the feasibility of framing the content of the SMS intervention to reflect either a promotion or prevention focus. Known as regulatory focus (Higgins, 1987), emerging research suggests interventions that target and frame messages about how people reach goals in their life through either a prevention or promotion focus may be beneficial at motivating people to self-regulate and sustain recent behavioral changes (Higgins, 2000) such as weight control (Fuglestad et al., 2008). In particular, messages framed to a promotion or prevention focus that are matched to an individual's personal preference of promotion or prevention, known as regulatory fit, may be increasingly beneficial at helping to motivate and sustain recent behavioral changes (Fuglestad et al., 2008; Higgins, 1987, 2000).

With regard to the message frequency, the habituation-tedium theory suggests that message frequency is important for message effectiveness (Berlyne, 1970). Repeated exposures to messages lead to familiarity and increased effectiveness (Berlyne, 1970). However, too many messages and repetition may lead to tedium, increased boredom and become burdensome (Berlyne, 1970). Thus, it is imperative that optimal frequency of message delivery be determined. Previous studies report daily SMS had a positive

clinical effect on behavior (Franklin et al., 2006; Patrick et al., 2009; Riley, Obermayer, & Jean-Mary, 2008) and a review of the literature on SMS weight loss interventions indicated that once a day may be appropriate to help motivate people to engage in weight loss behaviors without creating substantial burden (Shaw & Bosworth, in press).

The objective of this study was to pilot a mHealth SMS intervention to promote sustaining recent weight loss in order to understand optimal frequency and timing of message delivery, and for feasibility and usability testing. We then used the results from the pilot study to design and construct a patient privacy compliant automated SMS application to deliver weight loss sustaining messages.

Methods

Message Development

Initially, we created 30 SMS on nutrition, exercise, and self-monitoring of weight, diet, and exercise; behaviors needed to sustain weight loss activity (Baum et al., 1991; R.W. Jeffery et al., 1984; Klem et al., 1997; Kramer et al., 1989; Schoeller et al., 1997; Wadden & Letizia, 1992; Wing & Hill, 2001; Wing & Phelan, 2005). Messages were the standard length of a single text message, 140 characters. Message content was derived from current diet and exercise guidelines (Haskell et al., 2007; Kant et al., 2004; U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2005), and the Duke University Diet and Fitness Center (DFC). Nutrition messages focused on strategies to promote fullness, portion control, and to avoid binge eating and trigger foods, planning meals, coping strategies and monitoring food intake. Exercise messages focused on

benefits of exercise, physical activity goals, overcoming barriers, barriers to initiating and maintaining exercise/physical activity, monitoring exercise amount and intensity, and fitness activities. Monitoring messages focused on monitoring weight, food intake, exercise, identifying poor habits, and reviewing progress with weight and behavior patterns over time.

We then framed each message to a promotion and prevention focus for a total of 60 messages (see Appendix A). Two expert health psychologists reviewed the messages to verify they were framed appropriately to match a prevention or promotion orientation. Promotion focused messages used words such as “reward,” “continue,” “check,” “monitor,” ”reach,” and “help.” An example of a promotion message was, “Monitor your progress and how you are doing. Schedule time to review your progress in your calendar.” Prevention focused messages used words and phrases such as “prevent,” “failure,” “risk,” “avoid,” “steering clear,” and “do not allow.” An example of a prevention message was, “Prevent over eating. Use smaller plates to avoid filling a larger plate with extra calories.” The messages were then pilot tested for their usefulness and relevance.

Study design

Recruitment. With IRB approval, participants were recruited from a residential weight management program in North Carolina known as the Duke Diet and Fitness Center (DFC). DFC provides a residential weight management program that helps people affected by excess weight and impaired physical fitness achieve better health through

weight loss, physical conditioning, and improved self-care habits. Clients enroll in a comprehensive program that provides education, practical behavioral strategies, and ongoing support to make long-term changes.

Eligible participants were obese at enrollment (BMI > 30) and who met the following inclusion criteria: 1) ≥18 years old; 2) able to speak and read English; 3) had completed a comprehensive diet and fitness program; 4) lost 5% of their body weight; 5) had their own mobile phone to personally receive SMS; 6) physically able to access SMS on their phone; 7) able to continue physical activity for 3 months; 8) did not have a joint replacement scheduled within 3 months; and 9) were capable of informed consent. Participants were compensated $50 for their participation in the study.

Potential participants were approached during a self-management class at the DFC; those who met the inclusion criteria and agreed to participate, signed an informed consent, and completed a survey including demographics and the Regulatory Focus Questionnaire (RFQ) (Higgins et al., 2001).

Intervention. Following informed consent, participants were provided with an orientation to the SMS intervention. As an initial delivery frequency to be tested, messages were sent out daily for 30 days at an arbitrary time, 9:00 A.M. A message delivery log was kept and checked daily to ensure participants were delivered the appropriate daily messages. Participants received messages (promotion or prevention) that matched with their RFQ results. Messages were set in a queue and alternated between nutrition, exercise and monitoring (see Appendix A for message content).

Following delivery of the messages for one month, an SMS was sent to participants asking them to respond via SMS with their self-reported weight at one month post-enrollment. E-mail was also sent to participants asking when they would be available to participate in a phone interview. If participants did not respond to the e-mail, the researcher called them on the phone to set up a time to conduct the interview. Interview questions were open-ended and focused on perception of the usefulness and attitudes towards the messages (Borrelli et al., 2005; Dane & Schneider, 1998; Resnick et al., 2005), intervention experiences (Borrelli et al., 2005; Dane & Schneider, 1998; Resnick et al., 2005), technical difficulties, intervention fidelity, and suggested changes for the intervention. With permission, interviews were recorded and transcribed. A subsequent SMS was sent after 3 months from the start of the intervention asking participants to respond with their self-reported weight.

Measures and variables. Demographics were obtained from self-report at baseline. Height, weight, and BMI were obtained at baseline from participants' medical record. Participants responded via SMS to the researcher with their self-reported weight after one and three months. The regulatory focus questionnaire (RFQ) (Higgins et al., 2001) was used at baseline to determine if participants had a stronger promotion or prevention focus in reaching their goals. This measure consists of 11 five-point Likert-type items (5 prevention, 6 promotion), which assesses the history of individuals' success at promotion and prevention tasks over the course of their lives. Scores range from -2 to +2. Positive scores indicate greater previous success in promotion self-regulation. Negative scores indicate greater previous success in prevention self-regulation. The

reliability for the promotion (α = .0.73) and prevention subscales (α = .0.80) has shown to be high and are modestly correlated (r = .21, p < .001), and content validity was demonstrated through expert review (Higgins et al., 2001). Test-retest reliability over a period of two months produced correlations of r = .79 for the promotion scale and .81 with the prevention scale (Higgins et al., 2001). Convergent validity was demonstrated with Jackson's personality research form (Jackson, 1974) and discriminant validity was shown with the behavioral approach system scales (BAS) /behavioral inhibition system (BIS) scale (Higgins et al., 2001). Regulatory focus scores were assessed at baseline.

Feasibility and acceptability were measured at 1 month post-baseline by a telephone interview. To assess feasibility and fidelity of the study design and delivery of treatment (Bellg et al., 2004), participants were asked how often they read the messages, if there were times when they did not read the messages, and if they encountered technical barriers. Participant responsiveness and treatment fidelity related to receipt of the messages (Bellg et al., 2004) were calculated based upon how useful and favorable (attitudes) participants felt about the intervention. Asking participants their perception of the usefulness and attitudes toward the SMS assessed acceptability, whether they liked the message content, and whether they liked SMS as an intervention tool for helping sustain weight loss. In addition, participants were asked if anything else occurred in their lives during the 90-day study period that may have affected sustaining their weight loss, such as a major life event or participation in other weight loss programs. To assess optimal frequency and timing to deliver the messages, participants were asked how they felt about the frequency and timing.

Data Analysis

Demographics and change in weight were calculated using descriptive statistics with SAS Version 9.3 (SAS Institute Inc., Cary, NC). Interview data were analyzed using conventional content analysis, a data reduction technique, to look for recurring themes (Graneheim & Lundman, 2004; D.F. Polit & Beck, 2004; Sandelowski, 1995) using Microsoft Excel 2007 (Microsoft, Redmond, Washington). Questions asked in the interviews regarding intervention perceived usefulness, attitudes (Borrelli et al., 2005; Dane & Schneider, 1998; Resnick et al., 2005), and experiences (Borrelli et al., 2005; Dane & Schneider, 1998; Resnick et al., 2005) guided the analysis. The content analysis involved dividing text into segments of information and the categorization and classification of patterns into code segments (Neuendorf, 2002). These code segments were then analyzed for frequencies and coded into categories. Inferences were made from the categories and collapsed into themes (Creswell, 2007). A second researcher reviewed the interviews for interrater reliability and agreement on outcomes. Results on perception of the usefulness and attitudes were divided into three categories of negative, positive, and neutral perceptions. Two researchers reviewed these data to ensure consistency in the findings. Data on frequency and timing of participant preferences of SMS delivery was tallied.

Results

Participant characteristics

Sixteen out of 50 participants approached, agreed to enroll in the study. All participants (*N* = 16) were enrolled between September and October 2010. Baseline demographics indicated that 13 (81%) were female, 15 (94%) were White,1 (6%) was African American, 10 (62.5%) were promotion focused, and 6 (37.5%) were prevention focused. All participants had a college level education. The mean baseline weight was 206.8 (*SD* = ± 39.8) pounds. All participants were capable of sending and receiving SMS and had previous experience with SMS. Of the 16 participants, 14 (87.5%) completed the study and participated in individual telephone interviews. 13 (93%) reported their weight at 1-month post-baseline during the phone interview and at 3-months post-baseline via SMS. Twelve (86%) participants either sustained or continued to lose weight at 1-month post-baseline and 11 (79%) participants sustained or continued to lose weight at 3-months post-baseline (see Table 3).

Table 3: Baseline Characteristics and Weight Over Time

Participant	Gender	Race	Regulatory focus	Baseline weight	1-month weight	1-month difference from baseline	3-month weight	3-month difference from baseline
1	F	W	Promotion	206	196	-10	*	
2	F	W	Promotion	183	172	-11	169	-14
3	M	W	Prevention	227	224	-3	205	-22
4	F	W	Prevention	232	226	-6	223	-9
5	M	W	Promotion	212	195	-17	191	-21
6	M	W	Promotion	239	*		*	
7	F	W	Promotion	220	212	-8	197	-23
8	F	WH	Promotion	212	209	-3	*	
9	F	W	Promotion	173	165	-8	181	+4
10	F	W	Prevention	194	*		183	-11
11	F	B	Prevention	306	277	-29	280	-26
12	F	W	Prevention	246	240	-6	244	-2
13	F	W	Promotion	169	169	0	150	-19
14	F	W	Prevention	145	140	-5	136	-9
15	F	W	Promotion	156	161	+5	161	+5
16	F	W	Promotion	188	186	-2	157	-31

* = no response; F = female, M = male; W = White non-Hispanic, WH = White Hispanic, B = Black or African American

Acceptability

Perception of the usefulness of the messages. The majority of participants (*n* = 10, 71%) felt the messages were useful in helping them sustain weight loss. One respondent said, “It really helped me. It was like having a pearl [of wisdom]. I liked that they reinforced behaviors.” Reinforcement and encouragement arose as a theme. Several participants said that the information helped to reinforce and remind them what behaviors they should be performing to sustain weight loss. For example, one participant stated that the messages, “helped get the message home.” Participants felt that the message content was appropriate and reflected behaviors they need to perform to sustain recent weight loss (a healthy diet, physical activity, and monitoring of progress). Several participants noted that they missed receiving the messages and were disappointed when the study ended.

Several (*n* = 3, 21%) participants enjoyed the messages, but they were not sure how much they helped them sustain their weight loss. These three participants said that they didn’t think the messages were enough and that other factors (e.g., social support) may have been more beneficial in helping them sustain weight loss. One participant said, “takes more than an e-mail [SMS] to lose weight.” These participants felt that additional elements should be added to the intervention. Some of their suggestions included: supportive phone calls, a mentoring program in-person or online, and an online support program with other people who are losing weight. In these cases, the social support aspect was missing. One participant (*n* = 1, 6%) did not find the messages useful at all.

This participant said the messages were annoying and redundant and did not enjoy receiving information they already knew. Of the 3 neutral and 1 negative responders, demographic characteristics or regulatory focus scores were not significantly different from the other participants.

A motivational theme emerged from the interviews. Participants (n = 4, 29%) felt that the messages were inspirational and served as "words of encouragement." However, other participants (n =3, 21%) said that the messages were not motivational and would prefer messages that give a "boost in self-confidence." Another two participants said that they would prefer to have a mix of both factual and motivational messages.

Attitudes towards the messages. Results indicated that the majority of participants (n = 13, 93%) were favorable toward the messages. Participants reported enjoying and receiving "a daily boost of confidence", and that they "always looked forward to it." These messages were also viewed as social support. For example, one participant said, "It says there is somebody out here who cares and is reminding you don't forget. It just starts your morning." Another participant said, "it was like having a buddy," while another said "it was like someone was over my shoulder. It was like a conscious."

Usefulness and attitudes towards SMS technology. All participants who completed the interview (n = 14, 100%) thought that SMS was a favorable communication medium and was a useful way to receive messages promptly and directly. As noted by one participant, "I always have my cell phone on me." Several participants (n = 4, 29%) noted SMS was useful because they were able to keep the messages on their

phone and it was easy to read them multiple times. Seven (50%) participants said that they read the messages multiple times. Four (29%) participants said that they preferred SMS compared to other mediums such as e-mail or telephone. However, one older participant said that she preferred e-mail to SMS. Three (21%) said they forwarded and shared the messages with other people who were also trying to lose weight.

Another theme that emerged was that SMS is a good tool to deliver short relevant messages. Three participants said that they found the messages useful because they consisted of small amounts of relevant information. One participant noted "I have the [weight loss program] material to go back and review, but what I am trying to figure out is what is the most powerful tool (information) for me." This participant said that SMS made it easy to find the information and it came directly to her.

Fidelity and message delivery

All participants (n = 14, 100%) said they read the messages when they knew they arrived. Most participants (n = 11, 79%) said that they read the messages every morning during the 30 days of message delivery. Several participants (n = 3, 21%) however did not read the messages upon arrival every morning. Of these participants, one said that she was more tied to e-mail and missed some messages coming in because her phone was on silent or she did not notice the message had arrived. Another was on vacation during part of the intervention and did not receive the messages during that time period. Another participant had technical difficulties with her phone and stopped receiving messages after two weeks.

All participants (n = 14, 100%) thought that the frequency of receiving a daily message promoted weight loss sustaining behaviors. Participants felt that weight loss is a daily activity and that receiving messages less frequently would be less effective. Several participants (n = 3, 21%) expressed that twice a day would still be appropriate and they indicated that a message in the morning and at night would be acceptable. All participants expressed that the best time to deliver daily messages was in the morning at approximately 8:00 A.M. in their respective time zone. This was expressed as an optimal time because it sets a precedent for the day. One participant noted that receiving a message later in the day may not be as effective because they may have already missed exercising or eaten something not on their dietary plan.

Of the 14 participants who completed the study, 12 (86%) participants either sustained or continued to lose weight at 1-month post-baseline and 11 (79%) participants sustained or continued to lose weight at 3-months post-baseline. Thus, it was possible to successfully collect weight loss data via SMS.

Lessons learned

This pilot study provided the following lessons learned for the development of an SMS application. These include the following:

1. Participants want at least one daily message
2. Messages should be delivered at 8 A.M. in a participant's respective time zone
3. Messages should not be beyond the standard text messaging length of 140 characters

4. Confirmation of message delivery is needed
5. Participants' phone numbers are considered protected health information (PHI) and must be used with a secure system

Application Development

The SMS application was written in C++, using the Microsoft Visual C++ 2010 compiler. Three code libraries were used: the Microsoft Visual C++ runtime, for basic computer services; Microsoft Foundation Classes, for user interface services; and libcurl, for secure hypertext transfer protocol secure (HTTPS) data transmission services.

The SMS application read a database of configuration information and subject information. Configuration information consisted of the text messages for each planned intervention group (promotion, prevention, and control) and the login information for the HTTPS-based SMS service. Subject information consisted of each participant's telephone number, time zone, intervention start date, and intervention group (promotion, prevention, or control).

The database was in the form of five text files on a secure file server. Three files held the list of messages for each intervention group, with one message on each line: promotion.txt, prevention.txt, and control.txt. One file held login information for the HTTPS-based SMS service, with the account name and password on separate lines, obfuscated by a simple encoding: login.txt. This file optionally held a confirmation number, where a text message confirming daily automatic operation was sent. The final file held subject information in comma-separated value (CSV) format: subjects.txt.

The SMS application also wrote logs of its activity. The database of logs consisted of text files stored on the same secure server as the configuration and subject data. Each log file was named by the date of activity described within the file.

The location of the secure file server was stored in a file, SMS.ini, placed in the same directory as the application itself. If this was not specified, the SMS application defaulted to its own directory.

The application had two modes of use: manual and automatic. Manual mode was for initial setup, testing, and error recovery. Automatic mode was for regular use throughout the course of the trial. Manual functions included SMS service login configuration, configuration verification, and message sending. Automatic functions were configuration verification and message sending.

The SMS login configuration function allowed the user to specify the account name and password for the HTTPS-based SMS service. The user could also specify the confirmation number where a text message confirming daily automatic operation was sent. Figure 4 shows this manual function.

Configuration verification read all of the configuration data and confirmed that there were no obvious errors. Configuration verification checked that the lists of text messages for each intervention group each contained 30 messages. Configuration verification checked that the SMS service login information was present. Finally, it checked that the subject information list was present and formatted correctly. Configuration verification had the option to be triggered manually through the user

interface, and was done automatically every time text messages were sent, whether manually or automatically.

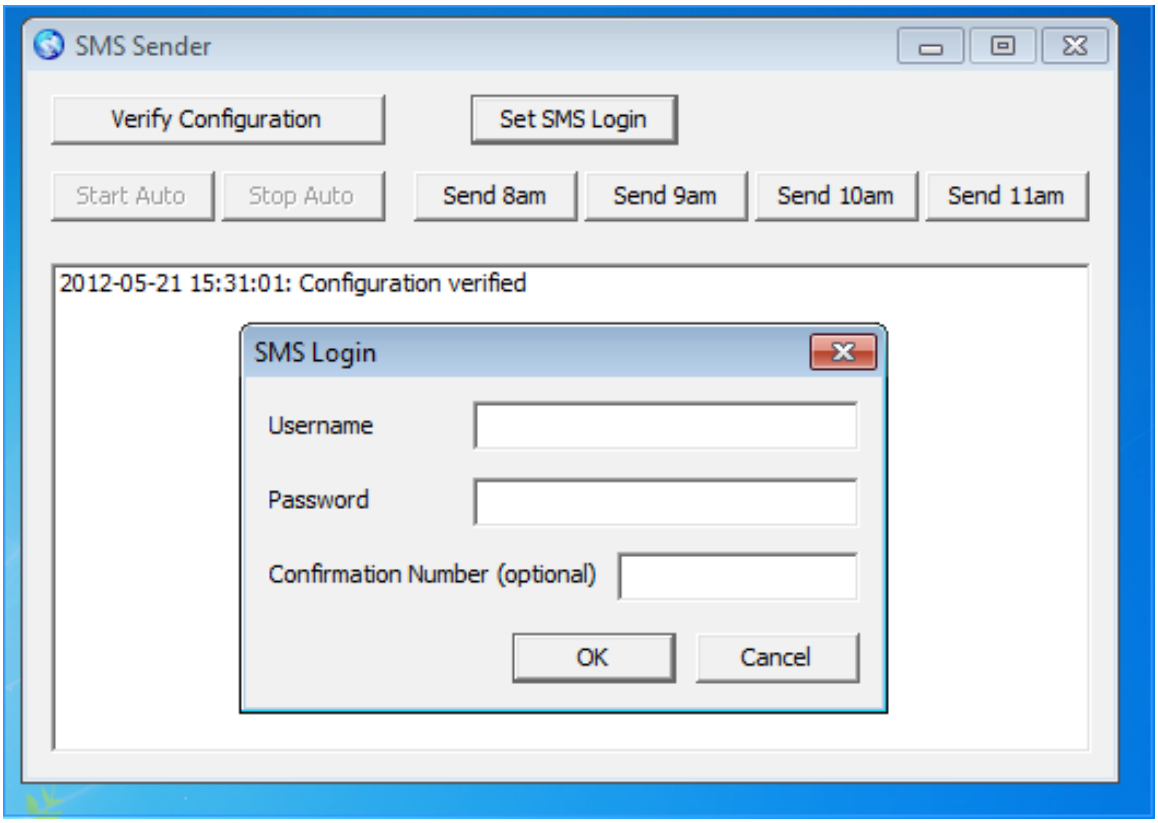

Figure 3: SMS Application, Manual Mode, SMS Login Configuration

Because the intervention specified that each subject received a text message at 8:00 A.M. local time during the course of the intervention, message sending in the SMS application worked by processing the subjects in batches based on time zone. This processing was able to be triggered manually by pressing a button in the user interface, or triggered automatically by setting the computer to run the SMS application as a scheduled task, with an appropriate command-line option.

The application assumed that all subjects were in the continental United States, and therefore had four options for sending a batch of messages. The application named the batches using the time that the batch was sent from, in this case the Eastern time zone. Thus, the batch sent to the Eastern Time zone was named “8am,” and the batch sent to the Pacific time zone was named “11am.” When processing of a batch began, the application went through the following steps:

1. Verified the configuration
2. Read the subject information and gathered the batch of subjects that were in the current time zone
3. Using the subject start date and the current date, calculated which day of the intervention each subject was on, discarding subjects whose intervention had not started yet, or whose intervention was over
4. Logged in to the HTTPS-based SMS service
5. For each subject in the batch:
    a. Selected the appropriate text message using the subject’s calculated intervention day and which intervention group the subject was in
    b. Sent the selected text message to the subject’s phone number
6. If the program was running in automatic mode, and the batch was the first batch of the day (8:00 A.M. batch), sent a confirmation text message to the confirmation phone number

If an error occurred at any step, the error was logged. Processing continued as much as was possible, including the text confirmation message in the final step. If errors

prevented the sending of any messages, the confirmation text message included this information. If a failure did occur during automatic processing, the user was able to launch the application in manual mode to identify and fix any configuration errors and to attempt sending the message again.

Automatic mode was configured with help from the operating system. For this trial, four Windows Scheduled Tasks were set up, one for each time zone. The tasks were configured to run daily at 8:00 A.M., 9:00 A.M., 10:00 A.M., and 11:00 A.M. Each task launched the SMS application with a command line option that instructed the application to automatically send the batch of messages for that particular time, like so:

- 8:00 A.M.: SMS.exe /run8
- 9:00 A.M.: SMS.exe /run9
- 10:00 A.M.: SMS.exe /run10
- 11:00 A.M.: SMS.exe /run11

The service was set up to "Run As" a user with access to the secure file server used to store the configuration, subject, and log files. This allowed the service to run daily and send all necessary messages without regular manual intervention.

Discussion

These results suggest that it was feasible to develop and deliver weight loss sustaining messages via SMS to people who have recently completed a structured weight loss program and are in the continued response phase of the Behavior Change Process. The majority of participants felt there was significant value in receiving the messages that 'fit' with their respective promotion or prevention preference. Many participants felt that

the messages helped them stay motivated. Several participants expressed that they felt they had a companion with the daily messages and that it was important to receive daily reminders. Of the three participants who had a neutral perception and the one who had a negative perception of the intervention, all indicated they would have preferred the messages to either be more motivational or have additional components such as a telephone element or online discussion group. There did not appear to be any significant differences in demographics or promotion or prevention preference in these three participants. All three continued to lose weight at month 3.

All participants were positive about the SMS delivery method. Participants expressed favorability towards SMS because messages were delivered directly to them. Most of the participants read the messages every day. Technical issues did arise, such as a non-functioning phone in one participant and a silent mode or delay in checking the messages by two others. No participants had problems responding via SMS their self-reported weight. Once a day was deemed as the most appropriate message frequency, and 8:00 A.M. as the most appropriate delivery time. However, several participants indicated that receiving messages twice a day, preferably at morning and night would be beneficial. In relation to the habituation-tedium theory, more than twice a day would be considered burdensome and create tedium, while fewer than once a day would not be effective and fail to reach habituation. Thus, the ideal frequency for message effectiveness was at least once a day and no more than two. SMS also emerged as an appropriate medium to collect data on weight.

From a theoretical perspective, this mobile health intervention was shown to be acceptable and feasible for the continued response phase of the Behavior Change Process. In addition, in accordance with regulatory focus theory we framed the message content to be either promotion or prevention focused. Thus, it was feasible to craft and deliver messages that reflect the two foci of the Regulatory Focus Theory, promotion or prevention respectively.

HIPAA Considerations

Patient privacy was a major consideration in the design and development of the SMS application. Data is transmitted to participants from a secure server, which reads protected health information (PHI; telephone numbers) and then transmitted data to a personal phone through a secure communication protocol HTTPS. HTTPS provides authentication of a third-party SMS service that this application used to transmit the messages. This was critical to provide assurance that the SMS application communicated with precisely the website it intended to and ensured the communicated content (e.g. PHI telephone numbers) were not read by any unintended third parties.

However, cell phones are often shared and other people could read information transmitted to participants. This is particularly true for SMS where user authentication is not available for an individual message at this time beyond having a password to access some phones. When designing IT systems such as this, data encryption must be written into the software development. mHealth interventions may often times use a 3rd party to transmit text messages (SMS), video messages, voice messages, or other data onto a

application or ‘app’. It is imperative that PHI is limited regarding what is transmitted and that these 3rd party companies or services also have privacy agreements.

Limitations

The majority of participants were from a more affluent and educated background, mostly White non-Hispanic, and not representative of the general U.S. population. This study also did not evaluate the effectiveness of the SMS intervention or the effects of the message framing on sustaining weight loss.

Conclusions

As a pilot study of a larger weight loss sustaining intervention, results from this study provide valuable insights on the feasibility of developing weight loss SMS, message framing, and the development an mHealth SMS application. Consistent with the literature (Fjeldsoe et al., 2009; Krishna et al., 2009; Shaw & Bosworth, in press), SMS was an accepted tool by participants to deliver health promotion content. Our next steps are to utilize a larger sample size to assess the effects of these weight loss-sustaining messages and the intervention on sustaining weight loss and preventing relapse; and to examine the differential effects of promotion and prevention framed weight loss messages on sustaining weight loss.

4. A Mixed-Methods Randomized Trial of a Short Message Service (SMS) Text Message Intervention on Sustaining Recent Weight Loss

Introduction

Obesity is a serious problem affecting nearly 34% of Americans (National Center for Health Statistics, 2009; Reuters, 2003). At over $190 billion annually (Cawley & Meyerhoefer, 2012), this condition is very costly (Finkelstein et al., 2004; National Center for Chronic Disease Prevention and Health Promotion, 2009) and is associated with multiple chronic diseases, including type 2 diabetes, cancer, and cardiovascular illnesses (Guh et al., 2009), as well as lower self-esteem, depression, discomfort in social situations, and lower quality of life (Obesity in America, 2009). Many people with obesity are successful at initial weight loss; however, it is almost always regained over time (Bray, 2009). Only one in six people successfully sustain weight loss (Kraschnewski et al., 2010). In fact, the rate of weight gain is highest immediately after cessation of a structured weight loss program (MacLean et al., 2009). Factors attributable to this relapse in weight regain include failure to maintain regular physical activity (Baum et al., 1991; R.W. Jeffery et al., 1984; Schoeller et al., 1997), follow a low-calorie diet (R.W. Jeffery et al., 1984), and monitor body weight (Baum et al., 1991; Kramer et al., 1989; Wadden & Letizia, 1992). There is a critical need to understand how people sustain recent weight loss. What is needed are easy and affordable intervention tools that promote sustainability and maintenance of weight loss (National Center for Chronic Disease Prevention and

Health Promotion, 2009; National Heart Lung and Blood Institute & National Institute of Diabetes and Digestive Kidney Diseases, 1998).

Due to low cost, ubiquity, and ease of use, healthcare communicated through mobile technology, or "mHealth", may be able to serve as an effective medium to reach people and facilitate weight loss behaviors. mHealth offers many methodological advantages over traditional healthcare mediums. mHealth reaches across geographic and economic boundaries, is delivered directly to people, and is easy and affordable to use (Patrick, Griswold, Raab, & Intille, 2008). mHealth also offers "reduced memory bias, the ability to capture time-intensive longitudinal data, date-and time-stamped data, and the potential for personalizing information in real-time" (NIH Office of Behavioral and Social Sciences Research, 2011). mHealth has the potential to serve as a platform to deliver information directly to people with content targeted to their weight loss behavior needs that can serve as cues to action; targeted health information and cues to action are strategies to encourage change and sustain healthy behaviors (Dijkstra, de Vries, & Roijackers, 1999; Kreuter & Wray, 2003).

More than 87% of the U.S. population use a mobile phone (CTIA Wireless Association, 2009). Over one trillion short message service (SMS), also known as text messages, are transmitted yearly and over 2.5 billion daily (CTIA Wireless Association, 2009). Preliminary studies on smoking, diabetes medication management, and weight loss initiation suggest that SMS has positive short-term behavioral and clinical outcomes (Anhoj & Moldrup, 2004; Benhamou et al., 2007; Brendryen et al., 2008; Casey et al., 2007; Dunbar et al., 2003; Ferrer-Roca et al., 2004; Fjeldsoe et al., 2009; Franklin et al.,

2006; Joo & Kim, 2007; Krishna et al., 2009; Lim et al., 2008; Patrick et al., 2009; Warwick et al., 2007). However, in order to leverage mHealth as a tool to promote behavior change, we must match effective content with effective delivery. We must understand how to deliver targeted information, the appropriate frequency and timing of delivery, how much to deliver, and most importantly provide relevant content that motivates and promotes self-regulation. Self-regulation is the ability to monitor one's own behavior, evaluate its effects, and adjust behavior as needed to continue and sustain progress towards a goal.

The Behavior Change Process by Alexander Rothman and colleagues (Rothman et al., 2004) was used as an overall framework to guide this intervention. This conceptual framework focuses on transitioning from unwanted unhealthy behaviors to healthy behaviors over four phases (see Chapter 1, figure 1). Interventions are needed to help people transition from an initial behavior change to a state of maintenance of the new behavior. For complex behaviors such as weight loss, the transition from continued response to maintenance is difficult. The relapse rate from continued response back to the unwanted behavior is high (Kramer et al., 1989; Wadden & Frey, 1997; Wadden et al., 1989). In other words, many people who lose weight "fall of the wagon," relapse, and return to their previous unhealthy behaviors. Ongoing assessment of the new behavior and adjustment to challenges is needed. Research suggests interventions that target and frame messages about how people reach goals in their life through either a prevention or promotion focus may be beneficial at motivating people to self-regulate and sustain

recent behavioral changes (Higgins, 2000) such as weight control behaviors (Fuglestad et al., 2008).

Regulatory focus theory contends that people use two kinds of strategies to work towards goals: approach-based (promotion) or avoidance-based (prevention) (Higgins, 1987, 2000). Approach-based strategies promote success to reach a goal, while avoidance-based strategies prevent failure to reach a goal. The approach that people tend to habitually use is known as their regulatory focus, either promotion or prevention. Although individuals use both promotion or prevention self-regulation strategies to pursue goals, some goals are viewed as more positive and pleasant when the goal strategy matches the individual's regulatory focus, known as "regulatory fit" (Higgins, 1987, 2000). Thus, the likelihood that someone will feel motivated to initiate and sustain a behavior change is increased (Spiegel et al., 2004). These matching messages are thought to enhance self-regulation and if received during the continued response phase of the Behavior Change Process may facilitate transition to maintenance and help prevent relapse. Thus, interventions which frame health messages towards one's regulatory focus may be beneficial at sustaining recent behavioral changes (Higgins, 2000) such as weight loss (Fuglestad et al., 2008). Furthermore, self-regulatory preference of promotion or prevention strategies may vary by the timing and specific behavior targeted as well. One study suggested that promotion focus is a better predictor of initial weight loss, yet prevention focus is a better predictor of maintenance of weight loss (Rothman et al., 2004).

Using the Behavior Change Process (Rothman et al., 2004) and regulatory focus theory (Higgins, 1987, 2000), an intervention was developed that leveraged SMS to deliver messages to people who have recently lost weight in attempt to help them sustain weight loss and prevent relapse. Design of the mHealth SMS application and message content are previously reported (see Chapter 3).

Methods

Purpose and Hypotheses

The purpose of this study was to test the acceptability, feasibility, and efficacy of daily weight loss sustaining messages on helping people sustain weight loss. Following the completion of a weight loss program, a 3-arm randomized controlled trial was conducted to compare the delivery of daily promotion and prevention weight loss sustaining messages on sustained weight loss to a control group that received general health messages. Messages were delivered for 1 month with a follow-up observation period of 3-months post-baseline.

Hypothesis 1: Participants randomized to either a promotion or prevention framed weight loss message intervention group would have an increased likelihood of sustained weight loss compared to a general health message group.

Hypothesis 2: Individuals with a lower regulatory focus score (indicative of greater prevention focus) were more likely to sustain weight loss if they received prevention messages (‘fit’) and those individuals with a higher regulatory focus score (indicative of greater promotion focus) were more likely to sustain weight loss if they

received promotion messages ('fit'). We hypothesized this because the literature demonstrates a greater likelihood that someone will feel motivated to initiate and sustain a behavior change when messages 'fit' with an individuals preference for promotion or prevention (Spiegel et al., 2004)

Hypothesis 3: Participants randomized to the prevention framed message group had an increased likelihood of sustaining weight loss compared to the promotion framed message group. We hypothesized this because at the later stages of the Behavior Change Process (i.e. sustaining phase that all participants entering the study were in), people are more sensitive to prevention framed strategies (Rothman et al., 2004).

Study Design

A randomized controlled trial using mixed methods was conducted with data collected at baseline, completion of the intervention at 1 month, and 3 months post-baseline. Participants were 120 obese adult men and women who received treatment at the Duke Diet and Fitness Center (DFC) for weight loss. Clients who met the following eligibility criteria were recruited for the study: 1) clinically measured BMI > 30 at the start of DFC treatment; 2) ≥18 years old; 3) able to speak and read English; 4) had completed a comprehensive diet and fitness program; 5) lost 5% of their body weight; 6) had their own mobile phone to personally receive SMS; 7) physically able to access SMS on their phone; 8) able to continue physical activity for 3 months; 9) did not have a joint replacement scheduled within 3 months; and 10) were mentally capable of informed

consent. The Duke University Medical Center Institutional Review Board approved the study.

Participant Recruitment

Recruitment occurred between May 2011 and February 2012. Participants were enrolled from the Duke DFC following completion of a residential weight management program. DFC helps people affected by excess weight and impaired physical fitness achieve better health through weight loss, physical conditioning, and improved self-care habits. Clients enroll in a comprehensive program that provides education, practical behavioral strategies, and ongoing support to make long-term changes. Potential participants were approached during a self-management class at the DFC. Those who met the eligibility criteria and agreed to participate signed the informed consented, completed the baseline questionnaires, and were provided with an orientation to the SMS intervention.

Randomization

Once the participants signed the informed consent and completed the baseline survey, they were randomized to one of the three following intervention groups: promotion-framed messages; prevention-famed messages; or a control group that received general health messages (See Appendices A and B). Computer generated permuted block randomization was used to ensure equal probability to either the promotion, prevention, or control message groups. The randomization yielded the

following sample sizes per group: promotion (n=41), prevention (n=40), and control (n=39).

Sample Size and Power

A sample size of 120, with approximately 40 per group, was enrolled in this study. This exploratory study was primarily designed to obtain estimates of effect sizes needed to plan a larger future study. Accounting for attrition, a sample size of 40 per group would allow a reasonable estimate of effect sizes. Power calculations indicated that a sample size of 90 per group would be needed to achieve 80% power to test the primary efficacy hypothesis and detect between-group differences in sustained weight loss for a medium effect (Cohen's w = 0.30 to 0.49). It was estimated the effect size for sustaining weight loss to be between 0.25 to 0.30 in range based on literature evaluating computer tailored and general behavioral weight loss interventions (Franz et al., 2007; Portnoy, Scott-Sheldon, Johnson, & Carey, 2009). Effect size estimates specific to the use of SMS for weight loss were unknown (Shaw & Bosworth, in press). Thus, the main goal of this initial study was to obtain effect sizes for the target population that will help guide future research.

Interventions and Attention-Control

Participants received a daily SMS (promotion, prevention, or general health message) for 30 days following the DFC structured weight loss program. SMS were set in a queue and automatically delivered daily at 8:00 a.m. in participants' respective time

zone through a HIPAA compliant SMS application (see Chapter 3). Message delivery was guided by the results from the previous pilot study and by the habituation-tedium theory which suggests that an ideal frequency of message delivery is critical for message effectiveness (Berlyne, 1970). Participants in the promotion and prevention intervention groups received messages that targeted diet, exercise and monitoring (Appendix A). All content was based upon weight loss literature and behaviors needed to sustain weight loss (Baum et al., 1991; Klem et al., 1997; Kramer et al., 1989; Wadden & Letizia, 1992; Wing & Hill, 2001; Wing & Phelan, 2005), namely regular physical activity (Baum et al., 1991; R.W. Jeffery et al., 1984; Schoeller et al., 1997), a low-calorie healthy diet (R.W. Jeffery et al., 1984), and monitoring of body weight (Baum et al., 1991; Kramer et al., 1989; Wadden & Letizia, 1992). Message development and framing are reported previously (see Chapter 3). Participants randomized to the intervention groups received messages framed appropriately to match a prevention or promotion orientation. Participants randomized to the attention control group received general health messages as an attention control (Appendix B). We chose an attention-control group over a standard-of-care control group to eliminate the possible confounders of simply receiving a daily message regardless of content, and the novelty effect of technology.

Data Collection and Measures

The primary outcomes measured were acceptability, feasibility and sustained weight loss. The secondary outcome was the moderating and predictive effects of regulatory focus scores on sustained weight loss. We used sustained weight loss as a

primary outcome instead of raw weight in order to assess whether people had remained in the sustaining phase of the Behavior Change Process. Baseline data collection occurred at the point of enrollment at the DFC and included surveys, which obtained demographic information, SMS use, and regulatory focus through the Regulatory Focus Questionnaire (RFQ; (Higgins et al., 2001). Height and weight were obtained from participants' medical charts. Baseline surveys were double-data entered into the database. Following completion of the 30-day intervention and 90 days post-baseline, participants received a SMS asking them to report their weight and were e-mailed a link to an online survey, which collected feasibility and acceptability of both the technology and the message content. Participants completed the survey using Research Electronic Data Capture (REDCap); (Harris et al., 2009) tools hosted at Duke University. REDCap is a secure, web-based application designed to support data capture for research studies, providing: 1) an intuitive interface for validated data entry; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for importing data from external sources. To further assess feasibility and acceptability, immediately following the 30-day intervention participants were also asked to undergo an individual telephone interview. Interviews were audio-recorded, with permission from the participants.

Participant Demographics. Height, weight, BMI and co-morbidities were obtained from participants' medical record at baseline. Cell phone use, type of cell phone

plan, and SMS were collected by self-report at baseline to determine experience with and ability to receive SMS.

Feasibility and Acceptability. Feasibility and acceptability of both the technology and the message content were measured at 1 month post-baseline in an online survey and in a phone interview. Participants were asked during the interviews to discuss their perception of the usefulness and attitudes toward the intervention and message content (Kreuter, Oswald, Bull, & Clark, 2000), their experiences with the intervention, technical difficulties and barriers they encountered, and how often they read the messages for intervention fidelity (Borrelli et al., 2005; Dane & Schneider, 1998; Resnick et al., 2005). The Attitudes and Behaviors toward SMS Weight Loss Scale was used to evaluate perception of the usefulness and attitudes toward the intervention and message content for sustaining weight loss. This scale assesses attitudes towards, intention to use, and behavioral use of SMS. This 13-item scale was adapted from the Attitudes Toward Mobile Advertising Scale (Tsang, Ho, & Liang, 2004) to ask participants about using SMS for sustaining weight loss rather than mobile advertising. This first 10-items are 5-point Likert-type and range from 1 (least favorable) to 5 (most favorable). The first 2 questions measure the entertainment value of the weight loss SMS (α = .94), questions 3 and 4 evaluate the informativeness (α = .71), and questions 5, 6, and 7 assess the irritability (α = .89). Questions 8, 9 and 10 estimate reference, trustworthiness, and attitudes, respectively. In addition, this scale measures intention to receive SMS, the extent of message reading, and the timing of message reading (See Appendix E). A measure of internal consistency was calculated, Cronbach's alpha, to estimate the

reliability of the Attitudes and Behaviors toward SMS Weight Loss Scale and the RFQ promotion and prevention subscales below. Alpha coefficients greater than .70 are considered indicative of good reliability (Nunnally, 1978).

Regulatory Focus Questionnaire. The RFQ (Higgins et al., 2001) was used to determine whether participants are promotion or prevention focused. The RFQ is an 11-item, two-factor scale (5 prevention, 6 promotion items) that assesses personality for strength of promotion and prevention strategy styles. This 5-point scale ranges from 1 (never or seldom) to 5 (very often). Scores range from -2 to +2. Positive scores indicate greater previous success in promotion self-regulation. Negative scores indicate greater previous success in prevention self-regulation. Reliability has been previously assessed for the promotion scale (α = .73) and prevention scale (α = .80) indicating good internal consistency (Higgins et al., 2001). The promotion and prevention scales are only modestly correlated (r = .21, p < .001) and content validity has been demonstrated through expert review (Higgins et al., 2001). Test-retest reliability over a period of two months produced correlations of r =.79 for the promotion scale and .81 with the prevention scale (Higgins et al., 2001). Convergent validity has been demonstrated with Jackson's personality research form and discriminant validity has been shown with the behavioral approach system scales (BAS) /behavioral inhibition system (BIS) scale (Higgins et al., 2001). Regulatory focus scores were assessed at baseline. Internal consistency reliability was assessed for the RFQ from data collected at baseline. The prevention subscale was found to be reliable (5 items; α = .76). However, the promotion subscale demonstrated poor reliability (6 items; α = .53).

Weight. At baseline, weight was recorded from the DFC medical records. At 1 and 3 months post-baseline, participants reported their weight taken on their home scale to the researcher via SMS. At baseline, participants were asked if they had lost the 5% of weight needed to qualify for the study. If participants reported that they had lost sufficient weight, it was assumed they were correct and qualified. Through medical chart review, this was verified after participants agreed to participate and had enrolled in the study. The accuracy of self-reported weight has been demonstrated in Internet-based weight loss treatment programs and has shown to be comparable to observed weight (Harvey-Berino et al., 2011). Harvey-Berino et al., (2011) found that observed and reported weights were significantly correlated at 0 and 6 months (r = 0.996 and 0.996, respectively). Weight change by self-report was found to be comparable to observed in a web-based obesity intervention. Sustained weight loss was expressed as a dichotomous outcome at each time point (0 = not sustained, 1 = sustained). For the purposes of this study and in accordance with the American College of Sports Medicine (Donnelly et al., 2009), sustaining weight loss was defined as a change of < = 5 pounds or < 3% change in weight following a weight loss program.

Data Analysis

Descriptive and inferential statistics were calculated using SAS Version 9.3 (SAS Institute Inc., Cary, NC). Non-directional statistical tests were performed and the level of significance was set at .05. Due to the exploratory nature of this study, for each test the level of significance was not adjusted for multiple testing. Categorical data are described

using number and percentages of patients that fall within each category, while continuous data is presented in means and standard deviations (Mean $\pm$ SD).

Descriptive statistics were used to summarize baseline demographic (including BMI) and SMS characteristics of the total sample of 120 and for the intervention groups (promotion, prevention, and control). A between-group analysis was conducted to determine whether the randomization method balanced the three interventions on baseline characteristics. A non-parametric Kruskal-Wallis Test was used to test for between-group differences in ranks between weight, BMI, age, and RFQ due to the non-normality of the data distributions. Chi-square test was used to test for differences in gender, race, education, household, marital, work and financial statuses; A Fisher's Exact Test was used to calculate differences in ethnicity, with ethnicity collapsed into whether or not people were Hispanic/Latino.

Content analysis and descriptive statistics were used to examine the feasibility and acceptability of the interventions as well as the participants' perception of the usefulness and attitudes toward the intervention and message content, and experiences of participating in the study. Interview data (N = 60) were collected until the point of saturation and analyzed using conventional content analysis, a data reduction technique, to look for recurring themes in the interviews using ATLAS Ti Version 7 (Scientific Software Development, Berlin, Germany). The content analysis involved dividing text into segments of information and the categorization and classification of patterns into code segments (Neuendorf, 2002). These code segments were then analyzed for frequencies reduced and coded into categories. Inferences were made from the categories

and collapsed into themes (Creswell, 2007). A second researcher reviewed half of the interviews for interrater reliability and agreement on outcomes. Perception of the usefulness and attitudes toward the intervention and message content (Borrelli et al., 2005; Dane & Schneider, 1998; Resnick et al., 2005), and experiences (Borrelli et al., 2005; Dane & Schneider, 1998; Resnick et al., 2005) guided this analysis. Percentages were used to summarize the following categorical data: (a) Perception of the usefulness and attitudes toward the intervention and message content; (b) how often messages were read; (c) and attitudes towards frequency and timing of message delivery.

Perception of the usefulness and attitudes toward the intervention and message content for sustaining weight loss were described using measures of central tendency and variability: mean, median, mode, standard deviation, minimum, and maximum. Fisher's Exact Tests for categorical outcomes and Kruskall-Wallis Tests for the continuous outcomes were used to examine between-intervention group differences on these measures. When significant intervention effects were detected ($p \leq 0.05$), *a posteriori* pairwise comparisons were performed to further evaluate differences among the three intervention groups using Wilcoxon Two-Sample Tests.

To examine the effects of the three intervention groups on sustaining weight loss at months 1 and 3 post-baseline, the proportion of cases with sustaining weight loss in each intervention group and the total sample were calculated. Two levels of analyses were employed when evaluating the primary outcome, sustaining weight loss. The first-level was the primary analysis, which applied the intent-to-treat (ITT) principle whereby all participants randomized to an intervention were included. Due to the homogeneity of

the sustained weight loss outcome, we were not able to conduct a mixed effects model. Thus, for the intent-to-treat analysis, missing data at months 1 and 3 were imputed as successfully sustaining weight loss. We imputed missing data as successfully sustaining weight loss because over 93% of the evaluable cases within each treatment group at months 1 and 88% at month 3 in each group, sustained their weight loss.

The ITT principle was used because it is the recommended analytic method for upholding randomization integrity (D. F. Polit & Gillespie, 2009). ITT allows a pragmatic assessment of the benefit of a treatment change (Roland & Torgerson, 1998) by reducing bias and minimizing random error that may occur when individuals who withdraw from an intervention or study are excluded (D. F. Polit & Gillespie, 2009; Soares & Carneiro, 2002). Though no imputation method can provide an unbiased assessment of the treatment, imputation is used to create an estimate of the treatment effect (Hollis & Campbell, 1999). The second-level of analysis of sustained weight loss included an evaluable case analysis, which included available data from those who reported their weight at months 1 and 3.

Generalized Linear Mixed Method (GLMM) applying Generalized Estimating Equations (GEE) for repeated measurements was considered to estimate and compare the probabilities of sustaining weigh loss over time in the three intervention groups. However, these data lacked heterogeneity so we employed cross-sectional chi-square and Fisher's Exact Tests to test for differences post-baseline at month 1 and month 3. *A priori* pairwise between-group comparisons using Fisher's Exact Test were conducted at months 1 and 3 for both the intent-to-treat and evaluable cases.

Regulatory focus at baseline was examined as a possible moderator or predictor of sustained weight loss according to the guidelines recommended by Kraemer and colleagues (2002) for clinical trials. As defined by Kraemer et al. (2002), a moderator is a pretreatment variable that interacts with the intervention condition to influence the intervention outcomes. Due to the low variability in the sustained weight outcome within each group, a moderator analysis could not be conducted in the intent-to-treat or evaluable cases. In contrast, non-specific baseline predictors of clinical outcomes are ones that influence outcomes regardless of the intervention. A predictor analysis using logistic regression with treatment and regulatory focus scores was conducted to determine to what extent regulatory focus as a non-specific predictor influences sustained weight loss at months 1 and 3. Figure 5. summarizes subject recruitment, enrollment, and the analysis process.

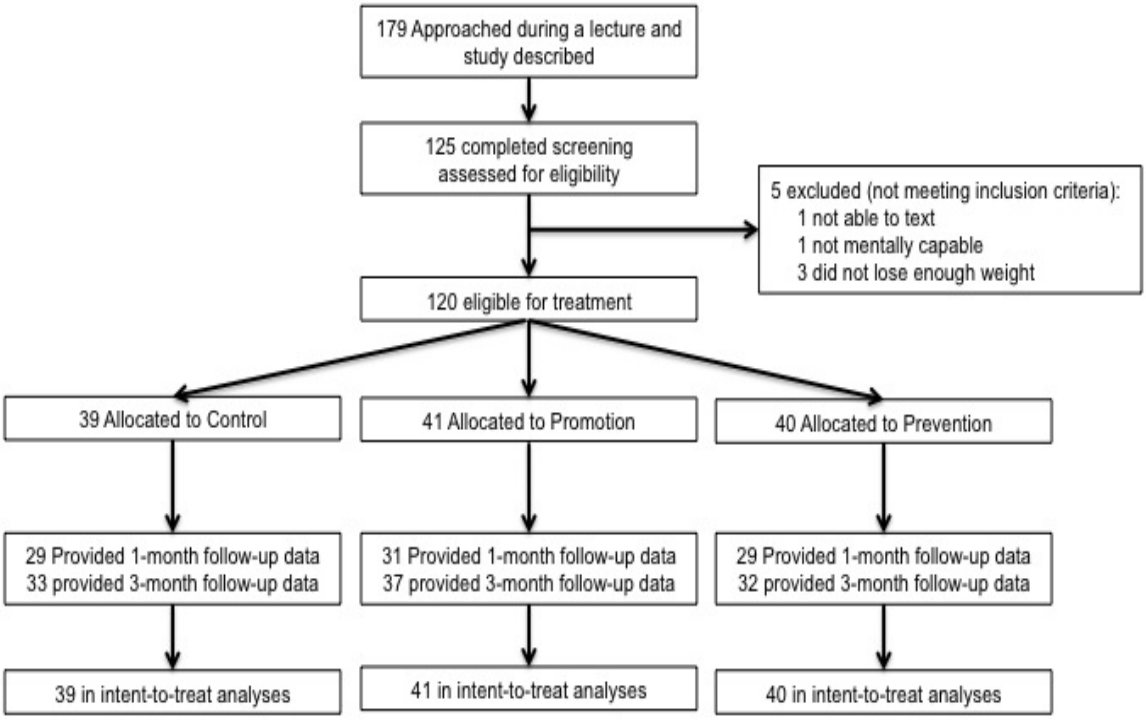

Figure 4: Consort Diagram

Results

From May 2011 to February 2012, a sample of 120 participants was recruited from a structured weight loss program. Approximately 179 people were approached to reach this sample size over a period of 33 weeks. Table 4 provides demographic information for the DFC population and the study sample, indicating the representativeness of the sample to the clinic population. Due to the nature of the recruitment process (a brief lecture was given at the end of a class at the DFC clinic describing the study and eligibility criteria and people who qualified and were interested in participating stayed after their class was over to enroll in the study), it is unknown why people chose not to participate in the study.

Table 4: Comparison of the Clinic Population and Study Sample

	Clinic Population (N=179)	Randomized Sample (N=120)
Weight in lbs. (means ± SD)	248.1 ± 72.7	262.3 ± 65.7
Age (means ± SD)	52.0 ± 15.5	53.3 ± 14.8
Gender (n % female)	99 (56%)	71 (59%)

Sample Characteristics. Tables 5 and 6 illustrate the baseline demographics of the study sample. Most participants were White (94%), college educated (81%), and financially stable (80%). A majority of the total sample was female (59%), currently working (58%), and half were married (48%). The mean weight in pounds was 247.5 ± *SD* 61.8 with a mean BMI of 38.1 ± *SD* 7.8. There were no significant between-group differences in the three intervention arms with regard to these baseline characteristics ($p > .05$).

Table 7 shows that most people use their cell phones often (83%), have a smart phone (77%), and many often send text messages (51%) and have an unlimited texting plan (58%) with no significant differences between groups at baseline ($p > 0.05$).

Table 5: Baseline Characteristics by Intervention Group

	Total (N=120)	Control (N=39)	Promotion (N=41)	Prevention (N=40)	χ^2	df	P
Weight in lbs. (mean ± SD)	247.5 ± 61.8	239.6 ± 50.4	250.8 ± 67.8	252.3 ± 65.6	0.54	2	.76
BMI (mean ± SD)	38.1 ± 7.8	37.3 ± 6.3	38.6 ± 8.6	38.4 ± 8.4	0.15	2	.92
Age (mean ± SD)	53.2 ± 4.7	54.8 ± 15.9	51.0 ± 12.9	54.3 ± 15.5	3.08	2	.21
Number in household (mean ± SD)	1.9 ± 0.7	1.8 ± 0.7	2.0 ± 0.8	1.9 ± 0.7	2.62	3	.62
Gender (n, % female)	71 (59%)	25 (64%)	26 (63%)	20 (50%)	2.09	2	.35
Race (n, % White)	113 (94%)	37 (95%)	36 (88%)	40 (100%)	5.50	2	.06
Ethnicity (n, % Hispanic/Latino)	10 (9%)	4 (11%)	3 (7%)	3 (8%)	0.45	2	.80
College degree or greater (n, %)	97 (81%)	32 (82%)	31 (78%)	34 (85%)	0.76	2	.69
Married or partnered (n, %)	57 (48%)	18 (46%)	19 (48%)	20 (50%)	0.12	2	.94
Currently working (n, %)	116 (58%)	20 (53%)	22 (56%)	25 (64%)	1.08	2	.58
Financially stable (n, %)	95 (80%)	32 (82%)	31 (78%)	32 (80%)	0.26	2	.88
Regulatory focus score (means ± SD)	0.24 ± 0.85	0.30 ± 0.87	0.16 ± 0.74	0.25 ± 0.93	0.29	2	.87

For race 1 = White and 0 = other. For ethnicity 1 = Latino and 0 = not Latino. For education, 1 = college degree and 0 = less than a college degree. For work status, 1 = currently working, 0 = not currently working or retired. For financial status, 1 = financially well off, "After paying the bills, you still have money for the special things you want", 0 = not having extra money. For marital status 1 = married or partnered, 0 = divorced, widowed, or never married. Household was collapsed to 3 categories of 1, 2, and 3 or more people living in the household. χ^2 = chi-square statistics for a chi-square test when the measure was categorical and a Kruskal-Wallis Test when the measure was continuous.

Table 6: Detailed Baseline Characteristics by Intervention Group

	Total	Control	Promotion	Prevention
Race (N)	120	39	41	40
White	113 (94%)	37 (95%)	36 (88%)	40 (100%)
Black or African American	2 (2%)	0 (0%)	2 (5%)	0 (0%)
Asian	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Native American/Alaskan Native	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Native Hawaiian or other Pacific Islander	1 (1%)	0 (0%)	1 (2%)	0 (0%)
White & Other	1 (1%)	0 (0%)	1 (2%)	0 (0%)
Other	4 (3%)	2 (%%)	3 (7%)	0 (0%)
Ethnicity				
Hispanic/Latino	10 (9%)	4 (11%)	3 (7%)	3 (8%)
Education (N)	119	39	40	40
10-12th grade	3 (25%)	0 (0%)	1 (3%)	2 (5%)
Some college	19 (16%)	7 (18%)	8 (20%)	4 (10%)
College degree	38 (32%)	13 (33%)	11 (28%)	14 (35%)
Post graduate	59 (49%)	19 (49%)	20 (50%)	20 (50%)
Marital status (N)	119	39	40	40
Married	53 (45%)	16 (41%)	17 (43%)	20 (50%)
Partnered	4 (3%)	2 (5%)	2 (5%)	0 (0%)
Divorced/separated	17 (14%)	5 (13%)	3 (8%)	9 (23%)
Widowed	9 (8%)	2 (5%)	3 (8%)	4 (10%)
Never married	36 (30%)	14 (36%)	15 (38%)	7 (18%)
Work status (N)	116	38	39	39
Not currently working	23 (20%)	8 (21%)	12 (31%)	3 (8%)
Retired	26 (22%)	10 (26%)	5 (13%)	11 (28%)

	Total	Control	Promotion	Prevention
Working part-time	14 (12%)	3 (8%)	6 (15%)	5 (13%)
Working full-time	53 (46%)	17 (45%)	16 (41%)	20 (51%)
Financial status (N)	119	39	40	40
Have difficulty paying the bills, no matter what you do	5 (4%)	1 (3%)	1 (3%)	3 (8%)
Have money to pay bills, but only because you have to cut back on things	7 (6%)	2 (5%)	3 (8%)	2 (5%)
Have money to pay bills, but little spare money to buy extra	12 (10%)	4 (10%)	5 (13%)	3 (8%)
After paying the bills, you still have money for the special things you want	95 (80%)	32 (82%)	31 (78%)	32 (80%)

Data presented as n (%) of N.

Table 7: Mobile Phone Characteristics

	Total	Control	Promotion	Prevention	P
How often do you use your cell phone?	119	39	40	40	.79
Often	99 (83%)	32 (82%)	35 (88%)	32 (80%)	
Sometimes	19 (16%)	7 (18%)	5 (13%)	7 (18%)	
Rarely/never	1 (0.8%)	0 (0%)	0 (0%)	1 (3%)	
Do you have a smart phone?	119	39	40	40	.76
Yes	92 (77.3%)	28 (72%)	32 (80%)	32 (80%)	
No	25 (21%)	10 (26%)	7 (18%)	8 (20%)	
Don't know	2 (1.7%)	2 (3%)	1 (3%)	0 (0%)	
How often do you send text messages?	119	39	40	40	.15
Often	61 (51.3%)	15 (39%)	26 (65%)	20 (50%)	
Sometimes	34 (28.6%)	13 (33%)	10 (25%)	11 (28%)	
Rarely/never	24 (20.2%)	11 (28%)	4 (10%)	9 (23%)	
If you have a text messaging plan, is it an unlimited texting plan?	117	38	41	38	.62
Yes	68 (58.1%)	24 (63%)	25 (61%)	19 (50%)	
No	23 (19.7%)	8 (21%)	6 (15%)	9 (24%	
Don't know	26 (22.2%)	6 (16%)	10 (24%)	10 (26%)	

Data presented as n (%) of N. P-value for 3 x 3 Fisher's Exact Test.

Retention

Of the participants who enrolled in the study, 102 (85%) completed the study and reported their weight at month 3 (control 85%, promotion 90%, prevention 80%; Table 14). The groups did not differ significantly in the months-1 (p = .97) and 3 (p = .43) attrition rates. Of the 18 participants who did not complete the study, only 2 (1.7%) gave reasons as to why they withdrew. Despite living in the U.S., these participants did not receive the text messages due to having an international phone number.

Intervention Fidelity

Table 8 illustrates that most participants (74%) read the messages right away. Among those who did not, most read the messages when they had time (20%). Nearly all of the participants read the entire message when they received it (95%). Interview data reflected similar findings. Of the 36 participants who commented on how often they read the messages, 27 (75%) stated every day, 5 (14%) said when they accessed their phone or had the time, and 4 (11%) said not every day. There were no differences between the groups on process measures ($p > 0.05$; Table 8).

From the interviews, many participants reported reading the messages multiple times. Of the participants who spoke about reading the messages multiple times (N = 19), many reported that because they owned a “smart phone”, the messages were grouped together so that they could reread them. One participant stated that due to the storing and grouping of messages, it was easy to “thumb through the list of them” and reread them “every once in a while… when you [are] sitting in line or waiting”.

Table 8: Detailed Process Measures of SMS

	Total (N=84)	Control (N=26)	Promotion (N=28)	Prevention (N=30)
I am willing to receive weight loss sustaining text messages	82	25	28	29
One or less messages a day	31 (39%)	12 (48%)	9 (32%)	13 (45%)
Two messages a day	44 (55%)	11 (44%)	18 (64%)	15 (52%)
Three messages a day	2 (3%)	0 (0%)	1 (4%)	1 (3%)
Over four messages a day	3 (4%)	2 (8%)	0 (0%)	0 (0%)
What do you do when you receive a weight loss sustaining text message?	83	25	28	30
Ignore it completely	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Read it occasionally	3 (4%)	1 (4%)	0 (0%)	2 (7%)
Read it after accumulating too many of them	2 (2%)	2 (8%)	0 (0%)	0 (0%)
Read it when I get time	16 (20%)	2 (8%)	4 (14%)	10 (33%)
Read it right away	60 (74%)	20 (80%)	24 (86%)	18 (60%)
How much do you read messages you received?	82	24	28	30
Not at all	2 (3%)	1 (4%)	0 (0%)	1 (3%)
Read about a quarter of a message	0 (0%)	0 (%)	0 (0%)	2 (7%)
Read about half of a message	0 (0%)	0 (%)	0 (0%)	0 (0%)
Read about three-quarters of a message	2 (3%)	0 (0%)	0 (0%)	0 (0%)
Read the whole message	76 (95%)	23 (96%)	28 (100%)	27 (90%)

Table 9: Process Measures of SMS

	Total (N=84)	Control (N=26)	Promotion (N=28)	Prevention (N=30)	χ^2	df	P
One to two messages	82 (98%)	25 (96%)	28 (100%)	29 (97%)	0.75	2	.68
Read the messages	83 78 (94%)	25 22 (88%)	28 28 (100%)	30 28 (93%)	3.35	2	.18
Read the whole message	82 78 (95%)	24 23 (96%)	28 28 (100%)	30 27 (90%)	3.12	2	.21

Data presented as n (%) of N. Data from "I am willing to receive weight loss sustaining text messages" was collapsed into "One or less messages a day" and "Two messages a day" = 1, and anything else = 0. Data from "What do you do when you receive a weight loss sustaining text message" was collapsed into "read it when I get time" and "read it right away" = 1, and anything else = 0. Data from "How much do you read messages you received?" was collapsed into "read the whole message" = 1 and anything less = 0. χ^2 = chi-square statistics for Kruskal-Wallis Test.

Table 10: Acceptability: Usefulness and Attitudes of SMS

	Total (N=84)	Control (N=26)	Promotion (N=28)	Prevention (N=30)	χ^2	df	P
I feel that receiving the text messages is enjoyable					.83	2	**.05** [a]
Mean ± SD	4.2 ± 1.0	3.9 ± 1.6	4.5 ± 0.8	4.3 ± 1.0			
Median	5.0	3.5	5.0	4.0			
Mode	5.0	5.0	5.0	5.0			
I feel that receiving the text messages is pleasant					.05	2	.22
Mean ± SD	4.1 ± 1.0	3.8 ± 1.2	4.3 ± 0.9	4.2 ± 0.9			
Median	4.0	3.5	4.5	4.5			
Mode	5.0	5.0	5.0	5.0			
I feel that the text messages are a good source for timely information					.43	2	.30
Mean ± SD	4.1 ± 1.1	3.8 ± 1.2	4.2 ± 1.2	4.2 ± 1.0			
Median	4.0	4.0	5.0	4.0			
Mode	5.0	5.0	5.0	5.0			
The text messages provide the information I need to help sustain weight loss					17.07	2	**< .01** [a]
Mean ± SD	3.6 ± 1.1	2.9 ± 1.1	4.0 ±1.0	3.9 ± 0.8			
Median	4.0	3.0	4.0	4.0			
Mode	4.0	3.0	5.0	4.0			
I feel that the text messages are irritating					5.24	2	.07
N	84	26	28	30			
Mean ± SD	1.7 ± 1.0	2.0 ± 1.2	1.4 ± 0.7	1.6 ± 0.9			
Median	1.0	1.5	1.0	1.0			
Mode	1.0	1.0	1.0	1.0			

	Total (N=84)	Control (N=26)	Promotion (N=28)	Prevention (N=30)	χ^2	df	P
I feel that the text messages are too much					3.24	2	.20
Mean ± SD	1.6 ± 1.0	1.9 ± 1.1	1.5 ± 1.1	1.6 ± 0.9			
Median	1.0	2.0	1.0	1.0			
Mode	1.0	1.0	1.0	1.0			
Content in the text messages are often annoying					6.28	2	**.04**[b]
Mean ± SD	1.8 ± 1.2	2.2 ± 1.4	1.4 ± 0.7	1.7 ± 1.3			
Median	1.0	1.5	1.0	1.0			
Mode	1.0	1.0	1.0	1.0			
I use the text messages as a reference for diet and exercise					5.20	2	.07
Mean ± SD	3.3 ± 1.3	2.8 ± 1.2	3.5 ± 1.3	3.5 ± 1.2			
Median	3.0	3.0	4.0	4.0			
Mode	4.0	3.0	5.0	4.0			
I trust the text messages					7.65	2	**.02**[a]
Mean ± SD	4.2 ± 1.0	3.8 ± 1.3	4.6 ± 0.7	4.4 ± 0.7			
Median	4.0	4.0	5.0	4.0			
Mode	5.0	5.0	5.0	4.0			
Overall, I like the text messages					7.32	2	**.03**[a]
Mean ± SD	4.2 ± 1.1	3.8 ± 1.2	4.5 ± 0.7	4.4 ± 0.7			
Median	5.0	4.0	5.0	4.0			
Mode	5.0	5.0	5.0	5.0			

1 = completely disagree, 3 = neutral (neither disagree nor agree), and 5 = completely agree. χ^2 = chi-square statistics for Kruskal-Wallis Test. A priori pairwise comparisons results were as follows: [a]: promotion > control, prevention > control, promotion = prevention; [b]: promotion > control, prevention control, promotion = prevention.

Reliability was assessed for the subscales of the Attitudes Toward Mobile Advertising-Modified Version Scale. Cronbach's alphas for the entertainment, informativeness, and irritation subscales were .94, .71, and .89, respectively. Due to the modification of the scale from the Attitudes Toward Mobile Advertising Scale (Tsang et al., 2004), the 2 items from the credibility subscale were split. These assessed trustworthiness of the SMS and whether the SMS were used a reference for diet and exercise. From a logical standpoint, the messages were not designed to act as references, yet they were distributed from a credible source. Results from the survey reflect this. The messages were highly trustworthy, but were not necessarily a reference for diet and exercise (Table 10). Thus, from these two items and the one question on attitudes, reliability on single items could not be assessed.

Overall, participants felt that receiving the text messages was enjoyable, pleasant, a good source of information, was not irritating, was not too much information, was trustworthy, and overall liked the messages. In 10, a Kruskal-Wallis Test was used to test for rank differences in the usefulness and attitudes of SMS. There was a significant difference in the rank sums of how enjoyable the messages were ($p = .05$), how much the text messages provided information needed to sustain weight loss ($p < .01$), how annoying the participants found the text messages ($p = .04$), how much the participants trusted the text messages ($p = .02$), and how much they liked the text messages ($p = .03$). Follow-up tests were then conducted to evaluate pairwise differences among the three groups.

A priori pairwise comparisons using Wilcoxon Two-Sample Tests indicated there were no differences between the promotion and prevention groups ($p > .05$) in the

usefulness and attitudes towards the SMS. There were significant differences however when comparing the control group to either the promotion or prevention groups. The promotion ($z = -3.57$ $p < .01$) and prevention groups ($z = -3.48$, $p < .01$) found the messages to be significantly more enjoyable than the control group. The promotion ($z = -3.57$, $p < .03$) and prevention groups ($z = -3.48$, $p < .01$) found the messages provided more information to sustain weight loss than the control group. The control group found the messages to be significantly more annoying than the promotion group only ($z = 5.0$, $p = .01$). The promotion group found the messages significantly more trustworthy than the control group ($z = -2.59$, $p < .01$), and there was a trend in increased trustworthiness of the messages in the prevention group compared to control ($z = -1.84$, $p = .06$). The promotion ($z = -2.46$, $p = .01$) and prevention ($z = -1.95$, $p < .05$) groups liked the messages significantly more than the control group.

Interview data indicated that the participants enjoyed receiving messages on their cell phone. A majority, 42 (91%) said that they preferred to get messages on their cell phone due to accessibility and convenience, “because my cell phone is always on me.” The text message also acted as an alarm, and was indication for some to read the message. One participant said, “it was better on my cell phone than on the PC, because I don’t necessarily read the e-mail. I look at it (e-mail) every other day sometimes. But my iPhone has an alarm feature, or something that triggers, and says okay.” Still, a few participants would have preferred to receive e-mails instead of SMS. These participants said that they didn’t constantly carry their cell phone with them and they preferred to read messages on their computer when they checked their e-mail.

Participants were asked about their impression of the messages during the interviews. Six major themes arose from the participant's impression of the text message application as shown in Table 11. Participants enjoyed the intervention and found it useful in helping them manage their weight loss. The SMS served as a cue to action and helped them overcome barriers and to "stay on track." The messages acted as a daily reminder and helped participants to stay focused and mindful of their daily weight loss goals. The SMS acted as a support tool for some participants as well. Several people commented on how they felt it was an extension of the DFC. The content itself was important as well. People read the messages and commented on how they would have liked the content to be even more tailored towards their needs (i.e. exercise, diet, motivation, behavioral issues, etc.). The message content also served as a resource on knowledge and behaviors for sustaining weight loss. Participants felt that the intervention duration was too short and wanted the intervention to be extended beyond 30 days. Though not specifically asked, several participants did mention that they would be willing to pay for the messages.

Table 11: Qualitative Themes and Subthemes (N=60)

	Theme	n (%)	Description	Verbatim exemplars
1.	Cue to action	47 (78%)	The intervention helped participants to stay focused, mindful, establish a daily routine, stay on track, feel motivated and acted as a daily reminder for their weight loss program	"The day I received the messages I stopped exercise. I missed like 4 days because of my business. And I said you have to make the time. And I planned to continue and not stop."
	Overcome barriers	55 (8%)	The intervention helped participants overcome barriers	"There were times you know when I would fall off plan and I would go back and scroll [through the messages]"
2.	Enjoyable	32 (53%)	Participants liked the intervention and some reported missing the daily messages	"When I got home and started getting those messages from you, I got so fired up and that phone went beep-beep and I went shooting out of here every morning to see the message of the day, fabulous… to me that was the best!"
3.	Useful	30 (50%)	Participants felt the SMS intervention was a useful tool for maintaining weight loss	"The usefulness of a daily reminder every morning, the bell goes off at some point, and you look at it and realize what you are doing."
4.	Importance of Content	23 (38%)	Participants would like a mix of content ranging from diet, exercise, monitoring, motivation, and behavioral strategies	"When I got the couple messages I guess you send on exercise, I wanted to you know go and exercise or I wanted to walk at least 3 or 4 times a week."
	Tailoring	13 (22%)	Participants felt the content should be tailored to their needs	"I would want to tailor the messages to the things that I was struggling most with"
	Resource for information	5 (8%)	Participants felt the messages served as a resource for diet and exercise information	"I don't plan on going back to Duke for a while. So its kind of like, the texts are here, and I can just fall back on that"
5.	Support	15 (25%)	The intervention was a support tool, added a connection to Duke, and made them feel they were paid attention to	"I love the idea of getting a text message every day, it was sort of like somebody out there cares"
6.	Duration	13 (22%)	Participants would like the weight loss intervention to be extended beyond 30 days	"I wish there was a way I could keep getting them"

Frequency and Timing

Table 8 indicated that almost all of the participants would like at least one message per day (98%) with over half (62%) reporting they would be willing to receive up to two messages per day. The interview data showed similar results. Of the 40 participants who commented on the frequency of message delivery, 39 (98%) said that they would like to receive at least one message daily and of those, 8 (20%) said they would be willing to receive up to two messages per day, and 1 (2%) person said they would like a message every other day. One of the participants who would like to receive up to two messages per day stated, “a reminder in the middle of the afternoon is always good. I start to slow down and I think about making dinner [and I think to myself], oh I don’t feel like it.”

Participants also commented on the message timing in the interviews. Of the 22 participants that commented on timing, 20 (91%) reported that they would prefer to receive a message in the morning. Message delivery at 8:00 A.M. was the general consensus. However, 2 (9%) said that 8:00 A.M. was too early. Participants spoke about how receiving a message in the morning (8:00 A.M.) helped to set the day. For example one woman said, “they were sent early in the morning so I am either getting them as I am starting out or having breakfast, or starting my day”.

Sharing the messages

From the interviews (N = 60), 19 participants specifically mentioned sharing the messages. Most often this was to friends (N = 11) or family (N = 6). Participants shared

the messages by word-of-mouth or forwarded the messages to other people's cell phones. One participant who forwarded the messages stated, "I send it to my sister every once in a while and she is also very overweight, and her struggle is portion sizes, so anything that comes in with portions that type of thing I send to her."

Efficacy

A sensitivity analysis comparing those who completed the study and those who dropped out, demonstrated no significant differences between the intervention groups and no significant difference in the attrition between the intervention groups using a Fisher's Exact test at months 1 (p = .97) and 3 (p =.43). In Tables 12 and 13, descriptive statistics on weight and change in weight were calculated. Due to the non-normal distribution of the data as indicated by a skewness or kurtosis value exceeding ±.7, a Kruskal-Wallis Test was performed to calculate rank differences between groups. As seen in Table 12, in there were no statistically significant between-group differences in weight at baseline, month 1, or month 3. Overall, 247.5 (SD = ± 61.8) pounds was the overall baseline mean weight, 235.0 (SD = ± 59.5) was the one month overall mean weight, and 232.6 (SD = ± 60.1) was the 3 month overall average.

Table 13 illustrates the overall change in weight was not statistically significant at months 1 (M = -8.9, SD = ± 9.54) and 3 (M = -13.3, SD = ± 15.5) from baseline as indicated by all p > .05. Table 14 describes the differences in sustained weight loss at 1 and 3 months by intervention group for the intent-to-treat and evaluable cases. However, there was a **clinically significant** change in weight between the three groups. At month 3, the control group lost on average 9.7 pounds (SD = ± 15.1), while the promotion and

prevention groups lost on average 14.6 (*SD* = ± 16.6) and 15.3 (*SD* = ± 14.5) pounds, respectively.

A Fisher's Exact test was used to test for between-group differences in proportion of cases with sustained weight loss in the intent-to-treat and evaluable cases. The intent-to-treat analysis indicated the three treatment groups tended to differ in the proportion of cases with sustained weight loss at months 1 and 3 (p = .10 and .08, respectively). *A priori* pairwise comparisons demonstrated no significant differences in sustained weight loss rates between prevention vs. promotion (z = 1.39, p = .16) at months 1 and 3. Although not statistically significant at the .05 level, the rates of sustaining weight loss were lower in the control relative to promotion (z = -1.44, p = .15) and prevention (z = -1.42, p = .15) at month 1. Likewise at month 3, though not statistically significant at the .05 level, the rates were lower in the control arm relative to promotion arm (z = -0.90, p = .36). However at month 3, there was a statistically significant increase in sustaining weight loss in the prevention group compared to the control (z = -2.05, p = .04).

The evaluable case analysis, showed no significant differences in sustaining weight loss at months 1 and 3 (p = .20. and .13, respectively). Although not statistically different between-groups at month 3 (p = .13), a priori pairwise comparisons indicated there was a significant increase in sustaining weight loss in the prevention group (z = 2.00, p = .04) compared to control. There were no differences between the control and promotion groups (z = -0.98, p = .32) and the promotion and prevention groups (z = 1.30, p = .19).

Effect sizes for pairwise comparisons for the binary sustained weight loss outcome were calculated for the evaluable cases and the intent-to-treat analyses (Table

15). A Cohen *w* of .30 to .49 indicated a medium effect and a value of .50 or greater represents a large effect (Braunstein, 2007).

The positive effects of the promotion and prevention interventions relative to the control condition were large at month 1 in both the intent-to-treat and evaluable cases. At month 3, large effect sizes were also observed between all three groups in the intent-to-treat and evaluable cases.

Power calculations indicate that sample sizes of 40 per arm provided approximately 73% power to detect a statistically significant difference in proportions when the two-tailed level of significance is set at .05 and the observed effect size is .40. Effect sizes demonstrate the impact of the active intervention, but the sample sizes provided insufficient power to detect a difference at the .05 level when medium effect size was observed.

Table 12: Evaluable Cases: Summary of Weight

Weight (lbs.)	Total (N=120)	Control (N=39)	Promotion (N=41)	Prevention (N=40)	χ^2	df	P
Baseline weight					.54	2	.76
N	120	39	41	40			
Means ± SD	247.5 ± 61.8	239.6 ± 50.4	250.2 ± 68.2	252.3 ± 65.6			
95% CI	172.5 – 361.6	171.0-323.8	171.2 – 461.4	178.0 – 363.1			
Minimum	140.0	169.0	140.0	158.2			
25th percentile	201.0	196.0	204.2	196.1			
Medium	236.8	226.0	235.8	241.7			
75th percentile	276.2	272.6	268.0	294.4			
Maximum	461.4	374.0	461.4	449.8			
Month 1 weight					.76	2	.69
N	89	29	31	29			
Means ± SD	235.0 ± 59.5	226.7 ± 47.9	234.2 ± 62.8	244.1 ± 66.7			
95% CI	167.0 – 336.0	167.0-311.0	163.0 – 400.2	178.2 – 374.0			
Minimum	136.0	165.0	136.0	149.0			
25th percentile	185.9	190.0	187.0	182.0			
Medium	225.4	217.0	228.0	238.0			
75th percentile	263.0	260.0	246.0	285.0			
Maximum	433.4	322.0	433.4	400.0			
Month 3 weight					.34	2	.85
N	102	33	37	32			
Means ± SD	232.6 ± 60.1	227.2 ± 51.6	232.7 ± 64.3	237.9 ± 64.5			
95% CI	165.0 – 326.6	159.8 – 307.0	167.0 – 409.0	165.0 – 368.0			
Minimum	133.0	150.0	133.0	145.0			
25th percentile	186.0	186.0	195.0	180.5			
Medium	221.2	218.0	221.3	230.0			
75th percentile	261.0	261.0	243.0	290.0			
Maximum	420.0	323.0	420.0	396.6			

CI = confidence interval; χ^2 = chi-square statistics for Kruskal-Wallis Test**.**

Table 13: Evaluable Cases: Change in Weight

Weight (lbs.)	Total (N=120)	Control (N=39)	Promotion (N=41)	Prevention (N=40)	χ^2	df	P
Month 1 weight					.48	2	.29
N	89	29	31	29			
Means ± SD	-8.9 ± 9.54	-6.9 ± 10.2	-9.5 ± 8.0	-10.2 ± 10.3			
95% CI	-27.5 – 3.4	-19.0 – 6.8	-27.8 – 0.0	-27.5 – 1.0			
Minimum	-49.8	-43.4	-28.0	-49.8			
25^{th} percentile	-13.2	-12.8	-14.8	-12.8			
Medium	-8.0	-5.4	-8.0	-10.0			
75^{th} percentile	-2.0	-0.4	-2.7	-3.8			
Maximum	8.2	8.2	1.0	5.4			
Month 3 weight					.35	2	.31
N	102	33	37	32			
Means ± SD	-13.3 ± 15.5	-9.7 ± 15.1	-14.6 ± 16.6	-15.3 ± 14.5			
95% CI	-46.0 – 8.8	-45.8 – 9.8	-52.4 – 9.6	-53.2 – 1.8			
Minimum	-64.4	-52.4	-64.2	-64.4			
25^{th} percentile	-21.0	-17.6	-24.4	21.6			
Medium	-11.3	-7.6	-11.6	-11.9			
75^{th} percentile	-3.0	-0.8	-2.0	-5.8			
Maximum	22.0	22.0	10.2	2.2			

CI = confidence interval; χ^2 = chi-square statistics for Kruskal-Wallis Test

Table 14: Intent-to-treat Cases vs. Evaluable Cases

Sustained weight loss	Total (N=120)	Control (N=39)	Promotion (N=41)	Prevention (N=40)	P
Intent-to-treat					
Month 1	118 (98%)	37 (95%)	41 (100%)	40 (100%)	.10[a]
Month 3	114 (95%)	35 (90%)	39 (95%)	40 (100%)	.08[b]
Evaluable cases					
N	89	29	31	29	
Month 1	87 (98%)	27 (93%)	31 (100%)	29 (100%)	.20[a]
N	102	33	37	32	
Month 3	96 (94%)	29 (88%)	35 (95%)	32 (100%)	.13[b]

Data presented as n (%) of N. Fisher's Exact Test was used for significance testing. Intent-to-treat = when missing, sustain = 1 (sustained weight loss) was imputed. *A priori* pairwise comparisons results were as follows: [a]: promotion = control, prevention = control, promotion = prevention; [b]: promotion = control, prevention > control, promotion = prevention.

Table 15: Effect Sizes for Pre-planned Pairwise Comparisons of Sustained Weight Loss

	Month 1	Month 3
Intent-to-treat		
Promotion vs. Control	0.82	0.44
Prevention vs. Control	0.82	1.22
Promotion vs. Prevention	0.01	0.40
Evaluative cases		
Promotion vs. Control	0.84	0.49
Prevention vs. Control	0.80	1.20
Promotion vs. Prevention	0.04	0.72

Cohen *w* effect sizes used to estimate magnitude of effect for the binary sustained weight outcomes

Baseline RFQ Score: Predictor analysis

Internal consistency reliability was assessed for the RFQ from data collected at baseline. The prevention subscale was found to be reliable (5 items; $\alpha = .76$). However, the promotion subscale demonstrated poor reliability (6 items; $\alpha = .53$). There were no differences between groups on total regulatory focus scores ($M = 0.24$, $SD = \pm 0.85$; $p = .87$), the promotion subscale ($M = 3.70$, $SD = \pm 0.52$; $p = .10$), or the prevention subscale ($M = 3.46$, $SD = \pm 0.80$; $p = .68$). Logistic regression analysis with group and baseline RFQ scores as a covariate indicated that the RFQ regulatory focus total score was not a significant predictor of sustaining weight loss at month 1 ($\chi^2 = .16$, df =1, $p = .71$) and month 3 ($\chi^2 = 1.55$, df =1, $p = .39$). The lack of association between baseline regulatory focus scores and sustained weight loss was also confirmed by a Spearman Point biserial correlation at month 1 ($r = .02$, df = 1, $p = .64$) and month 3 ($r = .08$, df =1, $p = .48$). Thus, we could not answer from this study the hypothesis of whether or not those who had a greater promotion or prevention focus who received messages that 'fit' had an increased success at sustaining weight loss.

Implementation, Challenges & HIPAA

The main challenges in implementation involved security and reliability. Because subject phone numbers are private health information (PHI), the SMS application could not simply be run from any desktop computer. The application had to run on a secure server that had the ability to transmit encrypted PHI beyond existing firewalls. This

demanded an SMS service that worked over encrypted hypertext transfer protocol secure (HTTPS) connections.

Additionally, the SMS service had to be able to support receiving text messages back from participants to the source phone number for the researcher to collect data. The SMS service supported this by sending such responses to the researcher's phone, which had to be secured and password-protected.

While the SMS application was architected for reliability, several issues occurred beyond the software's direct control. The "Run As" user account for the Windows Scheduled Tasks, whose credentials provided secure access to the subjects' PHI, had a typical user password expiration regime, and the Windows Scheduled Tasks had to be reconfigured each time the account password changed. Additionally, a particular software update and reboot on the server deactivated all Windows Scheduled Tasks on the machine, and they had to be reconfigured as well. The confirmation text message was instrumental in identifying these issues so that they could be rectified quickly. The implication of this was that on two days, messages were delayed by a couple of hours and some participants may have received a message at 11:00 A.M. instead of 8:00 A.M.

Other pragmatic barriers can be traced to participants' cell phones and their respective cell phone plans. Due to the nature of how newer smart phones provide access to and display text messages, it was much easier for people with a smart phone to learn how to text and to review previous messages. Two (1.7%) participants who entered the study simply did not receive the text messages initially. After numerous e-mails and working to fix the problem, it was determined that even though the participants lived in the USA, their phone numbers were international and the online text messaging service

we used did not send texts to international numbers. The failure to recognize the phone number was international occurred because when the primary author texted the participants during recruitment the text messages sent from their personal phone transmitted without error.

Of the 60 people who completed the telephone interview, 5 noted that they only read the messages when they turned on their phone. Although they may have read all of the content, they did not necessarily read the messages when they were delivered every morning. An additional 4 people also reported that they received and read the messages, but not necessarily every day. One participant noted that she did not read the messages on the weekend when she didn't want her phone near her. Results from the SMS survey as seen in Table 8 demonstrate the same barrier. Of the 82 people who completed the survey, 3 (4%) indicated they only read the messages occasionally and 2 (2%) said they read the messages when they accumulated too many of them.

Discussion

This study provides valuable insights on the use of a mHealth SMS intervention to help people sustain weight loss in the continued response phase of the Behavior Change Process. Our analyses showed both technical and pragmatic barriers of our mHealth intervention, how to deliver weight loss sustaining messages, appropriate content to deliver, the acceptability of the intervention, the perception of the usefulness of cell phones as a healthcare delivery medium, and the efficacy of SMS on sustaining weight loss.

Consistent with the literature, these findings demonstrate that SMS is a feasible and acceptable mode for weight loss interventions (Bauer et al., 2010; Fukuoka et al., 2010; McGraa, 2010; Patrick et al., 2009; Shapiro et al., 2008; Shaw & Bosworth, in press; Sirriyeh et al., 2010; Zuercher, 2009). A majority of the participants felt there was significant value in receiving messages via SMS that promote recent weight loss sustaining behaviors. Many participants felt that short messages, which promote exercise, a healthy diet and monitoring of weight following recent weight loss, helped them stay motivated to sustain weight loss behaviors. All participants were positive about the delivery method. Most read the messages and many reported reading them multiple times. Participants expressed favorability towards SMS because messages were delivered directly to them in an easy to use manner, which was capable of storing messages, and that could easily be reviewed multiple times. Most participants read the messages every day. There was no problem with participants responding via SMS their self-reported weight. This indicates that SMS is also an appropriate tool to collect data on weight.

This study adds important insight on the frequency and timing of SMS delivery for weight loss behaviors. According to participants, once a day was deemed as the most appropriate frequency. This was expressed because weight loss is a daily challenge. Morning at 8:00 A.M. was determined to be the most appropriate time of delivery since people have not yet begun their day and it helped motivate them for the remainder of the day. Some participants also indicated that receiving messages twice a day, preferably at morning and night would be beneficial. Interestingly, several participants reported sharing the messages with other people who were also trying to lose weight. Technical issues did arise, such as a non-functioning phone in one participant, two participants

having international phone numbers, and a silent mode or delay in checking the messages by two others.

Results from the intent-to-treat analysis indicated that there was an increase in the number of people who sustained weight loss at month 3 in the intervention groups compared to control. The ITT increased the *N* in each group and added power to pull out, as indicated below, a trend that was already evidenced in the evaluable case analysis. Thus, as a binary outcome imputing success was the most logical approach. Likewise among the evaluable cases, more participants sustained weight loss at month 3 in the promotion and prevention groups compared to control. This means that more people sustained their weight loss in the intervention groups compared to the control group. A sensitivity analysis between those who reported their weight and those who did not, demonstrated no significant differences between these two groups in terms of demographic and clinical characteristics. Thus, results were not necessarily affected by attrition.

The observed effect sizes with regards to impact of the intervention on sustained weight loss were medium to large when a medium effect was observed (Cohen $w = .40$), the sample size provided less than 80% statistical power to detect medium effect sizes. Thus, a larger study with at least 80% power is needed to further examine the effects of this promising intervention.

From a clinical standpoint, more participants sustained their weight loss in the intervention groups compared to control. Effects size findings indicate a moderate to large effect size (Cohen, 1988) indicating the promotion and prevention groups has a higher proportion of sustained weight loss relative to the control group. In addition, there

was a clinically significant loss in weight between the control and two intervention groups. However, it did not seem to make a difference whether individuals were in the promotion or prevention group.

The continued response phase of the Behavior Change Process is illustrated as a tension between a person's capability and motivation to consistently perform a new pattern of behavior, and the challenges that lead to lapses and relapses (Rothman et al., 2004). Themes from the interviews revealed that the intervention served as a daily cue to action and served as a motivator to continue participants' new weight loss behaviors (see Table 11). The messages promoted self-efficacy, acted as a support tool, and helped some participants overcome barriers. Participants felt the daily messages served as a reminder, promoted mindfulness, kept them focused, and motivated them to stay on track with their weight loss program. Because many people who lose weight begin to regain weight within the first month of completing a structured weight loss program (MacLean et al., 2009), these results advocate that the intervention may have aided participants to prevent relapse and continue in the continued response phase of the Behavior Change Process.

Results from this study also provide some insight on the use of regulatory focus and the framing of messages to either promotion or prevention. The message framing between promotion and prevention did not necessarily impact the self-reported favorability or acceptability of the messages. However, there was an increase in the perception of the usefulness and attitudes of the messages in the promotion and prevention groups compared to the control group. Thus, the content of the messages was essential. There was also notable difference in the promotion and prevention groups compared to control in sustained weight loss. A trend in increased sustained weight loss

was noted between the intervention group and control groups. However, pairwise comparisons indicated that these differences were most pronounced between the prevention and control groups. The literature suggests that at the earlier phases of behavior change, regardless of individual regulatory focus, promotion focused strategies are superior to prevention focused strategies (Rothman et al., 2004). This is because people are more sensitive to achieving future outcomes and promoting future success when initiating and beginning a change in behavior. Whereas in the later stages of the Behavior Change Process (i.e. sustaining and maintenance) people are more sensitive to prevention strategies and seek to prevent losing the achievements they have worked hard for (Rothman et al., 2004). Thus the results herein might indicate that regardless of regulatory fit, the prevention message group had a greater success in sustaining weight loss compared to the control group, rather than the promotion group compared to control. This may be due to the participants in this study being in the sustaining phase of the Behavior Change Process.

Furthermore, the moderating effects of the regulatory focus scores could not be assessed due to a lack of variability in the data. Thus from this study, conclusions cannot be made that matching a promotion or prevention framed message to an individual's regulatory focus of promotion or prevention had an effect on sustained weight loss. In addition, though the reliability of the prevention subscale was good (6 items; $\alpha = .76$), perplexingly, the reliability of the promotion subscale was poor (6 items; $\alpha = .53$). Results indicated no significant differences between groups on the promotion subscale. An additional analysis examining the variability of specific items from the promotion subscale suggested limited variability in the answers. The poor performance of the

subscale makes it difficult to draw conclusions on regulatory fit. Thus, this subscale should be used in future studies only after the measure is pilot-tested for internal consistency reliability with a sample with the same characteristics as those who will be recruited for the anticipated study.

With regard to HIPAA, patient privacy was a major consideration in the design and development of this study. Data were transmitted to participants from a secure server, which read protected health information (telephone numbers) and then transmitted data to a personal cell phone. However, cell phones are often shared and other people could read information transmitted to participants through a text message. This is particularly true for SMS, where user authentication is not available for an individual message at this time, beyond having a password to access some phones. When designing IT systems such as this, data encryption must be written into the software development. Mobile health interventions may often times use a 3rd party to transmit text messages (SMS), video messages, voice messages, or other data into an application or 'App'. It is imperative that PHI is limited as to what is transmitted and that these 3rd party companies or services also have privacy agreements.

For a larger trial with more time and resources, care should be taken in assigning user accounts for automatic software operation, and server updates to a server running automatic software for the trial should require notification of the researcher and support staff. Additionally, moving the configuration and subject data from secure text files to a secure, password-protected database may help with account credential and password issues while also improving the ability to enter and process large amounts of subject data.

Limitations

The majority of participants were from a more affluent and educated background, mostly White non-Hispanic, and not representative of the general U.S. population. Therefore, generalizability is limited to this particular clinic. Another limitation was that the definition for sustaining weight loss was based upon a national guideline, research that observed weight loss at 12 months, not 3 (Donnelly et al., 2009). Thus, this made it easier for participants to qualify for having sustained weight loss. This study only examined weight loss 3-months post-baseline and the intervention itself was only 1 month. It is unknown what the effect of the intervention was beyond 3 months. Most importantly, the study was not sufficiently powered to detect differences between groups on the primary outcome, sustained weight loss, when the effects were in medium small range. A sample size of 90 per group would have been needed to reach statistical significance in sustained weight loss when the effects were less than 0.40. In addition, there was no standard-of-care control group to compare the intervention and attention-control group with. Thus, conclusions cannot be made as to how much simply receiving a daily message regardless of content had on impact sustained weight loss. It is unknown why there was an increase in self-reported weight at month 3 compared to month 1. It is hypothesized that it may be related to burden. At month 1, participants had just received daily SMS for a month, were asked to complete an online survey, a telephone interview, and to report their weight via SMS; versus at month 3 participants were only asked to report their weight via SMS and complete an online survey.

Implications for practice

With obesity reaching epidemic proportions in the U.S. alone and the high relapse rate of those who fail to sustain weight loss, an increase in just 10% of people who are able to sustain weight loss and continue towards the maintenance phase of the Behavior Change Process through such an intervention could potentially have considerable benefit. As supported by the literature (Shaw & Bosworth, in press) SMS is an appropriate and accepted tool to deliver diet and exercise interventions. Tools such as this SMS weight loss intervention have the potential to be implemented in the clinical setting as a low cost way to extend weight loss programs and keep in-touch with clients over time. Delivery of at least one message per day in the morning is an acceptable frequency and timing for behaviors related to weight loss; up to two messages a day may be suitable. Studies also report daily messages had positive clinical effects of SMS on behavior (Franklin et al., 2006; Patrick et al., 2009; Riley et al., 2008). Consistent with the literature (Haskell et al., 2007; Kant et al., 2004; U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2005), message content should focus on diet, exercise, monitoring, and behavioral issues related to weight loss. Furthermore, it may be warranted for the content delivered to be tailored towards the specific needs of patients.

Future Research

Overall, results show promise in exploring the effects of this intervention in a larger sample, over an extended period of time and diverse settings. Further research is needed to test if the intervention helps people transition from the continued response

phase of the Behavior Change Process to maintenance, how a different schedule of message delivery would impact behavior change, and to test how a more tailored approach of content could help people sustain weight loss. Investigation is also needed to examine the use of mobile applications, which may involve a more in-depth and comprehensive intervention experience that can give immediate feedback to the participant on their progress and transmit data directly to a provider such as weight, blood pressure, and exercise frequency. Furthermore, additional research is necessary on the effects of promotion and prevention framed messages and an individual's regulatory focus on sustained weight loss. The Attitudes and Behaviors Towards Weight Loss SMS Scale was adapted from a measure that assesses attitudes towards mobile advertising (Tsang et al., 2004). Due to this modification, the two instruments cannot be compared. Further psychometric testing is needed to test the effectiveness of the modified measure in other weight loss populations.

Health services research is also warranted such as examining cost-effectiveness and the effects on access to care. Due to the automaticity of the SMS application and ubiquity of cell phones, an intervention such as this has the potential to be transmitted to thousands of people at low cost. Though the SMS application must reside on a HIPAA secure server, the required personnel resources for this SMS intervention are minimal; consisting mostly of inserting a phone number, start date, and a name to welcome people. SMS itself is very affordable with an average cost of .10¢ per message sent and received.

Conclusion

Communication technologies such as mobile phones may serve as an effective medium to deliver affordable health promotion and disease prevention care to a wide array of people due to their ubiquity and penetration into people's everyday lives. However, emerging and promising technologies must be matched with content that successfully resonates and motivates people to change and sustain behaviors. Our intervention results demonstrate that it is not only feasible and acceptable to use mobile phones as a HIPAA compliant health care delivery platform, but that participants find it useful, and were overall positive towards this mobile health intervention. Markedly, there was a clinically significant increase in weight loss and the number of people who sustained weight loss in the promotion and prevention groups compared to control. Notably, effect sizes were significant and demonstrated a large effect of the promotion and prevention interventions on sustaining weight loss relative to control.

5. Conclusion

Obesity has reached epidemic proportions in the U.S. With nearly two-thirds of American adults are obese or overweight (National Center for Health Statistics, 2009), obesity is one of the leading health issues in U.S. society (Obesity in America, 2009; Simon et al., 2006). Although structured weight loss programs for treatment of obesity have generally been successful at weight loss, avoiding weight regain is a major challenge (Bray, 2009; Kraschnewski et al., 2010). We must continue to develop effective interventions that people will use and adopt that will lead to sustaining weight loss behaviors (Centers for Disease Control and Prevention, 2009; National Heart Lung and Blood Institute & National Institute of Diabetes and Digestive Kidney Diseases, 1998). Due to affordability, universal adoption, ease of use, and accessibility directly to people regardless of geographic location, healthcare communicated through mobile technology, or "mHealth", may be able to serve as an effective intervention medium to reach a large number of people to facilitate weight loss behaviors. A review of the literature demonstrated limited information regarding message content, and timing and frequency of message delivery and only 3 of 14 SMS-related interventions reviewed demonstrated a statistically significant effect on weight loss, diet or exercise. Moreover, information on how to integrate and leverage SMS as a health promotion tool for weight loss was also limited in the literature (Shaw & Bosworth, in press).

The Behavior Change Process (Rothman et al., 2004) was used as a guide to understand how to develop an intervention to help people sustain recent weight loss.

Furthermore, research suggests interventions that target and frame messages about how people reach goals in their life through either promotion or prevention focus may be beneficial at motivating people to self-regulate and sustain recent behavioral changes (Higgins, 2000) such as those related to weight loss (Fuglestad et al., 2008). The goal of this research was to design a weight loss sustaining intervention that would help people stay in the continued response phase of the Behavior Change Process and help prevent relapse. Using the Behavior Change Process and regulatory focus theory, an intervention was developed that leveraged short message service (SMS) to deliver messages to people who have recently lost weight in attempt to help them sustain weight loss.

A pilot study was first conducted to inform the development of a mHealth SMS software application designed to deliver messages to people to help them to sustain their recent weight loss. Results suggested that it was feasible to develop and deliver weight loss sustaining messages via SMS to people who have recently completed a structured weight loss program and are in the continued response phase of the Behavior Change Process. In addition, it was feasible to craft and deliver messages that reflect the two foci of the Regulatory Focus Theory, promotion or prevention respectively. The majority of participants felt there was significant value in receiving the messages. All participants were positive about the SMS delivery method. Once a day was deemed as an appropriate message frequency, and 8:00 A.M. as the acceptable delivery time. Findings from the pilot study allowed us to develop an SMS application to be used in a subsequent randomized controlled trial with 3 groups that would receive either promotion framed

messages, prevention framed messages, or general health messages as a control. We then tested the feasibility, acceptability, perception of the usefulness, and efficacy of an SMS intervention in a 3-arm mixed methods RCT.

Results from the exploratory RCT showed that it was feasible to design and deliver promotion and prevention framed weight loss sustaining messages at the continued response phase of the Behavior Change Process. Furthermore, participants found the message content and intervention acceptable and a majority perceived value in receiving messages via SMS that promote weight loss sustaining behaviors. Interview data implied that the intervention served as a reminder and daily cue to action. Many people were favorable towards receiving a daily reminder, which they noted helped them to stay focused, and in some cases to keep them motivated. A minimum of one message delivered at approximately 8:00 A.M. was deemed the optimal delivery time and frequency. This was particularly true for weight loss, which many participants reported as a daily struggle that begins every morning. Lastly, with regard to weight loss outcomes, more people sustained their weight loss at month 3 in the promotion and prevention groups compared to the control group in both the intent-to-treat and evaluable case analyses. This means that more participants sustained their weight loss in the two intervention groups compared to the control group. Effect sizes also indicate medium to large effect sizes at months 1 and 3 in the promotion and prevention groups relative to the control group. Therefore, these findings may serve as a reference for future interventions

designed to help people thwart relapse and transition from a state of sustaining recent weight loss behaviors to a state of maintenance.

In addition, these results suggest that cues to action, external events that prompt a desire to make a health change, are important components of sustaining behaviors for weight loss. This is supported by the literature and dominant theories of behavior change such as the Health Belief Model (Janz & Becker, 1984). Cues to action have been found to help promote exercise (Pak Hei & Chou, 2005) and have beneficial effects in weight loss programs (Daddario, 2007). Future research warrants adding and evaluating cues to action to the Behavior Change Process conceptual model. Application to the theories of regulatory focus and fit are less direct. It was feasible to frame SMS messages to a promotion or prevention focus, and regardless of framing or fit participants were overall positive and accepting of them. There was an overall trend in differences in sustaining weight loss between the promotion and prevention groups compared to the control. When comparing each individual group to the control group, pairwise comparisons indicated these differences were most pronounced between the prevention and control groups. Results indicated that the prevention message group had a greater success in sustaining weight loss compared to the promotion group regardless of fit. This may be due to the participants in this study being in the continued response phase of the Behavior Change Process. The continued response phase is characterized as a tension between a person's capability and motivation to consistently perform new behaviors, and the challenges that lead to lapses and relapses (Rothman et al., 2004). A feeling of satisfaction indicates the

decision to change was appropriate and provides validation for continued effort. This satisfaction is compared against whether the experiences with engaging in the new behavior meet or exceed their expectations of the outcomes of the behavior change. In addition, people must continue to be confident that they have the ability (self-efficacy) to continue the new behavior, and they begin to see initial rewards with regard to weight loss. The promotion and prevention interventions may have promoted some of these factors. In particular, the content of the messages promoted self-efficacy and focused on consistent performance of weight loss behaviors.

The literature supports this conclusion and advocates that in the later stages of the Behavior Change Process (i.e. sustaining and maintenance) people are also more sensitive to prevention strategies and seek to prevent losing the achievements they have worked hard for (Rothman et al., 2004). Therefore, further research is needed to evaluate if prevention framed messages, in general, are more beneficial than promotion framed messages at motivating people to self-regulate and sustain weight loss behaviors. Furthermore, due to a lack of statistical power and homogeneity in the data, impact of message 'fit' could not be determined. Further research is needed.

mHealth

mHealth and it's components such as SMS, have been touted as one of the many tools that can improve health outcomes through ready access to quality of health services around the world (NIH Office of Behavioral and Social Sciences Research, 2011). This is largely due to the pervasive nature of cellular telephone mobile technology, affording

access over 87% of the world (International Telecommunications Union, 2011), which provides near universal access to people regardless of demographic factors or geographic location. Continuingly evolving, people have embraced mobile technology into their everyday lives. Although mHealth shows promise as a beneficial tool we must be careful of technology-driven hype. This technology, in and of itself, is only a communication medium; it must be matched with theory driven content and tested in randomized controlled trials to determine its efficacy in improving health outcomes. Human behavior, health, and illness are multifaceted and influenced by numerous factors ranging from environmental, social, to biological. Merging mobile technology with health care will be no easy feat and many questions remain answered. For every behavior that mobile technology is proposed to improve, we must know the appropriate content, how and when to deliver it, and the effects over time.

Limitations

Generalizability from this research is limited. The majority of participants were from a more affluent and educated background, mostly White non-Hispanic, and not representative of the general US population. The definition for sustaining weight loss was based upon a national guideline (Donnelly et al., 2009), research that observed weight loss at 12 months, not 3 months. Thus, this made it easier for participants to qualify for having sustained weight loss. This study only examined weight loss 3-months post-baseline and the intervention itself was only 1 month. Therefore these results can only be interpreted as beneficial up to 3 months following completion of a weight loss program.

Most importantly due to the exploratory nature of this study, there was insufficient power to detect differences between groups on the primary outcome, sustained weight loss. There was also not a standard-of-care control group to compare the intervention and attention-control group with. Thus, conclusions cannot be made as to how much simply receiving a daily message regardless of content had on impacting sustained weight loss. There was no measurement across subjects to evaluate if participants viewed the promotion and prevention messages as treated. However despite these limitations, findings support further research. Effect sizes indicated a medium to large effect of sustaining weight loss, a trend in statistical significance in sustaining weight loss, and a clinically significant increase in weight loss in the promotion and prevention group relative to control.

mHealth limitations. This study only leveraged SMS text messaging. There are many other features of mHealth that may be just as or increasingly more beneficial. These include video and picture messages, two-way interactive communication, mobile applications or 'Apps', geospatial tracking, social networking, and many others. The nature of this intervention was also not very interactive. It largely involved participants simply reading a daily message. Though this added an element of simplicity, a more interactive intervention, such as one where participants could receive daily tailored feedback on their exercise and diet based upon information they enter into a mobile application, could have increasing benefits.

Implications for Clinical Practice

SMS interventions have the potential to be easy-to-use tools that clinicians including nurses, physicians, and other care providers, can use to help patients sustain healthy behaviors. Because text messaging is such a ubiquitous medium of communication, it can allow providers to easily reach and deliver care directly to their patients. One can envision this SMS application being leveraged in primary care clinics and weight loss specific centers such as the DFC as a way to extend care affordably beyond the in-person visit. Tools such as this could also easily be integrated into a patient-provider Internet portal such as Duke Medicine's "Health View." This could provide a home where clinicians associated with Duke Medicine could direct their patients to communicate through in a HIPAA-secure environment.

Implications for Future Research

Results from this research suggest that more rigorous examinations of the effects of this SMS intervention are warranted. A longitudinal study with a larger population and more diverse population in diverse settings that examines the effects of this intervention on diet, exercise, and other common co-morbidities associated with obesity would provide more conclusive results about the effects of this intervention on weight loss behaviors and ultimately sustaining weight loss. A longitudinal investigation would also help to determine if this intervention helps people transition from a state of sustaining weight loss to maintenance. A study conducted over a longer period of time such as over 12 months may also foster more variability in the data (e.g., sustained weight loss

outcome) and provide further insight in to the use of regulatory focus and fit from both a moderating and mediating perspective. Additional health services research is also needed (e.g., cost-effectiveness, access to care) of this SMS intervention.

Further research is also needed to examine how more comprehensive and interactive mobile applications, which use SMS, can be developed and leveraged to improve weight maintenance. With the advent of smart phones and mobile devices such as iPads and tablets, an application or "app" could be utilized as a dynamic intervention medium to deliver health care and in particular to help promote self-management. An "app" typically refers to software used on a smartphone or mobile device such as Android, iPhone, BlackBerry or iPad. Mobile phone applications have various communication abilities. These include, but are not limited to, self-record keeping, auto-monitoring, customizable auto-feedback, and direct communication to and from a provider. Research involving cell phone applications is currently ongoing. For example, one current study involves a behavioral intervention delivered almost exclusively via cell phone using self-monitoring and social networking features of cell phone applications (Svetkey, 2010). Other examples of how an app may be utilized to help sustain and manage recent weight loss could be through meal customization and automatic geospatial tracking and feedback for exercise and/or physical activity.

Closing

Systematic improvement in diet, physical activity and many other behaviors, could lead to a significant benefit for society. Nevertheless, there is a constant challenge

to find effective ways to change behaviors to promote health and prevent disease that lead to improved health outcomes. For sustaining weight loss, the participants in this study found an SMS intervention that delivers daily evidence-based messages acceptable and overall useful in the continued response phase of the Behavior Change Process. One message per day and up to two was the optimal delivery frequency and a message at 8:00 A.M. was the ideal timing. Overall, the promotion and prevention groups showed a clinically significant increase in weight loss and the number of people who sustained weight loss compared to control. Notably, effect sizes were significant and demonstrated a large effect of the promotion and prevention interventions on sustaining weight loss relative to control. Consistent with the literature that suggests people are more sensitive to prevention strategies in the later stages of the Behavior Change Process (Rothman et al., 2004), prevention framed messages may have been more useful in helping participants sustain weight loss. In closing, technological tools such as this SMS intervention that are constructed and guided by evidence-based content and theoretical constructs show promise in helping people sustain healthy behaviors that can lead to improved health outcomes.

Appendix A: Weight Loss Sustaining Promotion and Prevention Messages

 = Nutrition focused message

Maximum character length: 140

 = Monitoring focused message

 = Exercise focused message

	Promotion	Prevention
1	Small diet changes add up. Eat breakfast every day. You will eat less during the day and it will help you reach your weight loss goals	Eat breakfast every day. It will prevent eating more during the day and gaining weight back. Small diet changes add up
2	Weigh yourself daily at the same time and on the same scale. This is important. Checking on your progress will help you control your weight	Check your progress and prevent failure. Weigh yourself daily at the same time and on the same scale. This will help you control your weight
3	Exercise regularly. Exercise will maintain a healthy weight, blood pressure and reduce problems with diabetes	Prevent diabetes problems, weight gain and worsening blood pressure. Not exercising affects the body's ability to handle blood sugar
4	Sustain your weight loss. Use the 'plate method'. Fill up 1/2 your plate with vegetables, ¼ with starch, ¼ with protein	Avoid eating too many calories. Use the 'plate method.' Fill up 1/2 your plate with vegetables, ¼ with starch, ¼ with protein
5	Check your food intake. Record everything you eat and portion sizes. Checking increases awareness of what you are eating	Check your food intake. Avoid falling into the trap of checking only "good days." Record everything you eat and portion sizes
6	Count steps to increase the amount you walk. Use your pedometer. Set a goal of adding 150 steps a day up to 5000 steps a day or 2.5 miles	Don't risk falling off the exercise bandwagon. Count your steps to increase the amount you walk up to 5000 steps a day or 2.5 miles
7	Use smaller plates. You will still clean your plate and feel satisfied and have better portion control.	Prevent over eating. Use smaller plates to avoid filling a larger plate with extra calories
8	Keep track of the things that lead to unplanned and overeating	Prevent yourself from unplanned eating. Keep track of the things that lead to unplanned and overeating
9	Activity burns calories and helps maintain weight. Climbing stairs, parking further away or walking to the office add up quickly to 30 min a day	Don't let exercise slip away. Small activities such as climbing stairs, parking further away or walking to the office add up quickly to 30 min a day
10	Eat slowly. Put fork down between bites. Check fullness level during meal. When full push your plate away. Satisfaction takes 15-20 min	Avoid feeling full and giving in to cravings. Eat slowly. Put fork down between bites. Check fullness level. Satisfaction takes 15-20 min

11	Keep exercising! After 1 year dieters who exercise maintain most of their original weight loss	Steer clear of gaining weight back. Dieters who do not exercise maintain only half of their original weight loss
12	Select healthy breakfast cereals. Follow the “5 and 5” rule - 5 grams fiber & 5 or less of sugar. Or try heart-healthy oatmeal with honey!	Steer clear of high sugar breakfast cereals. Follow the “5 and 5 rule.” 5 grams of fiber and 5 or less grams of sugar
13	Monitor your progress and how you are doing. Schedule time to review your progress in your calendar	Remember not to forget to monitor your progress. Schedule time to review your progress in your calendar
14	Exercise helps more than just with weight loss. It helps to decrease high blood pressure, improve diabetes and decrease cholesterol	Exercise helps more than just with weight loss. It helps to prevent cancer, diabetes, high blood pressure and gaining weight back.
15	Reward yourself. It’s OK to have a little sweet foods such as pie, cookies, and candy, and alcohol	Prevent yourself from overindulging. It’s OK to have a little sweet foods such as pie, cookies, and candy, and alcohol
16	Cross train. Vary your exercise: walk, bike, elliptical, water /chair aerobics. It will help you stay motivated and have fun!	Prevent boredom, injury and over training with your exercise. Cross train: walk, bike, elliptical, water/chair aerobics
17	Identify and change habits and foods that lead to binges including risky foods kept in the house such as chips or watching TV while eating	Avoid being tempted by foods and habits that lead to binges. Don’t keep risky foods in the house such as chips or watch TV while eating
18	Stay on top of how you are doing. Review your monitoring forms to check for patterns. Monitor at least 2-3 times a week	Prevent yourself from slipping. Pick 2-3 days to monitor and every so often review your monitoring forms to check for patterns
19	For general fitness: exercise 30 minutes daily. 8-10 exercises, 8-15 repetitions, 1-3 sets, 30-90 second rest between sets	Don't exercise too little and stop all together: exercise 30 minutes daily. 8-10 exercises, 8-15 repetitions, 1-3 sets, 30-90 second rest between sets
20	Use a grocery list for grocery shopping and only buy planned for items. This will help you buy good healthy foods.	Prevent temptation to buy unhealthy foods. Avoid meal planning or shopping for groceries when you are hungry
21	Limit size of portions at mealtimes by measuring planned servings. Keep measuring utensils readily available	Don’t let portion sizes increase in size. Keep measuring utensils readily available and measure planned servings at mealtimes
22	Weigh yourself daily. Place the weight on a graph to see trends over time. It is natural to fluctuate daily due to things such as water	Don’t feel surprised and upset when daily weighing. Place the weight on a graph to see trends over time. It is natural to fluctuate daily
23	Plan meals in advance to increase self-awareness – 3 meals and up to 2 snacks per day going no longer than 4-5 hours between eating	Plan meals in advance to avoid overeating and being tempted to select poor foods – 3 meals, 2 snacks/day no more than 4-5 hrs between eating

24	Be aware of your blood pressure and monitor it. Check it when and where you can: at home, the doctor's office, blood pressure machine at the drug store, etc.	Prevent or reduce high blood pressure. Keep track of your blood pressure at home, the doctor's office, machine at the drug store, etc.
25	Stay motivated! At the beginning of the week plan your exercise sessions and treat them like you would any other appointment	Prevent becoming demotivated. At the start of the week plan exercise sessions and treat them like any other appointment
26	Monitor your blood sugar as prescribed and HbA1c every 3-6 months. Keep track of fluctuations and where they are to see how much they are	Avoid large fluctuations in your blood sugar. Monitor your blood sugar as prescribed and HbA1c every 3-6 months
27	When you don't feel like working out, bargain with yourself to exercise for just 10 minutes then see how you feel	Don't fall into the slippery slope of not feeling like exercising. Contract with yourself to exercise for just 10 min then see how you feel
28	Make small changes. Use trade-offs such as: I will have dessert every OTHER night or, I will only eat half of the dessert	Avoid tempting foods. Use trade-offs such as: I will have dessert every OTHER night or, I will only eat half of the dessert
29	Any exercise is better than no exercise. Use a strategy to find a way to get in at least some exercise	Don't slip into the "I don't have time to exercise" today excuse. Any exercise is better than no exercise.
30	Use restaurant strategies: 2 vegetable servings, 1 caloric beverage. If calories are listed keep meals below 800	Don't be tempted to overeat when at restaurants: 2 vegetable servings, 1 caloric beverage, don't arrive hungry. Keep meals below 800 calories

Appendix B: Attention Control Messages

1. Frequent hand washing is one of the best ways to avoid getting sick and spreading illness
2. High blood pressure increases the risk of heart disease and stroke. Risk factors: obesity, too much alcohol, smoking, and family history
3. Sleep is just as important as diet and exercise
4. Facebook may be good for your health: staying in touch with family and friends can ward off memory loss and help you live longer
5. People that suffer from gum disease are twice as likely to have a stroke or heart attack
6. Motorists who talk on cell phones are more impaired than drunk drivers with blood-alcohol levels exceeding .08
7. Deep Breathing gives health benefits similar to aerobics
8. Researchers have linked sitting for prolonged periods with a number of health problems and premature death from cardiovascular disease
9. Annual eye exams detect vision problems, eye disease and general health problem before you are aware a problem exists
10. People who don't get enough sleep are more likely to have bigger appetites
11. The number one cause of blindness in the United States is diabetes
12. Stay up to date with vaccines. A tetanus shot is needed every 10 years
13. Smoking is the most significant cancer risk factor that we can reduce. Avoid smoking and exposure to smoke
14. Laughing lowers levels of stress hormones, and strengthens the immune system
15. Ask your doctor about the best cancer-screening schedule for you. Treatment is most likely to be successful when detected early
16. If you notice changes in a mole's color, height, size, or shape, you should have a dermatologist (skin doctor) evaluate it
17. Risk of headaches are associated with inactivity, not enough water, overweight and not enough sleep
18. Critically evaluate online health information. Consider the source, author, and publication date. Focus on quality. Be skeptical
19. You burn more calories sleeping than you do watching television
20. Apples, not caffeine, are more efficient at waking you up in the morning
21. If you sprain your ankle you should: rest, elevate, ice, and support the ankle with a bandage or ace-wrap
22. Recent studies indicate flossing reduces the risk of a heart attack by preventing gum disease
23. Long-term use of air fresheners may contribute to indoor pollution, which can sometimes trigger asthma and other lung problems

24. Disinfect kitchen surfaces. The kitchen and counter tops are full of bacteria from food preparation.
25. Temperature can affect appetite. A cold person is more likely to eat more food
26. Weight gained after early 20s is linked to higher chances of heart disease, cancer, gallstones, asthma, snoring
27. Grilling meat can create cancer-causing chemicals. Coat it with a thick marinade to reduce the amount of such chemicals
28. Washing your hands after using a waterless hand sanitizer can strip lipids away and cause skin to become dry and crack
29. Milk's not the only drink that builds healthy bones. Tomato juice reduces the risk of bone loss too
30. Wear sunscreen. It prevents skin cancer and premature aging

Appendix C: Selected Data Collection Forms and Tools

Telephone Script

Directions: This interview will be conducted within 3 weeks of study completion

Focus: To assess participants perceived usefulness, attitudes, and experiences of participating in the study

Introduction:
Hello, this is Ryan Shaw calling from the Duke University School of Nursing in Durham, North Carolina. May I please speak to _____?
***If the participant is there continue with the script.
***If the participant is not there, ask when it would be a good time to speak with _____?

Describe the Reason for the Call:
(Example of phone call to potential participant)
We are calling to learn about your experiences with receiving the weight loss sustaining text messages.
Would you be willing to answer some questions regarding your experiences?
Please understand that your current or future medical care at Duke University or another facility will not be affected if you choose not to participate.
If no*: Thank them for their time*
If yes*: Review the purpose of the study and the types of questions that are going to be asked. Remind participants that they will receive $20 for completing the interview and that the interview is being audio-taped.*
Questions:
Perceived Usefulness/Quality of program delivery & treatment fidelity(Borrelli et al., 2005; Dane & Schneider, 1998; Resnick et al., 2005)
1. How useful did you find the text messages to be in helping you sustain your weight loss?
Probe: What about sustaining diet? Sustaining exercise? Sustaining monitoring?

Attitudes/Participant responsiveness & treatment fidelity related to receipt (Borrelli et al., 2005; Dane & Schneider, 1998; Resnick et al., 2005)
2. How do you feel about getting these weight loss sustaining messages?
3. Did you view the messages as promoting success or as preventing failure?
4. How much did you like the messages you read?
5. How did it make you feel to get these on your cell phone?
6. Did you have any problems with accessing or receiving the messages on your phone?
7. What worked for you?
8. What did not work for you?

Adherence to the program/dose of the program delivered(Borrelli et al., 2005; Dane & Schneider, 1998; Resnick et al., 2005)
9. How often did you read the messages?
10. Did you read them multiple times?
11. Are there times when you did not read the messages?
12. How do you feel about how often (frequency) you got the messages?
13. Did you share the messages?

Experiences/Participant responsiveness & treatment fidelity related to receipt(Borrelli et al., 2005; Dane & Schneider, 1998; Resnick et al., 2005)
14. What did you get out of participating in the study?
15. Can you tell me some positive things about the study?
16. Can you tell me some negative things about the study?
17. What changes would you make to this study?

Check for other ideas and suggestions overall
18. Would you recommend getting these messages to someone else?
19. Do you have any other suggestions or thoughts?

Field notes:
Record information describing the interview experience. Any impressions or events that occurred during the interview.

Closing
Thank you for participating in our research study. Please understand that your answers will remain confidential. Give them follow-up contact information such as the telephone number of the PI.

Attitudes and Behaviors toward SMS Weight Loss Scale

Adapted from Tsang et al. (2004)

1 = completely disagree, 3 = neutral (neither disagree nor agree), and 5 = completely agree.

1. I feel that receiving the text messages is enjoyable	1	2	3	4	5
2. I feel that receiving the text messages is pleasant	1	2	3	4	5
3. I feel that the text messages are a good source for timely information	1	2	3	4	5
4. The text messages provide the information I need to help sustain weight loss	1	2	3	4	5
5. I feel that the text messages are irritating	1	2	3	4	5
6. I feel that the text messages are too much	1	2	3	4	5
7. Content in the text messages are often annoying	1	2	3	4	5
8. I use the text messages as a reference for diet and exercise	1	2	3	4	5
9. I trust the text messages	1	2	3	4	5
10. Overall, I like the text messages	1	2	3	4	5

11. I am willing to receive weight loss sustaining text messages:
    1. Less than one message a day
    2. Two messages a day
    3. Three messages a day
    4. Over four messages a day

12. What do you do when you receive a weight loss sustaining text message?
    1. Ignore it completely
    2. Read it occasionally
    3. Read it after accumulating too many of them
    4. Read it when I get time
    5. Read it right away

13. How much do you read messages you received?
    1. Not at all
    2. Read about a quarter of a message
    3. Read about half of a message
    4. Read about three-quarters of a message
    5. Read the whole message

Appendix D: Recruitment Materials

Figure 5: Flyer

Sustaining Weight Loss Study

To learn more about this study, please contact:

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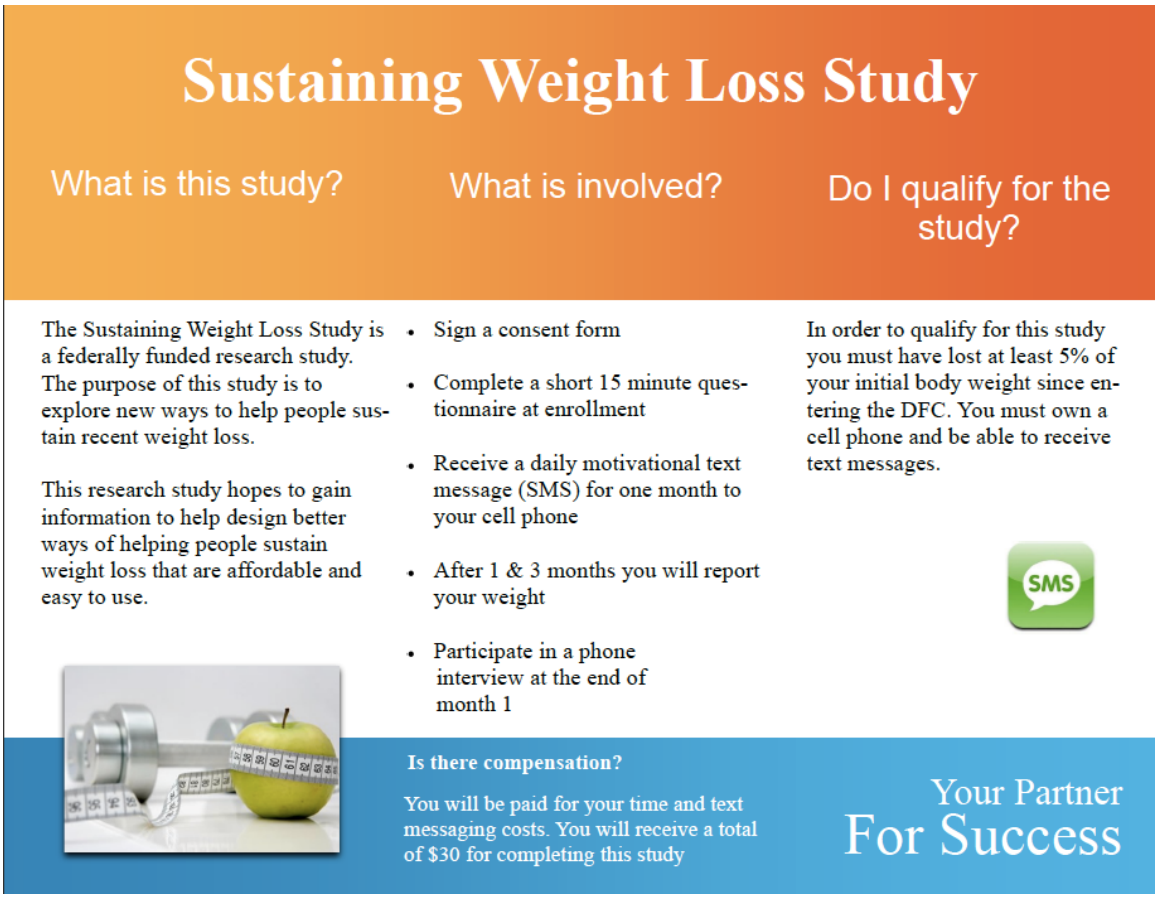

Figure 6: Brochure

References

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*, 179-211.

Albright, C. L., Pruitt, L., Castro, C., Gonzalez, A., Woo, S., & King, A. C. (2005). Modifying physical activity in a multiethnic sample of low-income women: one-year results from the IMPACT (Increasing Motivation for Physical ACTivity) project. *Ann Behav Med, 30*(3), 191-200. doi: 10.1207/s15324796abm3003_3

Anderson, L. H., Martinson, B. C., Crain, A. L., Pronk, N. P., Whitebird, R. R., O"Connor, P. J., & Fine, L. J. (2005). Health care charges associated with physical inactivity, overweight, and obesity. *Prev Chronic Dis, 2*(4), A09. doi: A09

Anderson, R. T., King, A., Stewart, A. L., Camacho, F., & Rejeski, W. J. (2005). Physical activity counseling in primary care and patient well-being: Do patients benefit? *Ann Behav Med, 30*(2), 146-154. doi: 10.1207/s15324796abm3002_7

Anhoj, J., & Moldrup, C. (2004). Feasibility of collecting diary data from asthma patients through mobile phones and SMS (short message service): response rate analysis and focus group evaluation from a pilot study. *J Med Internet Res, 6*(4), e42. doi: e4210.2196/jmir.6.4.e42

Atun, R., & Sittampalam, S. (2006). A review of the characteristics and benefits of SMS in delivering healthcare. The role of mobile phones in increasing accessibility and efficiency in healthcare report: Vodafone.

Baldwin, A. S., Rothman, A. J., Hertel, A. W., Linde, J. A., Jeffery, R. W., Finch, E. A., & Lando, H. A. (2006). Specifying the determinants of the initiation and maintenance of behavior change: an examination of self-efficacy, satisfaction, and smoking cessation. *Health Psychology, 25*(5), 626-634. doi: 10.1037/0278-6133.25.5.626

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliff, NJ: Prentice-Hall.

Bandura, A. (1991). Social cognitive theory of self-regulation. *Organizational Behavior and Human Decision Processes, 50*(248-287).

Bartholomew, L. K., Parcel, G. S., Kok, G., & Gottlieb, N. H. (2006). *Planning Health Promotion Programs: An Intervention Mapping Approach*. San Francisco: Jossey-Bass.

Bauer, S., de Niet, J., Tinman, R., & Kordy, H. (2010). Enhancement of care through self-monitoring and tailored feedback via text messaging and their use in the treatment of childhood overweight. *Patient Education and Counseling, 79*(3), 315-319. doi: 10.1016/j.pec.2010.03.014

Baum, J. G., Clark, H. B., & Sandler, J. (1991). Preventing relapse in obesity through posttreatment maintenance systems: Comparing the relative efficacy of two levels of therapist support. *Journal of Behavioral Medicine, 14*, 287-302.

Bellg, A. J., Resnick, B., Minicucci, D. S., Ogedegbe, G., Ernst, D., Borrelli, B., . . . Czajkowski, S. (2004). Enhancing treatment fidelity in health behaviors change studies: Best practices and recommendations from the NIH behavior change consortium. *Health Psychology, 23*(5), 443-451. doi: 10.1037/0278-6133.23.5.443

Benhamou, P. Y., Melki, V., Boizel, R., Perreal, F., Quesada, J. L., Bessieres-Lacombe, S., . . . Hanaire, H. (2007). One-year efficacy and safety of Web-based follow-up using cellular phone in type 1 diabetic patients under insulin pump therapy: the PumpNet study. *Diabetes Metab, 33*(3), 220-226. doi: S1262-3636(07)00058-4

Berlyne, D. E. (1970). Novelty, complexity, and hedonic value. *Perception and Psychophysics, 8*(5A), 279-286.

Bijnen, F. C., Caspersen, C. J., Feskens, E. J., Saris, W. H., Mosterd, W. L., & Kromhout, D. (1998). Physical activity and 10-year mortality from cardiovascular diseases and all causes: The Zutphen Elderly Study. *Arch Intern Med, 158*(14), 1499-1505.

Blanck, H. M., Dietz, W. H., Galuska, D. A., Gillespie, C., Hamre, R., Khan, L. K., . . . Densmore, D. (2006). State-specific prevalence of obesity among adults - United States, 2005. *MMWR CDC Surveillance Summaries, 55*(36), 985-988.

Borrelli, B., Sepinwall, D., Ernst, D., Bellg, A. J., Czajkowski, S., Breger, R., . . . Orwig, D. (2005). A new tool to assess treatment fidelity and evaluation of treatment fidelity across 10 years of health behavior research. *Journal of Consulting and Clinical Psychology, 73*(5), 852-860. doi: 2005-13740-008

Braunstein, J. W. (2007). How to Calculate Effect Size for Dissertation Students and Researchers Retrieved July 12, 2012, from http://www.researchconsultation.com/how-to-calculate-effect-size-help.asp

Bray, G. A. (2009). Behavioral treatment strategies for obesity management. *Review of Endocrinology*, 14-16.

Brendryen, H., Drozd, F., & Kraft, P. (2008). A digital smoking cessation program delivered through internet and cell phone without nicotine replacement (Happy Ending): randomized controlled trial. *Journal of Medical Internet Research, 10*(5). doi: 10.2196/jmir.1005

Brug, J., Oenema, A., & Ferreira, I. (2005). Theory, evidence and Intervention Mapping to improve behavior nutrition and physical activity interventions. *Int J Behav Nutr Phys Act, 2*(1), 2. doi: 1479-5868-2-2

Carver, C. S., & Scheier, M. (1996). Principles of self-regulation: Action and emotion. In E. T. Higgins & R. Sorrentino (Eds.), *Handbook of motivation and cognition: Foundations of social behavior* (Vol. 2, pp. 645-672). New York: Guilford Press.

Casey, R. G., Quinlan, M. R., Flynn, R., Grainger, R., McDermott, T. E., & Thornhill, J. A. (2007). Urology out-patient non-attenders: are we wasting our time? *Ir J Med Sci, 176*(4), 305-308. doi: 10.1007/s11845-007-0028-8

Cawley, J., & Meyerhoefer, C. (2012). The medical care costs of obesity: an instrumental variables approach. *Journal of Health Economics, 31*(1), 219-230. doi: 10.1016/j.jhealeco.2011.10.003

Centers for Disease Control and Prevention. (2009). Overweight and Obesity - Causes and Consequences Retrieved October 17, 2009, from http://www.cdc.gov/obesity/causes/index.html

Cesario, J., Grant, H., & Higgins, E. T. (2004). Regulatory fit and persuasion: transfer from "Feeling Right.". *Journal of Personality and Social Psychology, 86*(3), 388-404. doi: 10.1037/0022-3514.86.3.388

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Cole-Lewis, H., & Kershaw, T. (2010). Text messaging as a tool for behavior change in disease prevention and management. *Epidemiology Review, 32*(1), 56-59. doi: 10.1093/epirev/mxq004

Creswell, J. W. (2007). *Qualitative Inquiry & Research Design: Choosing Among Five Approaches* (2nd ed.). Thousan Oaks, CA: Sage Publications.

CTIA Wireless Association. (2009). CTIA Semi-Annual Wireless Industry Survey. Washington, DC.

Curry, S. J., & McBride, C. M. (1994). Relapse prevention for smoking cessation: review and evaluation of concepts and interventions. *Annual Review of Public Health, 15,* 345-366. doi: 10.1146/annurev.pu.15.050194.002021

Daddario, D. K. (2007). A review of the use of the health belief model for weight management. *Medsurg Nursing, 16*(6), 363-366.

Dane, A. V., & Schneider, B. H. (1998). Program integrity in primary and early secondary prevention: are implementation effects out of control? *Clinical Psychology Review, 18*(1), 23-45. doi: S0272-7358(97)00043-3

Diabetes Prevention Program Research Group. (2002). The diabetes prevention program (DPP): Description of lifestyle intervention. *Diabetes Care, 25*, 2165-2171.

Dijkstra, A., de Vries, H., & Roijackers, J. (1999). Targeting smokers with low readiness to change with tailored and nontailored self-help material. *Preventive Medicine, 28*(2), 203-211. doi: 10.1006/pmed.1998.0407

Donnelly, J. E., Blair, S. N., Jakicic, J. M., Manore, M. M., Rankin, J. W., & Smith, B. K. (2009). American College of Sports Medicine Position Stand. Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults. *Medicine and Science in Sports and Exercise, 41*(2), 459-471. doi: 10.1249/MSS.0b013e3181949333

dotMobi. (2012). Global mobile statistics 2012 Home: all the latest stats on mobile Web, apps, marketing, advertising, subscribers and trends... *Mobile Marketing Tools* Retrieved July 8, 2012, from http://mobithinking.com/mobile-marketing-tools/latest-mobile-stats - mobilemessaging

Dunbar, P. J., Madigan, D., Grohskopf, L. A., Revere, D., Woodward, J., Minstrell, J., . . . Hooton, T. M. (2003). A two-way messaging system to enhance antiretroviral adherence.
Journal of the American Medical Informatics Association, 10(1), 11-15.

Dunn, A. L., Marcus, B. H., Kampert, J. B., Garcia, M. E., Kohl, H. W., 3rd, & Blair, S. N. (1999). Comparison of lifestyle and structured interventions to increase physical activity and cardiorespiratory fitness: a randomized trial. *JAMA, 281*(4), 327-334.

Ferrer-Roca, O., Cardenas, A., Diaz-Cardama, A., & Pulido, P. (2004). Mobile phone text messaging in the management of diabetes. *Journal of Telemedicine and Telecare, 10*(5), 282-285.

Finch, E. A., Linde, J. A., Jeffery, R. W., Rothman, A. J., King, C. M., & Levy, R. L. (2005). The effects of outcome expectations and satisfaction on weight loss and maintenance: correlational and experimental analyses--a randomized trial. *Health Psychology, 24*(6), 608-616. doi: 10.1037/0278-6133.24.6.608

Finkelstein, E. A., Fiebelkorn, I. C., & Wang, G. (2004). State-level estimates of annual medical expenditures attributable to obesity. *Obesity Research, 12*(1), 18-24. doi: 10.1038/oby.2004.4

Fjeldsoe, B. S., Marshall, A. L., & Miller, Y. D. (2009). Behavior change interventions delivered by mobile telephone short-message service. *Am J Prev Med, 36*(2), 165-173. doi: S0749-3797(08)00892-1

Fjeldsoe, B. S., Miller, Y. D., & Marshall, A. L. (2010). MobileMums: a randomized controlled trial of an SMS-based physical activity intervention. *Annals of Behavioral Medicine, 39*(2), 101-111. doi: 10.1007/s12160-010-9170-z

Fogg, B., & Eckles, D. (2007). *Mobile persuasion: 20 perspectives on the future of behavior change*. Stanford, CA: Stanford Captology Media.

Fogg, B. J. (2003). *Persuasive technology: using computers to change what we think and do*. San Francisco, CA: Morgan Kaufmann.

Franklin, V. L., Waller, A., Pagliari, C., & Greene, S. A. (2006). A randomized controlled trial of Sweet Talk, a text-messaging system to support young people with diabetes. *Diabetic Medicine, 23*(12), 1332-1338. doi: 10.1111/j.1464-5491.2006.01989.x

Franz, M. J., VanWormer, J. J., Crain, A. L., Boucher, J. L., Histon, T., Caplan, W., . . . Pronk, N. P. (2007). Weight-loss outcomes: a systematic review and meta-analysis of weight-loss clinical trials with a minimum 1-year follow-up. *Journal of the American Dietetic Association, 107*(10), 1755-1767. doi: 10.1016/j.jada.2007.07.017

Fuglestad, P. T., Rothman, A. J., & Jeffery, R. W. (2008). Getting there and hanging on: the effect of regulatory focus on performance in smoking and weight loss interventions. *Health Psychology, 27*(3 Suppl), S260-270.

Fukuoka, Y., Vittinghoff, E., Jong, S. S., & Haskell, W. (2010). Innovation to motivation - pilot study of a mobile phone intervention to increase physical activity among sedentary women. *Preventive Medicine, 51*(3-4), 287-289. doi: 10.1016/j.ypmed.2010.06.006

Funk, K. L., Elmer, P. J., Stevens, V. J., Harsha, D. W., Craddick, S. R., Lin, P. H., . . . Appel, L. J. (2008). PREMIER--a trial of lifestyle interventions for blood pressure control: intervention design and rationale. *Health Promot Pract, 9*(3), 271-280. doi: 1524839906289035

Glanz, K., Rimer, B. K., & Su, S. M. (2005). Theory at a Glance A Guide for health Promotion Practice (2 ed.): National Cancer Institute.

Goggin, G. (2006). *Cell phone culture: Mobile technology in everyday life*. New York: Routledge.

Graneheim, U. H., & Lundman, B. (2004). Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. *Nurse Education Today, 24*(2), 105-112. doi: 10.1016/j.nedt.2003.10.001

Green, L. W., & Kreuter, M. W. (1999). *Health promotion planning: An educational and ecological approach*. Mountain View, CA: Mayfield.

Guh, D. P., Zhang, W., Bansback, N., Amarsi, Z., Birmingham, C. L., & Anis, A. H. (2009). The incidence of co-morbidities related to obesity and overweight: a systematic review and meta-analysis. *BMC Public Health, 9*, 88. doi: 1471-2458-9-88

Haapala, I., Barengo, N. C., Biggs, S., Surakka, L., & Manninen, P. (2009). Weight loss by mobile phone: a 1-year effectiveness study. *Public Health Nutr, 12*(12), 2382-2391. doi: 10.1017/S1368980009005230

Harris, P. A., Taylor, R., Thielke, R., Payne, J., Gonzalez, N., & Conde, J. G. (2009). Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform, 42*(2), 377-381. doi: 10.1016/j.jbi.2008.08.010

Harvey-Berino, J., Krukowski, R. A., Buzzell, P., Ogden, D., Skelly, J., & West, D. S. (2011). The accuracy of weight reported in a web-based obesity treatment program. *Telemed J E Health, 17*(9), 696-699. doi: 10.1089/tmj.2011.0032

Haskell, W. L., Lee, I. M., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A., . . . Bauman, A. (2007). Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc, 39*(8), 1423-1434. doi: 10.1249/mss.0b013e3180616b27

Higgins, E. T. (1987). Self-discrepancy: a theory relating self and affect. *Psychological Review, 94*(3), 319-340.

Higgins, E. T. (2000). Making a good decision: value from fit. *American Psychologist, 55*(11), 1217-1230.

Higgins, E. T., Friedman, R. S., Harlow, R. E., Idson, L. C., Ayduk, O. N., & Taylor, A. (2001). Achievement orientations from subjective histories of success: Promotion pride versus prevention pride. *European Journal of Social Psychology, 31*, 3-23.

Hollis, S., & Campbell, F. (1999). What is meant by intention to reat analysis? Survey of published randomised controlled trials. *BMJ, 319*, 670-674.

Hoque, N., McCusker, M., Murdock, S., & Perez, D. (2010). The Implications of Change in Population Size, Distribution, and Composition on the Number of Overweight and Obese Adults and the Direct and Indirect Cost Associated with Overweight and Obese Adults in Texas Through 2040. *Population Research and Policy Review, 29*(2), 173-191. doi: 10.1007/s11113-009-9135-8

Hurling, R., Catt, M., Boni, M. D., Fairley, B. W., Hurst, T., Murray, P., . . . Sodhi, J. S. (2007). Using Internet and mobile phone technology to deliver an automated

physical activity program: Randomized controlled trial. *Journal of Medical Internet Research, 9*(2), e7. doi: 10.2196/jmir.9.2.e7

International Telecommunications Union. (2011). The World in 2011: ICT Facts and Figures. Geneva, Switzerland.

Jackson, D. N. (1974). *The Personality Research Form*. Port Huron, MI: Research Psychologists Press.

Janz, N., & Becker, M. (1984). The health belief model: A decade later. *Health Education Quarterly, 11*, 1-47.

Jeffery, R. W., Bjornson-Benson, W. M., Rosenthal, B. S., Lindquist, R. A., Kurth, C. L., & Johnson, S. L. (1984). Correlates of weight loss and its maintenance over two years of follow-up among middle-ages men. *Preventive Medicine, 13*, 155-168.

Jeffery, R. W., Forster, J. L., French, S. A., Kelder, S. H., Lando, H. A., McGovern, P. G., . . . Baxter, J. E. (1993). The Healthy Worker Project: a work-site intervention for weight control and smoking cessation. *American Journal of Public Health, 83*(3), 395-401.

Joo, N. S., & Kim, B. T. (2007). Mobile phone short message service messaging for behaviour modification in a community-based weight control programme in Korea. *J Telemed Telecare, 13*(8), 416-420. doi: 10.1258/135763307783064331

Kant, A. K., Graubard, B. I., & Schatzkin, A. (2004). Dietary patterns predict mortality in a national cohort: the National Health Interview Surveys, 1987 and 1992. *Journal of Nutrition, 134*(7), 1793-1799.

Katzmarzyk, P. T., & Janssen, I. (2004). The economic costs associated with physical inactivity and obesity in Canada: an update. *Canadian Journal of Applied Physiology, 29*(1), 90-115.

Kim, Y. (2006). The Role of Regulatory Focus in Message Framing in Antismoking Advertisements for Adolescents. *Journal of Advertising, 35*(1), 143-151.

Klem, M. L., Wing, R. R., McGuire, M. T., Seagle, H. M., & Hill, J. O. (1997). A descriptive study of individuals successful at long-term maintenance of substantial weight loss. *American Journal of Clinical Nutrition, 66*(2), 239-246.

Kornman, K. P., Shrewbury, V. A., Chou, A. C., Nguyen, B., Lee, A., O'Connor, J., . . . Baur, L. A. (2010). Electronic therapeutic contact for adolescent weight managmeent: The Loozit study. *Telemedicine and e-Health, 16*(6), 1-8.

Kraemer, H. C., Wilson, G. T., Fairburn, C. G., & Agras, W. S. (2002). Mediators and moderators of treatment effects in randomized clinical trials. *Archives of General Psychiatry, 59*, 877-883.

Kramer, F. M., Jeffery, R. W., Forster, J. L., & Snell, M. K. (1989). Long-term follow-up of behavioural treatment for obesity: Patterns of weight gain among men and women. *International Journal of Obesity Related Metabolic Disorders, 13*, 124-136.

Kraschnewski, J. L., Boan, J., Esposito, J., Sherwood, N. E., Lehman, E. B., Kephart, D. K., & Sciamanna, C. N. (2010). Long-term weight loss maintenance in the United States. *Int J Obes (Lond)*. doi: ijo201094

Kreuter, M. W., Oswald, D. L., Bull, F. C., & Clark, E. M. (2000). Are tailored health education materials always more effective than non-tailored materials. *Health Education Research, 15*(3), 305-315.

Kreuter, M. W., & Wray, R. J. (2003). Tailored and targeted health communication: strategies for enhancing information relevance. *Am J Health Behav, 27 Suppl 3*(Suppl 3), S227-232.

Krishna, S., Boren, S. A., & Balas, E. A. (2009). Healthcare via cell phones: a systematic review. *Telemed J E Health, 15*(3), 231-240. doi: 10.1089/tmj.2008.0099

Latimer, A. E., Rivers, S. E., Rench, T. A., Katulak, N. A., Hicks, A., Hodorowski, J. K., . . . Salovey, P. (2008). A Field Experiment Testing the Utility of Regulatory Fit Messages for Promoting Physical Activity. *Journal of Experimental Social Psychology, 44*(3), 826-832. doi: 10.1016/j.jesp.2007.07.013

Lee, A. Y., & Aaker, J. L. (2004). Bringing the frame into focus: the influence of regulatory fit on processing fluency and persuasion. *Journal of Personality and Social Psychology, 86*(2), 205-218. doi: 10.1037/0022-3514.86.2.205

Lee, I. M., & Skerrett, P. J. (2001). Physical activity and all-cause mortality: what is the dose-response relation? *Medicine and Science in Sports and Exercise, 33*(6 Suppl), S459-471; discussion S493-454.

Leventhal, H., Benyamini, Y., & Brownlee, S. (1997). Illness representations: Theoretical foundations. In K. J. Petrie & J. A. Weinman (Eds.), *Perceptions of Health and Illness*. Amsterdam: Harwood.

Leventhal, H., & Cameron, L. (1987). Behavioral theories and the problem of compliance. *Patient Education and Counseling, 10*, 117-138.

Lim, M. S., Hocking, J. S., Hellard, M. E., & Aitken, C. K. (2008). SMS STI: a review of the uses of mobile phone text messaging in sexual health. *International Journal of STD and AIDS, 19*(5), 287-290. doi: 10.1258/ijsa.2007.007264

Lin, P. H., Appel, L. J., Funk, K., Craddick, S., Chen, C., Elmer, P., . . . Champagne, C. (2007). The PREMIER intervention helps participants follow the Dietary Approaches to Stop Hypertension dietary pattern and the current Dietary Reference Intakes recommendations. *J Am Diet Assoc, 107*(9), 1541-1551. doi: S0002-8223(07)01363-6

Ling, R. (2004). *The mobile connection: The cell phone's impact on society*. San Francisco: Morgan Kaufmann Publishers.

MacLean, P. S., Higgins, J. A., Wyatt, H. R., Melanson, E. L., Johnson, G. C., Jackman, M. R., . . . Hill, J. O. (2009). Regular exercise attenuates the metabolic drive to regain weight after long-term weight loss. *Am J Physiol Regul Integr Comp Physiol, 297*(3), R793-802. doi: 10.1152/ajpregu.00192.2009

Marcus, B. H., Lewis, B. A., Williams, D. M., Dunsiger, S., Jakicic, J. M., Whiteley, J. A., . . . Parisi, A. F. (2007). A comparison of Internet and print-based physical activity interventions. *Arch Intern Med, 167*(9), 944-949. doi: 167/9/944

Marcus, B. H., Napolitano, M. A., King, A. C., Lewis, B. A., Whiteley, J. A., Albrecht, A., . . . Papandonatos, G. D. (2007). Telephone versus print delivery of an individualized motivationally tailored physical activity intervention: Project STRIDE. *Health Psychol, 26*(4), 401-409. doi: 2007-09406-003

McGraa, K. L. (2010). *The effects of persuasive motivational text messaging on adherence to diet and exercise programs across different personality traits* (PhD), Fielding Graduate University. (3409401)

Morak, J., Schindler, K., Goerzer, E., Kastner, P., Toplak, H., Ludvik, B., & Schreier, G. (2008). A pilot study of mobile phone-based therapy for obese patients. *Journal of Telemedicine and Telecare, 14*(3), 147-149. doi: 10.1258/jtt.2008.003015

National Center for Chronic Disease Prevention and Health Promotion. (2009). OBESITY Halting the Epidemic by Making Health Easier Retrieved October 17, 2009, from http://www.cdc.gov/NCCdphp/publications/AAG/obesity.htm

National Center for Health Statistics. (2009). Health, United States, 2008 With Chartbook. Hyattsville, MD: Centers for Disease Control and Prevention.

National Heart Lung and Blood Institute, & National Institute of Diabetes and Digestive Kidney Diseases. (1998). Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: National Institute of Health.

National Institute of Diabetes and Digestive and Kidney Diseases. (2003). Physical Activity and Weight Control. Bethesda Maryland: National Institute of Health.

Neuendorf, K. A. (2002). *The Content Analysis Guidebook*. Thousand Oaks, CA: Sage Publications.

Newton, K. H., Wiltshire, E. J., & Elley, C. R. (2009). Pedometers and text messaging to increase physical activity: randomized controlled trial of adolescents with type 1 diabetes.
Diabetes Care, 32(5), 813-815. doi: 10.2337/dc08-1974

NIH Office of Behavioral and Social Sciences Research. (2011). mHealth Retrieved September 22, 2011, from http://obssr.od.nih.gov

Norman, G. J., Zabinski, M. F., Adams, M. A., Rosenberg, D. E., Yaroch, A. L., & Atienza, A. A. (2007). A review of eHealth interventions for physical activity and dietary behavior change. *American Journal of Preventive Medicine, 33*(4), 336-345. doi: 10.1016/j.amepre.2007.05.007

Nunnally, J. (1978). *Psychometric Theory*. New York: McGraw-Hill.

Obesity in America. (2009). Understanding Obesity Retrieved December 19, 2009, from http://www.obesityinamerica.org/understandingObesity/index.cfm

Pak Hei, B., & Chou, A. W. (2005). From cues to action: Information seeking and exercise self-care among older adults managing chronic illness. *Canadian Journal on Aging, 24*(4), 395-408.

Paluska, S. A., & Schwenk, T. L. (2000). Physical activity and mental health: current concepts. *Sports Medicine, 29*(3), 167-180.

Park, M. J., Kim, H. S., & Kim, K. S. (2009). Cellular phone and Internet-based individual intervention on blood pressure and obesity in obese patients with hypertension. *Int J Med Inform, 78*(10), 704-710. doi: 10.1016/j.ijmedinf.2009.06.004

Patrick, K., Griswold, W. G., Raab, F., & Intille, S. S. (2008). Health and the mobile phone.
American Journal of Preventive Medicine, 35(2), 177-181. doi: 10.1016/j.amepre.2008.05.001

Patrick, K., Raab, F., Adams, M. A., Dillon, L., Zabinski, M., Rock, C. L., . . . Norman, G. J. (2009). A text message-based intervention for weight loss: randomized controlled trial.
J Med Internet Res, 11(1), e1. doi: 10.2196/jmir.1100

Perkins, A. J., & Clark, D. O. (2001). Assessing the association of walking with health services use and costs among socioeconomically disadvantaged older adults. *Prev Med, 32*(6), 492-501. doi: 10.1006/pmed.2001.0832

Perri, M. G. (1998). The maintenance of treatment effects in the long-term management of obesity. *Clinical Psychology: Science and Practice, 5*, 526-543.

Perri, M. G., & Corsica, J. A. (2002). Improving the maintenance of weight loss in behavioral treatment of obesity. In T. A. Wadden & A. J. Stunkard (Eds.), *Handbook of Obesity Treatment* (pp. 357-359). New York, NY: Guilford Press.

Perri, M. G., Nezu, A. M., Patti, E. T., & McCann, K. L. (1989). Effect of length of treatment on weight loss. *Journal of Consulting and Clinical Psychology, 57*(3), 450-452.

Petty, R. E., & Cacioppo, J. T. (1986). The elaboration likelihood model of persuasion. *Advances in Experimental Social Psychology, 19*, 123-162.

Pi-Sunyer, X., Blackburn, G., Brancati, F. L., Bray, G. A., Bright, R., Clark, J. M., . . . Yanovski, S. Z. (2007). Reduction in weight and cardiovascular disease risk factors in individuals with type 2 diabetes: one-year results of the look AHEAD trial. *Diabetes Care, 30*(6), 1374-1383. doi: 10.2337/dc07-0048

Polit, D. F., & Beck, C. T. (2004). *Nursing research: Principles and methods* (7th ed.). Philadelphia: Lippincott Williams & Wilkins.

Polit, D. F., & Gillespie, B. M. (2009). The use of the intention-to-treat principle in nursing clinical trials. *Nursing Research, 58*(6), 391-399. doi: 10.1097/NNR.0b013e3181bf1505

Portnoy, D. B., Scott-Sheldon, L. A., Johnson, B. T., & Carey, M. P. (2009). Computer-delivered interventions for health promotion and behavioral risk reduction: A meta-analysis of 75 randomized controlled trials, 1988-2007. *Preventive Medicine, 47*(1), 3-16. doi: 10.1016/j.ypmed.2008.02.014

Prestwich, A., Perugini, M., & Hurling, R. (2010). Can implementation intentions and text messages promote brisk walking? A randomized trial. *Health Psychology, 29*(1), 40-49. doi: 10.1037/a0016993

Prochaska, J. O., & Velicer, W. F. (1997). The transtheoretical model of health behavior change.
American Journal of Health Promotion, 12(1), 38-48.

Pronk, N. P., & Wing, R. R. (1994). Physical activity and long-term maintenance of weight loss.
Obesity Research, 2(6), 587-599.

Resnick, B., Inguito, P., Orwig, D., Yahiro, J. Y., Hawkes, W., Werner, M., . . . Magaziner, J. (2005). Treatment fidelity in behavior change research: a case example. *Nursing Research, 54*(2), 139-143. doi: 00006199-200503000-00010

Reuters. (2003). CDC chief: Obesity top health threat Retrieved December 19, 2009, from http://www.cnn.com/2003/HEALTH/diet.fitness/10/29/obesity.threat.reut/index.html

Rice, R., & Katz, J. (2003). Comparing Internet and mobile phone usage: Digital divides of usage, adoption and dropouts. *Telecommunications policy, 27*, 297-623.

Riley, W., Obermayer, J., & Jean-Mary, J. (2008). Internet and mobile phone text messaging intervention for college smokers. *Journal of American College Health, 57*(2), 245-248. doi: R4883H2681063U21

Roland, M., & Torgerson, D. J. (1998). What are pragmatic trials? *BMJ, 316*(7127), 285.

Rosenstock, I. M., Strecher, V. J., & Becker, M. H. (1988). Social learning theory and the health belief model. *Health Education Quarterly, 15*, 175-183.

Rothman, A. J. (2000). Toward a theory-based analysis of behavioral maintenance. *Health Psychology, 19*(1 Suppl), 64-69.

Rothman, A. J., Baldwin, A. S., Hertel, A. W., & Fuglestad, P. T. (2004). Self-regulation and behavior change: Disentangling behavioral initiation and behavioral maintenance. In K. Vohs & R. Baumeister (Eds.), *The handbook of self-regulation research: Research, theory and applications* (pp. 130-148). New York, NY: Guilford.

Rothman, A. J., Hertel, A. W., Baldwin, A. S., & Bartels, R. (2007). Integrating theory and practice: Understanding the determinants of health behavior change. In J. Shah & W. Gardner (Eds.), *Handbook of Motivation Science* (pp. 494-507). New York, NY: Guilford Press.

Sandelowski, M. (1995). What it is and how to begin. *Research in Nursing and Health, 18*(4), 371-375.

Scarborough Research. (2008). El Paso, Salt Lake City, Dallas and Memphis are the top text messaging markets in the U.S. New York: Scarborough Research.

Schoeller, D. A., Shay, K., & Kushner, R. F. (1997). How much physical activity is needed to minimize weight gain in previously obese women? *American Journal of Clinical Nutrition, 66*, 551-556.

Shapiro, J. R., Bauer, S., Hamer, R. M., Kordy, H., Ward, D., & Bulik, C. M. (2008). Use of text messaging for monitoring sugar-sweetened beverages, physical activity, and screen time in children: a pilot study. *J Nutr Educ Behav, 40*(6), 385-391. doi: S1499-4046(07)00995-5

Shaw, R. J., & Bosworth, H. B. (in press). Short Message Service (SMS) Text Messaging as an Intervention Medium for Weight Loss: A Literature Review. *Health Informatics Journal*.

Simon, G. E., Von Korff, M., Saunders, K., Miglioretti, D. L., Crane, P. K., va Belle, G., & Kessler, R. C. (2006). Association between obesity and psychiatric disorders in the US adult population. *Archives of General Psychiatry, 63*, 824-830. doi: 10.1001/archpsyc.63.7.824

Singh, M. A. (2002). Exercise to prevent and treat functional disability. *Clinics in Geriatric Medicine, 18*(3), 431-462, vi-vii.

Sirriyeh, R., Lawton, R., & Ward, J. (2010). Physical activity and adolescents: an exploratory randomized controlled trial investigating the influence of affective and instrumental text messages. *Br J Health Psychol, 15*(Pt 4), 825-840. doi: 10.1348/135910710X486889

Soares, I., & Carneiro, A. V. (2002). Intention-to-treat analysis in clinical trials: principles and practical importance. *Revista Portuguesa de Cardiologia, 21*(10), 1191-1198.

Spiegel, S., Grant-Pillow, H., & Higgins, E. T. (2004). How regulatory fit enhances motivational strength during goal pursuit. *European Journal of Social Psychology, 34*, 39-54.

Svetkey, L. (2010). Cell Phone Intervention in Young Adults (CITY). Duke University: National Heart, Lung, and Blood Institute.

Toobert, D. J., Strycker, L. A., Barrera, M., & Glasgow, R. E. (2010). Seven-year follow-up of a multiple-health-behavior diabetes intervention. *Am J Health Behav, 34*(6), 680-694. doi: 10.5555/ajhb.2010.34.6.680

Tsang, M. M., Ho, S., & Liang, T. (2004). Consumer attitudes toward mobile advertising: An empirical study. *International Journal of Electronic Commerce, 8*(3), 65-78.

U.S. Department of Health and Human Services and U.S. Department of Agriculture. (2005). Dietary Guidelines for Americans (6 ed.). Washington, DC.

Wadden, T. A., & Frey, D. L. (1997). A multicenter evaluation of a proprietary weight loss program for the treatment of marked obesity: A five-year follow-up. *International Journal of Obesity Related Metabolic Disorders, 22*, 203-212.

Wadden, T. A., & Letizia, K. A. (1992). Predictors of attrition and weight loss in patients treated by moderate and severe caloric restriction. In T. A. Wadden & T. B. Itallie (Eds.), *Treatment of the seriously obese patient* (pp. 383-410). New York: Guilford.

Wadden, T. A., Sternberg, J. A., Letizia, K. A., Stunkard, A. J., & Foster, G. D. (1989). Treatment of obesity by very low calories diet, behavior therapy, and their

combination: A five-year perspective. *International Journal of Obesity Related Metabolic Disorders, 13*, 39-46.

Wang, G., Helmick, C. G., Macera, C., Zhang, P., & Pratt, M. (2001). Inactivity-Associated medical costs among US adults with arthritis. *Arthritis and Rheumatism, 45*(5), 439-445.

Wang, Y., & Beydoun, M. A. (2007). The obesity epidemic in the United States--gender, age, socioeconomic, racial/ethnic, and geographic characteristics: a systematic review and meta-regression analysis. *Epidemiologic Reviews, 29*, 6-28. doi: mxm007

Warwick, Z., Dean, G., & Carter, P. (2007). B safe, B sorted: results of a hepatitis B vaccination outreach programme. *Int J STD AIDS, 18*(5), 335-337. doi: 10.1258/095646207780749673

Weight-control Information Network. (2010). Overweight and Obesity Statistics (pp. 7): National Institute of Diabetes and Digestive and Kidney Diseases.

Weinstein, N. D. (1993). Testing for competing theories of health-protective behavior. *Health Psychology, 12*, 324-333.

Wing, R. R., & Hill, J. O. (2001). Successful weight loss maintenance. *Annual Review of Nutrition, 21*, 323-341. doi: 10.1146/annurev.nutr.21.1.323

Wing, R. R., & Phelan, S. (2005). Long-term weight loss maintenance. *American Journal of Clinical Nutrition, 82*(1 Suppl), 222S-225S. doi: 82/1/222S

Yancy, W. S., & Boan, J. (2006). Adherence to diet recommendations. In H. B. Bosworth, E. Z. Oddone & M. Weinberger (Eds.), *Patient treatment adherence concepts, interventions, and measurements* (pp. 95-124). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Zuercher, J. L. (2009). *Developing strategies for helping women improve weight-related health behaviors.* (PhD), University of North Carolina at Chapel Hill, Chapel Hill. (49990873)

Biography

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