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Mobile Health Interventions for Adult Obesity in the United States: Analysis of Effectiveness and Efficacy

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ABSTRACT
The Unites States continues to struggle with the negative health effects associated with increasing population obesity, a problem which has historically difficult, if not impossible, to solve. Mobile health applications represent a potential partial solution to this problem. We examine the existing literature on the effects of mobile health applications on body weight, waist circumference, BMI, and lifestyle, examining both physical findings as well as adherence, satisfaction and cost effectiveness. The use of mobile for weight reduction looks promising, but evidence is mixed, which is not surprising given the rapidly evolving nature of the mobile application field.

Keywords
Obesity, mobile technology

1 INTRODUCTION

Obesity, a significant health problem in the United States, has become an epidemic (Ogden et al., 2014). In 2014, the incidence of adult obesity exceeded 35% in three states (Arkansas, West Virginia, and Mississippi) with levels above 20% in the remaining states (State of Obesity, 2015). The number of obese people in the US is expected to continue to escalate for some time: around 65 million more adults will be obese in 2030 (Wang et al., 2011).

Obese individuals – those with Body Mass Index (BMI) $\geq$ 30 kg/m² (WHO, 2015) - are at a higher risk of developing serious health issues such as diabetes, cardiovascular diseases and endometrial cancer, thereby leading to high rates of morbidity and mortality (Akholkar and Gandhi, 2015; Apovian and Gokce, 2012). This obesity-related increase in morbidity and mortality has contributed to a substantial rise in healthcare costs (Withrow and Alter, 2011). An analysis of the trend in healthcare spending predicted an inflation of $22-66 million in healthcare expenses in the U.S. by 2030, with obesity being a key risk factor for the diseases that were major contributors of this increased cost burden (Wang et al., 2011).

Three factors have substantially influenced development of obesity: behavioral, environmental and genetic factors (Marti, Martinez-González and Martinez, 2008; Genoni et al., 2014). The National Heart, Lung, and Blood Institute (NHLBI) (2012) noted an association between energy imbalance and excessive caloric intake (especially of low-nutrition foods) and insufficient physical activity; current health status, stress levels and medication were also indicated as influencing the development of obesity.

Different type of behavioral interventions such as diet monitoring, exercise programs, and counselling have resulted in a clinically significant weight loss in obese people (Wing and Phelan, 2005). However, long term adherence to lifestyle modifications have often been quite expensive, time consuming, and challenging (Henry, Chilton and Garvey, 2013).

Incorporation of technology in the healthcare field has offered the potential for improvement in quality and efficiency as well as reduction of associated costs (Chaudhry et al., 2006; Kane, 2014). The utilization of technological tools such as the internet and mobile devices (e.g., Smartphones, iPads) has been rapidly expanding in the field of technology-based behavioral interventions designed to address specific medical issues. The uses of these devices in behavioral interventions have ranged from simple reminder text messages to software application support (Dallery, Cassid and Raiff, 2013).

Intervention programs featuring mobile-based technology (mhealth) have increasingly been used to manage obesity (Coons et al., 2012). Such platforms are attractive because they are flexible (portable), cost effective and accessible (Handel, 2011). Technologies like mhealth could transform interventions targeted at preventing or managing obesity from the current physician- and hospital-based interventions to self-care in the community, which involves self-monitoring of lifestyle modifications (Bacigalupo et al., 2013).

The technological competencies of mobile technologies have steadily developed over time. Because these technologies permitted relatively effortless dissemination of information on a large scale to a huge population, they tend to be cost effective (Epstein and Bequette, 2013); e.g., providing e-mail counselling and motivation for the purpose of weight loss has been shown to radically decrease service costs when compared to face-to-face counseling. (Raaijmakers et al., 2015) and Short Message Services (SMS) has grown in popularity as a way to deliver health information mainly due to its low cost and simplicity (Shaw and Bosworth, 2012).

Smartphones have begun to incorporate functionalities of other mobile technologies such as pagers, cell phones and PDAs, which explains why they have become extremely popular among healthcare professionals as well as the general public (Wu et al., 2010). In 2015, 64% of American adults owned a smartphone, and 62% of smartphone owners had used their phone in the past year to look up information about a health condition (Pew Research Center, 2015). Smartphone technology is now becoming more widely utilized for the prevention and control of obesity, with different type of Smartphone applications already developed and put into use in obesity management (Breton, Fuemmeler and Abroms, 2011).

The novel and more effective curative and preventive approaches include Smartphone features such as Global Positioning System (GPS), movement sensor, microphones, cameras and web connectivity (Wolfenden, Brennan and Britton, 2010). These features have the potential to be used in different ways in efforts to lose weight; e.g., smartphone software could utilize motion sensors and GPS to create maps of exercise routes and provide users with real-time feedback regarding movement speed, step counts, energy expenditure and the completion of exercise goals. In addition, smartphone cameras could recognize foods and calculate the calorie content of a meal automatically from images or videos with few human interventions (Wolfenden, Brennan, and Britton, 2010).

Thus, an exciting opportunity to deliver obesity interventions remotely has been proffered by mobile technology (Klasnja and Pratt, 2012). However, the question of whether such interventions are effective and worthwhile in comparison to the conventional practices with respect to costs has been raised, making assessment of their efficacy and cost-effectiveness crucial.

2 RESULTS

Mobile Interventions for Obesity: Effect on Body Weight

Effect on body weight was measured in several different forms, depending on the study. Some used weight loss in kgs or lbs; others used change in BMI in kg/m^2 or change in waist circumference in cm. Weight loss was often measured both at baseline and at post-intervention, either by study staff alone or self-reported by subjects supplemented with study staff measurement.

Results of studies examining the effects of mobile phone interventions on body weight changes were mixed, with Allen et al. (2013), Steinberg et al. (2013), Thomas and Wing (2013). Sze et al. (2015) and Willey and Walsh (2016) reporting statistically significant effects, while Norman et al. (2012) and Shapiro et al. (2012) reporting no statistically significant findings. For these studies, weight loss in active treatment groups ranged from 1.3 kg to 10.9 kg and from −1.1 kg to 2.4 kg in control groups. Steinberg et al. (2012), for example, used a smartphone-enabled scale for daily weighing, with a web-based weight loss graph and weekly emails with tailored feedback and lessons. This Weighing Everyday to Improve and Gain Health (WEIGH) study found a significant improvement in the interventional group compared to the control group.

Out of the four interventions employing mobile devices other than mobile phones, two had significant findings favoring the intervention. Spring et al. (2013) found that subjects at 12 months had lost 6.3 lbs. with use of PDAs for weight self-monitoring while the control group lost 0.05 lbs and Archer et al. (2012) found significant within-group weight reductions compared to baseline in three intervention groups at nine months, with mean weight loss of 1.9 kg in the Group Weight-Loss education group, 3.6 kg in Sense Wear Armband and 6.6 kg in the armband in combination with group weight-loss education. Turner-McGrievy and Tate (2011) and Burke et al. (2012) did not find significant between-group differences.

Mobile Interventions for Obesity: Effect on Waist Circumference

Significant reductions in waist circumference favoring the mobile device intervention groups were found in three studies (Allen et al., 2013; Burke et al., 2012; Willey and Walsh, 2016). In the Smart coach for Lifestyle Management (SLIM) trial, Allen et al. (2013) observed that waist circumference was reduced 7.0 cm in males and 5.7 cm in females in the Intensive Counselling with Smart Phone group, 6.5 cm in males and 3.6 cm in females in the Low Intensity Counselling with Smart Phone group, and 3.4 cm in males and 0.89 cm in females in the Smart Phone only group, with the control group showing waist circumference reductions of 3.0 cm in males and 3.2 cm in females.

During the Self-monitoring and Recording using Technology (SMART) trial (Burke et al., 2012), the highest percentage reduction of waist circumference occurred in the PDA with feedback group (PDAFB), 6.4%, while in the PDA only and control groups waist circumference reduced by 5.0% and 4.0%, respectively. The intervention group using the YouPlus mobile app reduced their mean waist circumference by 7.7 cm or 6.6% (Willey and Walsh, 2016).

Mobile Interventions for Obesity: Effect on BMI

Of the three trials that measured BMI, two documented significant reductions. Turner-McGrievy and Tate (2011) reported that the treatment group reduced BMI by 1.0 kg/m^2, while the controls reduced it only by 0.1 kg/m^2. In the SLIM trial, a BMI reduction of 1.4 kg/m^2 in the intensive counseling intervention group, 1.3 kg/m^2 in the intensive counseling plus smartphone intervention and smartphone intervention only groups, 2 kg/m^2 in the intensive counseling plus smartphone intervention group was reported (Allen et al., 2013).

Sze et al. (2015), in a pilot study, demonstrated no statistically significant difference in BMI reduction for either adults or children, although both groups found the web-based system to be useful, helpful and easy to use.

Mobile Interventions for Obesity: Effect on Lifestyle Behavior

Change in Dietary Behavior

Three studies measured changes in fruit and vegetable intake (Allen et al., 2013; Norman et al., 2012; Turner-McGrievy and Tate). Turner-McGrievy and Tate (2011) found an increase in levels of daily fruit intake by 0.4 points and vegetable intake by 0.2 points on the Prime Screen Questionnaire in the experimental subjects in the enhanced podcast group relative to baseline levels. Their control group increased their fruit intake by 0.01 and decreased vegetable intake by 0.2 points. Allen et al. (2013) found that fruits and vegetables servings increased in all groups except for a slight decrease in smartphone only group in the SLIM study. In the Mobile Diet Intervention through Electronic Technology (mDiet) study, an increase by two servings in the fruit and vegetable intake was observed (Norman et al., 2012).

Changes in eating behavior were examined in four studies (Gilliland et al., 2015; Norman et al., 2012; Turner-McGrievy and Tate, 2011; Sze et al., 2015). Based upon a six-month intervention in which the experimental group received 2-5 weight management text-messages/day compared to the usual-care comparison group, with 3 24-hour recalls assessing fruit/vegetable intake change and the eating behavior inventory (EBI) measuring change in eating behaviors, Norman et al. (2012) concluded that moderate short-term weight loss was achieved by sending text-messages which promoted healthy eating strategies. In contrast, the study conducted by Turner-McGrievy and Tate (2011) using Podcast-only or Podcast+Mobile groups, both of which were instructed to use a diet and physical activity monitoring application (app) on their mobile device and to interact with study counselors and other participants on Twitter, no significant difference was found in weight loss between the two groups.

A smartphone app intervention tool (SMARTAPPetite) targeted change in eating behavior as a primary outcome in a quasi-experimental study by Gilliland et al. (2015), who found a strong association between program participation and improvements in healthy eating. However, no direct effect was found on the consumption of healthy foods. Sze et al. (2015), using a Web-based system accessible by mobile devices, determined that change in eating behavior favored the intervention group, but the changes were not statistically significant.

Changes in daily caloric intake were measured in several studies, but results were not statistically significant. Decreases of 415.6, 468.2, 218.5, 249.2 kcal/day in caloric intake in the intensive counseling intervention, intensive counseling plus smartphone intervention, a less intensive counseling plus smartphone intervention and smartphone intervention only groups, respectively, were demonstrated in the SLIM trial (Allen et al., 2013). Although none of their outcome measures was significantly significant, Allen et al. (2013) concluded that the results of their pilot trial provided preliminary support for using a smartphone application for self-monitoring as an adjunct to behavioral counseling. The MAMRT trial found larger reductions in energy intake of 455.6 kcal/day versus 382.4 kcal/day for EFT vs control (Sze et al., 2015), and Turner-McGrievy and Tate (2011) reported reductions in daily caloric intake that did not reach statistical significance.

Change in Physical Activity

In five out of eight studies, physical activity levels increased in the mobile device intervention groups relative to the control groups.

Assessment of physical activity by recording step counts was done by Shapiro et al. (2012). Compared to the controls (which received only monthly newsletters), the experimental group receiving daily interactive SMS and MMS was found to have increased step by almost 3000 steps per day, and higher step counts were associated with greater weight loss ($p<.05$). Although no group differences in weight loss were found over 6 or 12 month time periods, the authors noted improvement in weight-related behaviors and weight outcomes. Fukuoka et al. (2010) reported an average daily total steps increased by approximately 800 or 15% over three weeks while study participants were encouraged daily by the mobile phone to increase steps by 20% from the previous week.

In a study over a much shorter time period (6 weeks) that evaluated effects of thrice weekly text messaging to older African-American adults, small improvements in daily step count and changes in results of the Leisure Time Exercise Questionnaire (a measure of perceived physical activity) were seen in the experimental group and control group respectively (Kim and Glanz, 2013). Both of these between-group differences were statistically significant.

Bond et al. (2014) tested a smartphone-based intervention to monitor excessive sedentary time (SED), a surrogate measure for obesity, in overweight/obese individuals. Thirty subjects wore the SenseWear Mini Armband to measure SED objectively for 7 days at baseline. Participants were then presented with 3 smartphone-based physical activity break conditions: a 3-min break after 30 SED min, a 6-min break after 60 SED min and a 12-min break after 120 SED min. All physical activity break conditions yielded significant decreases in SED and increases in light and moderate-to-vigorous physical activity ($p<0.005$), but the 3-min condition was superior to the 12-min condition in decreasing SED and increasing light physical activity ($p<0.05$).

King et al. (2013) developed and tested three types (social, analytic and affect) of mobile applications in a randomized clinical trial. Participants across all three apps reported significant mean increases in weekly minutes of brisk walking across the 8-week intervention period ($p< 0 .0001$) and significant decreases in the daily amount of discretionary time spent viewing television ($p<0.02$). All three apps were found to be generally easy to use and acceptable by the participants, who had no prior experience with smartphones.

In three studies conducted by Allen et al. (2013), Napolitano et al. (2013) and Turner-McGrievy and Tate (2011), change in physical activity was insignificant.

Mobile Interventions for Obesity: Effect on Adherence and Satisfaction

Program adherence was measured in ten studies, each of which recorded greater adherence levels in the intervention group compared to the control group. In four of these studies, a greater adherence was significantly associated with greater weight loss. Adherence in the intervention groups ranged from 60-85%. Rabin et al. (2011) specifically examined impact of three mobile apps on adherence and satisfaction and observed that participants found all apps easy to use and somewhat helpful with an above average level of satisfaction. In another study although a difference was noticed, it did not reach statistical significance (Willey and Walsh, 2016). Additionally, one study reported increased self-weighing frequencies for the patients when compared to controls (Svetky et al., 2015).

Mobile Interventions for Obesity: Cost Effectiveness

Only one study evaluated cost-effectiveness of Sense Wear armband, a mobile armband device that can be used to provide weight loss intervention (Archer et al., 2012), concluding that the technology-based approaches were more cost effective and efficacious than traditional approaches in promoting weight loss via lifestyle changes in sedentary, overweight, and obese adults.

In another study, technological components of weight management programs such as SMS, websites, and smartphone apps were reviewed. Four apps (FitBit, iStepLog, My Meal Mate and Weight Watchers Mobile) out of the 22 included in the analysis had data on their efficacy. All of these four apps were downloadable for free (Gilmore et al., 2014).

In the Text4Diet trial conducted by the Shapiro et al. (2012), overweight and obese adults were randomized to receive daily interactive and personally weight-relevant text-messages or monthly e-newsletters. Examination of participants' willingness to pay for the intervention found that 89% were willing to pay $4.99 per month. SMS cost of average 10¢ per message was extremely affordable (Shaw, 2012).

Relatively low execution costs were reported for MAMRT despite its numerous components, as additional user creation (participants/investigators) and the supporting software (MySQL and Audacity) used were free. As the MAMRT was not limited to any specific device, participants were able to use the system at no extra cost. (Sze et al., 2015).

In the SLIM trial, the authors stated that face-to-face counselling supplemented with smartphone technology for self-monitoring was cost-effective, noting weight loss levels comparable to intensive counselling plus smartphone group in the less intensive counseling plus smartphone group (Allen et al., 2013).

3 DISCUSSION

This literature review summarizes the results of published studies utilizing mobile technology directed at overweight and/or obese populations with regard to their efficacy and cost-effectiveness. There was consistent evidence suggesting that mobile-based technological interventions were often efficacious in leading to changes in weight, BMI, waist circumference and lifestyle behavior. Clinically significant weight loss was achieved in the mobile intervention groups across most studies. All three studies tracking waist circumference of the subjects showed a decline in waist circumference favoring the mobile device intervention groups. A majority of trials also noted BMI reductions in the intervention groups.

Primarily, lifestyle behaviors were targeted. The interventions measuring changes in dietary intake and dietary behavior revealed an increase in fruit and vegetable intake and positive changes in eating behavior in all subjects in the treatment groups. Overall, 80% of the studies that investigated caloric intake demonstrated a decrease in daily caloric intake. Increases in physical activity in the form of daily steps and exercise ranging from low to vigorous in intensity were observed in more than half of the studies.

Among the studies reviewed, there was limited discussion or evaluation on the cost-effectiveness. However, the findings of the only study that conducted an economic evaluation of mobile device based interventions used in obesity implied that the estimated costs per participant per kilogram lost incurred by the technology-based approaches were lower than the standard care control and traditional approach. A predominance of apps reviewed here were offered free of cost although some had minimal costs associated with the SMS component of the intervention. According to a systematic review performed by Gilmore et al. (2014), a large portion of the smart phone applications were free or inexpensive permitting them to be easily accessible to the general population.

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