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Smartphone Application Interventions to Increase Weight Loss: A Systematic Review

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Smartphone Application Interventions to Increase Weight Loss: A Systematic Review

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Smartphone Application Interventions to Increase Weight Loss: A Systematic Review

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The obesity epidemic has reached a critical level in this country. The most recent estimates state that 78.6 million adults in the U.S. are obese. As this number is expected to continue to rise in the coming years, new strategies will need to be developed to combat this devastating disease. One promising approach is the use of mobile phones as an intervention for obesity. Unfortunately, there is little research that specifically investigates the use of smartphone applications (apps) for weight loss.

This systematic review will evaluate the current pool of evidence and assess the effectiveness of smartphone application interventions to increase weight loss. The electronic databases MEDLINE, CINAHL, and PsycInfo were searched for randomized controlled trials that assessed the use of smartphone applications as a weight loss intervention.

A total of 6 articles were included in this review, with the number of participants in each article ranging from 212 to 57 participants. Of the 6 included articles, only one demonstrated a significant increase in weight loss in the smartphone app group compared to the control (-4.2kg, P=0.04). However, in all of the articles that utilize a smartphone application as an adjunct to a weight loss program, the effect sizes ranged from 0.1kg to 2.9kg in favor of weight loss. On the other hand, when an app is utilized as a stand-alone intervention, there were no trends in weight change.

Although the effect appears to be minimal, smartphone applications, when used in conjunction with another weight loss intervention, can have a positive effect on increasing weight loss. However, smartphone application interventions appear to be ineffective when used as the sole strategy for weight loss.

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List of Abbreviations

ANOVA	analysis of variance
App	application (smartphone application)
BMI	body mass index
CDC	Centers for Disease Control and Prevention
HEI-05	Healthy Eating Index 2005
IC	intensive counseling
ICP	intensive counseling plus smartphone application
LICP	less intensive counseling plus smartphone application
M	memo
NDSR	Nutrition Data System for Research
NHANES	National Health and Nutrition Examination Survey
PANAS	positive and negative affect
PD	paper diary
PDA	personal digital assistant
PM	podcast plus mobile group
PO	podcast only
SP	smartphone application only
SA	smartphone app
TRIAD	Translating Research Into Action for Diabetes
W	website

Chapter 1 Introduction

In the U.S., obesity has become a modern day epidemic, and the increasing trends are well documented. For example, in 1990 the prevalence of obesity in the United States was 13%.[1] Fast forward to 2008 and the prevalence of obesity jumped to 28% (Figure 1).[1] According to 2014 estimates from the Centers for Disease Control and Prevention (CDC), one-third (78.6 million) of adults in the U.S. population are obese.[2] When overweight adults are factored in, 69% of the U.S. adult population is either overweight or obese.[3] The rates of obesity get higher for some groups when adults are separated by race. Non-Hispanic blacks have the highest age-adjusted rates of obesity at 47.8%, and Hispanics have the second highest rate at 42.5%; non-Hispanic whites and non-Hispanic Asians have the lowest rates of obesity at 32.6% and 10.8% respectively.[2] This obesity epidemic, unfortunately, is not confined to the adult population. Since 1990 obesity amongst U.S. children has more than doubled.

Figure 1. Prevalence of obesity over time in the U.S. population[1].

Some of the latest estimates from the National Health and Nutrition Examination Survey (NHANES) state that 34.5% of children aged 12-19 are either obese or overweight, with an obesity rate of 20.5% .[4] In 1990, the obesity rate amongst the same age group was 10.5%.[5]

Unfortunately, there are many diseases that are intimately associated with obesity. For example, a strong risk factor for type 2 diabetes is obesity. As individuals increase caloric intake and decrease physical activity, their bodies produce more and more adipose tissue, leading to obesity. Obesity leads to an increase in peripheral insulin resistance (the body cannot use insulin effectively), which leads to an increased production of insulin by beta cells of the pancreas. Eventually, the beta cells will "burn out" and no longer produce insulin. This leads to worsening diabetes and uncontrolled blood glucose.[6] The correlation between obesity and diabetes can be demonstrated when trends of obesity are compared to trends of diabetes. As previously stated, the prevalence of obesity jumped from 13% to 28% between 1990 and 2008.[1] This trend is almost identical to the increases seen in diabetes. From 1990 to 2012, the prevalence of diabetes went from 3.5% to 8.3%.[1] In fact, some articles suggest that for every 1kg increase in body weight, there is a 9% increase in diabetes risk.[7]

Obesity is also a major risk factor for hypertension and coronary artery disease. The Framingham Heart Study found that being overweight or obese is associated with 26% of hypertension cases in men and 28% of hypertension cases in women respectively.[8] Another study that pooled data from 97 cohort studies found a significant increase in the risk of coronary heart disease in overweight and obese individuals.[9] This study found that for every increase in body mass index (BMI) of 5kg/m2, there is a

statistically significant increased risk of coronary heart disease by 1.27%.[9] Beyond even these medical conditions, obesity increases the risk of dyslipidemia, stroke, hepatobiliary disease, osteoarthritis, cancers, and many other medical conditions.[10]

Beyond the health burden of the individual, the increasing obesity trend has also placed a substantial financial burden on the U.S. healthcare system. Obesity alone has an estimated annual cost of 147 billion dollars.[11] At the individual level, obesity is responsible for an increase of $1,429 to medical costs annually.[11] This is particularly troubling because the risk of obesity is inversely related to socioeconomic status in the adult population of U.S. women. According to the National Centers for Health Statistics, 29% of women who live above the 350% income poverty level are obese; while 42% of women who live below the 130% income poverty level are obese.[12] This leads to a disproportionate detrimental monetary effect on poor women in this country.

Fortunately, altering modifiable risk factors, such as increasing physical activity and decreasing caloric intake, can lead to a reduction in the physical and financial burden caused by obesity. In fact, the risk of these negative health consequences can be reduced if only 5%-10% of body weight is lost.[13]

Smartphones are an ever increasing presence that have become a staple in everyday life. As of 2014, seven out of ten Americans own a smartphone.[14] This is an enormous increase considering that just 19% of mobile phone users had a smartphone in 2009.[15] In Millennials, one of the largest segment populations in the United States, smartphones have a penetrance of 85%.[14] Not only are smartphones becoming increasingly common, but they are also being used more than ever before. According to a Neilson report, the average smartphone owner spent 34 hours using smartphone apps and

browsing the internet on a mobile device each month.[16] Because of the increasing penetrance and reliance on smartphones, there is a vast opportunity to utilize smartphone applications to promote weight reduction. In fact, one study found that two-thirds of participants supported a mobile phone weight-loss intervention.[17]

Multiple studies have previously reported the beneficial impact of using mobile phone interventions to reduce weight/obesity. Unfortunately, there have been very few articles that investigate the effectiveness of weight reduction with the use of smartphone applications. One systematic review that looked into the utilization of mobile phones to increase physical activity and reduce weight found that all included studies measuring weight loss, waist circumference, or BMI reported a significant decrease in these outcomes.[18] However, this review focused mainly on the use of text messaging interventions and included only two articles that assessed smartphone applications.[18] The purpose of this systematic review is to evaluate the current evidence that assesses the effectiveness of smartphone application interventions to increase weight loss in adults.

Chapter 2 Methods

Design:

This article is a systematic review of peer-reviewed randomized controlled trials.

Variables of Interest:

The key independent variable of interest is the use of a weight loss smartphone application. The Key dependent variable of interest is weight change. Thus, the search strategy will focus on articles that measure the effect of smartphone application interventions on weight change. For this review article, a smartphone application is defined as software that is downloaded onto a smartphone and used by a participant.

Literature Search Strategy:

The electronic databases MEDLINE, CINAHL, and PsycInfo were searched for randomized controlled trials that assessed the use of smartphone applications as a weight loss intervention. The mesh terms used were mobile applications, mobile, portable software, portable electronic, apps, weight loss, diet reducing, weight reduction programs, obesity, body weight, overweight, body mass index, cell phones, software, computers, handheld, and waist circumference. All of the mesh terms were combined with “and”. The search was limited to articles published in the English language and duplicates were removed. The search history for each database can be found in Appendix A. The search was performed on March 13, 2015, by the University of Texas Medical Branch Librarian Julie Trumble.

Inclusion Criteria:

The inclusion criteria for this systematic review are 1. A randomized controlled trial. Only randomized controlled trials were used because they represent the strongest

level of evidence.[19] 2. Weight change measured as an outcome. This review article focuses on the application of smartphone apps to increase weight loss. If an article does not measure weight loss as an outcome, then the article was not included because it does not apply to this review articles' question. 3. Adult populations. This review article is focusing on weight loss in the adult population. Articles that focus on pediatric populations were excluded because the results would have been skewed and not as generalizable to adults. 4. Utilization of a smartphone application as one of the main interventions used. This inclusion criterion will exclude articles that do not have a smartphone application treatment group. For example, if a study allocates a smartphone application as an optional intervention, then the effects of the smartphone app on the outcome will be unmeasurable. In these instances, the study will not be answering the fundamental question of this systematic review and will be excluded. 5. The Intervention cannot be used in the process of disease management. Articles that focus on weight loss in the course of disease management will limit the generalizability of this systematic review if included. For example, an article evaluating the effects of a smartphone application on weight loss in dialysis patients will not apply to the general population. These patients require unique and closely monitored diets, and their weights will fluctuate based on water and sodium balance in a way that is not seen in the general population.[20] If these articles were applied to the question asked by this review, too many confounding variables would alter the results. Therefore, these studies were not included.

Chapter 3 Results

The literature search resulted in a total of 261 articles. Figure 2 provides a flow chart of search results and selection of studies included in this systematic review. Titles and abstracts were studied, of which, 249 articles were excluded because they did not meet inclusion criteria. Articles not having a randomized controlled design and not using a smartphone application intervention were the two most common reasons for exclusion from this study with 117 and 38 studies respectively. Other reasons for exclusion were not measuring weight change as an outcome (33), focusing on disease process/management (30), focusing on pediatric populations (23), or being a duplicate of previously excluded studies (8). 12 full articles were then reviewed because they could not be excluded based on the title and abstract alone. Of the 12 articles that could not be excluded with the title and abstract alone, 6 articles met inclusion criteria and were included in this systematic review. 4 of the 6 excluded articles were not included in this systematic review because they did not use a smartphone app as an integral aspect of the intervention. As described above in the 4th inclusion criteria, these articles did not require the intervention group to use a smartphone app. The use of a smartphone app was only an optional intervention to be used at the discretion of the participants. These studies could not determine the individual contribution of the smartphone application. Thus, these articles offer no benefit in answering the question being asked by this review article. The other two excluded articles did not measuring weight change as an outcome.

The studies that met inclusion criteria were conducted between 2011 and 2014.[23, 21, 25] 4 out of the 6 studies were conducted within the United States.[21, 22, 23, 25] The remaining two studies were conducted in the United Kingdom and Austrailia.[24, 26]

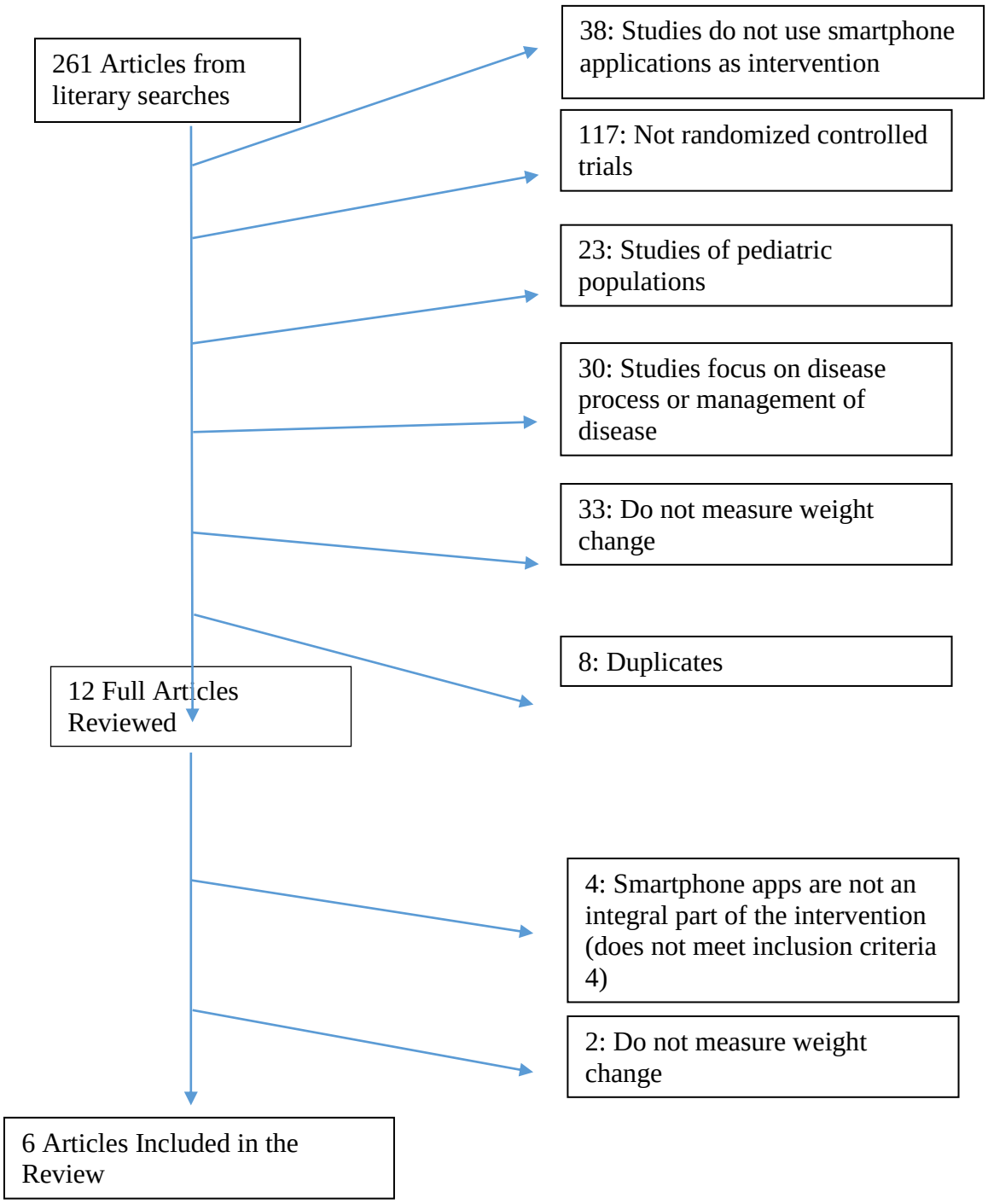

Figure 2. Flow chart of systematic review and study selection

The total number of participants for all 6 trials was 619. 72% of participants were female, with one study consisting exclusively of female participants.[26] The size of the trials ranged from 57 to 212 participants.[26, 21] All participants were 18 years or older, as a study of adults was one of the inclusion criteria. The average age of participants ranged from 41.8 to 44.9 years old.[24, 22] All participants were deemed free of any medically managed conditions that may interfere with their ability to participate in the study. Table 1 presents the characteristics of the 6 articles that met inclusion criteria.

Three of the six included articles utilized a smartphone application as the only intervention allocated to the intervention group.[22,24,25] These interventions compared weight loss and other outcomes to intensive and less intensive counseling with and without a smartphone, a weight loss website and paper diary, and the memo feature (on a smartphone) and paper diary.[22,24,25] The study that included intensive and less intensive counseling with and without a smartphone also included a stand-alone smartphone application intervention group.[22] The remaining 2 studies did not use a smartphone app as the only allocated intervention. These two studies used a smartphone app as an adjunct to weight loss podcasts or a meal replacement program.[24,26]

Five of the six articles utilized a smartphone application that had the capability to track calories consumed and calories expended during exercise.[21,22,23,24,25] Only one of the applications did not specify the ability to track exercise.[26] In all of the apps, calories consumed could be entered directly by the participant, or calories could be determined from a food/calorie database that was pre-loaded on the app. All apps provided real-time caloric consumption data for the day, and each app provided the amount of calories left to consume to meet desired weight loss. These allotted calories were adjusted for exercise

automatically by the application. One of the apps did not use a system that counted the amount of calories consumed, but it used a system of 5 meal categories instead.[26] This was done to simplify the process of dietary monitoring to encourage further usage of the application. Two of the applications used for weight monitoring also had a social networking feature that allowed for participants in the study to share progress and encourage one another.[21, 22] One of the interventions designated a social networking app, which was separate from the weight management application, to send participants 2 encouraging weight loss messages a day.[23] Another application provided supporting text messages from a database that were tailored to each individual's progress.[24] Information on all of the smartphone applications used for each study can be found in Table 1.

All interventions were effective at producing weight loss. However, only one of the studies resulted in a statistically significant increase in weight loss among the app group compared to the control group.[24] This difference was only seen between the smartphone app and website groups (P= 0.04), but it was not observed when the smartphone app was compared to the paper diary group (P= 0.12).[24] This study also noted that the smartphone app group had the greatest decrease in body fat (-2.4kg).[24] Unfortunately, this trial was not powered to detect changes in anthropometric data. The other underpowered study that was included in this review found no significant difference between anthropometric data; however, the authors did note that the interventions augmented with a smartphone app lost more weight than the stand-alone interventions.[22] They also found that a higher percentage of the smartphone app augmented groups had the highest percentage of participants reach clinically significant weight loss (≥5%

weight loss).[22] Furthermore, this study found that the stand-alone smartphone app intervention lost the least amount of weight. [22]

Five studies report weight loss as average kg weight loss over the entire study.[21,22,23,24,25] Three of these studies utilized an app as an adjunct for weight loss therapy. [21,22,23] All three of these articles showed a trend of increased weight loss with the addition of a smartphone app. When a smartphone app is added to usual primary care, the average weight loss increased by 0.3kg.[21] In the study conducted by Allen et al, an app was added to high and low-intensity weight loss counseling.[22] In this study, the addition of the smartphone app increased weight loss by 0.8kg in the less intensive counseling plus app group and 2.9kg in the high-intensity counseling plus smartphone app group when compared to high-intensity counseling alone.[22] The third study utilized an app as an adjunct to weight loss podcasts.[23] This study also demonstrated more weight loss in the adjunct group with an increase in weight loss of 0.1kg.[23] Two of the three studies that utilize a stand-alone smartphone app show a decrease in weight loss when compared to the controls.[22,25] In the Allen et al study, the smartphone app group lost 3.3kg while the high-intensity weight loss counseling-only group (control) lost 2.5kg.[22] When a smartphone app is compared to the memo feature on a smartphone and a paper diary, the smartphone app lost 3.5kg and 0.9kg less than the controls respectively.[25] The other stand-alone smartphone app intervention demonstrated an increase in weight loss of 2.9kg and 1.3kg when compared to a website and paper diary.[24] However, the only statistically significant difference between any of the smartphone interventions and controls appreciated in this review was between the stand-alone smartphone app group

and website only group.[24] Refer to table two for weight change, p values, and effect sizes of each study.

Five of the six studies found that the smartphone app intervention groups had a significant increase in participant utilization of the assigned intervention (app and/or adjuvant treatment).[22, 23, 24, 25, 26] The study that compared podcasts with and without a smartphone app for the delivery of weight loss treatment found that the addition of the smartphone app significantly increased the amount of podcasts downloaded over the study period (P= 0.001). [22] The study that compared a smartphone app to the memo feature on a phone and a paper diary for weight loss treatment noted that the smartphone app participants had a significantly higher number of completed dietary entries (P= 0.024).[25] The study that compared an app to website and paper diary found a similar significant increase in participation amongst the app group as measured by completed days of dietary entry (P= 0.01).[24]

Three studies evaluated for user satisfaction with regard to the smartphone application.[21, 24, 26] Of the smartphone intervention participants in one study, the authors found significantly more users were satisfied with the intervention compared to the website and paper diary groups (P= 0.05).[24] The other two studies did not assess satisfaction statistically, but they did find higher percentages of satisfaction with the intervention (smartphone app) compared to the control groups. One study discovered that the primary reason for discontinuation of app use was due to the tedious nature of the app.[21] However, that same study noted that 100% of the participants who completed the study with the app stated that it was easy to use.

Table 1 Summary of included studies

Citation, Location	Sample	Study Design, Purpose	Outcome Measures	Statistical analysis, Results	Limitations
Laing et al (2014),[21] UCLA primary clinics Los Angeles, CA	Inclusion criteria: ≥ 18 years old, BMI ≥ 25 kg/m^2, and smartphone ownership. Exclusion criteria: current, planned, or pregnancy in past 6 months, lack of interest in weight loss, or current use of a smartphone app for weight loss. 212 participants were randomized to participate in the study and 211 completed the study. 154 (72%) participants were female, and the average age of the participants was 43.	Block randomization was utilized to ensure an equal distribution of overweight and obese participations in each group. The two blocks consisted of participants with a BMI between 25 and 30 kg/m^2 and a BMI greater than 30 kg/m^2. The participants were randomized into a usual primary care for weight loss group (control) or a usual primary care group for weight loss plus the MyFitnessPal app (intervention). The MyFitnessPal app has an easy to use interface that can track calories consumed and exercise. The participants were able to input their weight loss goals, and the app would calculate amount of calories that could be consumed to reach their weight loss goal. The app also included networking features that allowed users to find friends and share their progress. The only information about healthy eating and weight loss given to the participants by the investigators occurred to both groups at 3 months. The control group participants were instructed to choose any weight loss activity that they preferred, as long as it was in line with their current primary care from their physician. The duration of the study was 6 months. The purpose of the study was to test the effect of providing a widely available weight loss app to patients in a primary care	Primary Outcomes: Change in weight at 6 months. Secondary Outcomes: Change in systolic blood pressure and 3 self-reported behavioral mediators of weight loss: exercise, dieting, and self-efficacy. The behavioral outcomes were measured via a survey that was adapted from the TRIAD (translating research into action for diabetes) study and diabetes empowerment scale. Outcome measures were assessed at baseline, 3, and 6 months.	The researchers used a linear mixed-effects model to compare changes in all the outcomes between groups from baseline to 3 and 6 months while controlling for clinical site. At 6 months, the control group had gained an average of 0.27 kg and the intervention group lost 0.30 kg for a between group difference of 0.30 kg (95% CI -1.50 to 0.95). However, there was no significant difference in weight loss between the groups (P= 0.63). The difference between the groups in regard to change in blood pressure was also non-significant (95% CI -7.1 to 3.8, P= 0.55). No significant difference in the self-reported behaviors of weight loss were found between the two groups.	1. Contamination between the groups was high. 13% of the control group used the MyFitnessPal app during the trial. 2. High attrition rates. 32% of the intervention group, and 19% of the control group were lost to follow up or withdrew from the study. 3. The duration of the study was only 6 months.

		setting.			
Allen et al (2013),[22] Baltimore, MD	Inclusion Criteria: Individuals between 21 and 65 years old, a BMI between 28 and 42 kg/m^2, had a smartphone and were willing to download the application. Exclusion Criteria: A history of myocardial infarction, angina, coronary artery bypass graft, percutaneous transluminal coronary angioplasty, congestive heart failure, or diabetes. Participants were also excluded if they had a condition that limited exercise, or if they were currently or planning on being pregnant. 68 participants were randomized and 43 (63%) followed up at the 6 month interval. The average age of participants was 45 ±11 years, and 78% of participants were female.	The random assignment procedure was not disclosed in this article. Participants were randomized into one of four interventions: intensive counseling (IC), intensive counseling plus smartphone (ICP), less intensive counseling plus smartphone (LICP), and smartphone only (SP). In the IC and ICP groups, the participants received healthy eating and exercise counseling weekly for the first month and biweekly for the next 5 months. In the LICP group, the participants received healthy eating and exercise counseling from a nutritionist twice during the first month and monthly for the next five months. The counseling in both groups focused on decreasing calories and increasing exercise. The smartphone only group did not receive any counseling. The smartphone application used was The Lose It! App which allowed participants to manage calories and exercise to accomplish their target weight. The app also provided real time feedback and opportunities for support through social networking. The duration of the study was 6 months. The purpose of the study was to evaluate the efficacy of a theoretically based behavioral intervention delivered by smartphone technology	Primary Outcomes: Change in weight from baseline, and percentage reduction in weight, BMI, and waist circumference. Secondary Outcomes: Changes in Diet and physical activity. Physical activity was evaluated with the Stanford 7-day physical activity recall, and dietary intake was measured from 3 day food records and analyzed using the Nutrition Data System for Research (NDSR) software version 2012. The primary and secondary outcomes were measured at baseline and 6 months.	The investigator performed an intention to treat analysis using the nonparametric Wilcoxon signed rank test. Participants in the ICP group lost the most weight (5.4 kg), while the LICP group lost slightly less (3.3 kg). The IC group and SP group lost 2.5 kg and 1.8 kg respectively. IC was better than SP group by 0.7kg, but use of app in the ICP increased effectiveness by 2.9kg. There were no significant differences between the groups (P= 0.89). Of the participants who completed the 6 month study, 64% in the ICP group and 40% in the LICP group lost 5% or more of their baseline body weight. Only 25% of the IC group and 20% of the SP group lost 5% of their baseline body weight. There was no P value given for ≥5% loss in body weight. Change in BMI had a similar trend (CI -0.8, ICP -1.8, LICP -1.1, SP -0.7, P= 0.79). Change in waist circumference followed a similar trend without significance(CI -3.0, ICP -7.01, LICP -6.5, SP -3.38, P= 0.36). Secondary outcomes in diet (CI -415.6, CIP -468.2, LICP -218.5, SP -249.2, P= 0.66) and	1. Small sample size (68) not powered to detect differences between groups. 2. High attrition rate of 37%. 3. 78% of participants were female. 4. 28% of participants who completed the trial used another intervention in addition to the one allocated to them. 5. Short term study (6 months)

				physical activity (IC -1.4, ICP -2.0, LICP -3.6, SP -0.19, P= 0.51) also showed no significance between groups. The study found no significant differences between the groups for any of the outcomes; however, the study was not powered to detect statistically significant differences between the groups.	
Turner-McGrievy et al (2011),[23] Raleigh-Durham, North Carolina	Inclusion Criteria: Individuals between 18 and 60 years old, a BMI between 25 and 45 kg/m^2, ability to complete the Physical Activity Readiness questionnaire, had access to a body weight scale, owned an iPhone, iPod, Blackberry, or android smartphone, and had access to the internet. Exclusion Criteria: Participants were excluded if they smoked, had an unstable medical condition, were unable to increase exercise, unable to attend three visits, had a psychiatric illness, are currently in	Participants were randomized into one of two groups with the use of a computerized random number generator: podcast only (PO) (n= 49) or podcast plus mobile group (PM) (n= 47). 2 long podcasts (15 minutes) a week were provided to the participants for 3 months, then 2 mini podcasts (5 minutes) per week were provided for the duration of the study. The long podcasts consisted of: nutrition and physical activity information, an audio blog of a person trying to lose weight, a soap opera, and goal setting activity. The mini podcasts consisted of nutritional and physical activity information only. The plus mobile group was instructed to use the Fat Secret's Calorie Counter app, which is a diet and physical activity monitoring app that allows participants to keep accurate logs of food and exercise. The app also has a database that allows for users to look up nutritional information. The plus mobile group was also instructed to use a social networking application (Twitter) to facilitate discussion and encouragement	Primary Outcomes: Change in body weight at 6 months. Secondary Outcomes: Changes in energy intake, fat intake, energy expenditure, self-efficacy, knowledge, and weight related eating behaviors (EBI score). All secondary outcomes were assessed with questionnaires: Dietary recall questionnaire, Paffenbarger Physical Activity Questionnaire for physical activity, Weight efficacy Life-Style Questionnaire for self-efficacy, Eating Behavior Inventory for eating behaviors, and cognitive load	All data were analyzed using an intention to treat analysis with imputation. T tests were calculated for differences between continuous variables, and paired-sample t tests examined differences between groups. Mean differences within 3 or more groupings was assessed with analysis of variance, and repeated measures ANOVA was used to assess changes over time. Participants in both groups lost an average of 2.7% of their initial body weight at the 6 month follow up for a non-significant difference between the groups (P= 0.98). The PM group lost an average of 2.4 kg, while the PO group lost an average of 2.3 kg. There were also no significant differences between the two groups with regard to change in energy	1. Only 60% of the plus mobile group reported actually using the smartphone app. 2. 32% of the control participants (podcast only) reported using a smartphone app as an intervention. 3. Study lasted only 6 months 4. Possible selection bias as non-completers were significantly younger and less likely to be white.

	a weight loss program, are pregnant or breastfeeding. 96 participants were randomized, and 86 participants followed up at the end of the 6 month study. 75% of the participants were female.	amongst participants. They also received 2 reinforcing messages a day through the social network app. The duration of the study is 6 months. The purpose of the study is to determine if the combination of podcasting, mobile support communication, and mobile diet monitoring can assist in weight loss.	questionnaire. The outcomes were assessed at baseline, 3, and six months.	intake (PO -242.5, PM -288.8, P= 0.69), energy expenditure (PO 96.7, PM 86.8, P= 0.79), self-efficacy (PO 20.1, PM 17.6 P= 0.64), fat intake (PO -14.5, PM -15.0, P= 0.92), or weight related eating behaviors (EBI score) (PO 9.8, PM 12.4, P= 0.27).	
Carter et al (2013),[24] United Kingdom	Inclusion Criteria: BMI of ≥27 kg/m2, between 18 and 65 years old, have a willingness to participate in the study, not pregnant, not breast-feeding, no planned pregnancy, not taking anti-obesity medication, not on insulin, no history of weight loss surgery, not on sertraline, access to the internet, ability to read English, Employed by a large employer in Leeds, and a willingness to be randomized. 128 participants were randomized at the beginning of the trial, and 79 participants	Participants were randomly minimized using the Minim software package to 1 of 3 groups. The minimization equally balanced the medians of BMI, age, and gender amongst the groups to allow for similar samples. The three groups in this 3-arm randomized controlled trial are: a smartphone app (SA), website (W), or paper diary (PD). The application used (My Meal Mate) which allows users to set goals for weight loss, monitor caloric intake, and record physical activity. The application also automatically responds to the caloric and exercise information entered by sending weekly encouraging text messages to the user. The text messages were previously produced and stored in an electronic library. Both the website and paper diary groups used an intervention that allowed for goal setting and self-monitoring. The paper diary group only had access to a calorie counting book. The duration of the study was 6 months. The purpose of the study was to assess the	Primary Outcomes: 6 month adherence to and usage of the intervention allocated. Satisfaction with the assigned intervention. Secondary Outcomes: Change in weight, BMI, and body fat. Body fat was measured by using the Weight Watchers 8958U Body Analyser Scale portable weighting scale. Usage of the intervention was determined by the investigators analyzing the caloric records of the participants for the number of completed days recorded. A completed day is considered as a day with ≥500 kcal energy	1-way ANOVA was used for normally distributed continuous outcomes, and the Kruskal-Wallis test was used for continuous outcomes that are not normally distributed. The Chi-Square test was used to analyze differences among groups for categorical data. Although, this study was not adequately powered to detect differences between groups, with respect to anthropometric data, the investigators used an intention to treat regression analysis to test between group differences for changes in anthropometric measures adjusted for baseline age, gender, and BMI. At 6 months, only three people dropped out of the SA group, while 23 people dropped out of both the W and PD group (P= 0.001). Completed days	1. The study was not powered to determine changes between the groups in anthropometric measures. 2. 38% attrition rate. 3. Unequal dropout rates between the groups is a potential for bias. 4. Contamination was a serious issue amongst all the groups.

	(61.4%) returned for the 6 month follow up. The average age of participants was 42 years old and 77% of participants were female. 91% of participants were also white.	feasibility and acceptability of a weight loss intervention delivered by a smartphone app.	record. Satisfaction was assessed with the use of a satisfaction questionnaire. The outcomes were assessed at baseline, 6 weeks, and 6 months.	recorded/usage was significantly higher in the SA group (82 days) when compared to the W (15 days) and PD groups (18 days) (P= <0.001). A significantly higher percentage of participants in the SA group (63.2%) were satisfied with their intervention when compared to the W (42.1%) and PD groups (50%) (P= 0.05). Average weight change at 6 months in the SA (4.2 kg) group was significantly more than the W (1.3 kg) group (P= 0.004), but not significantly more than the PD (2.9 kg) group (P= 0.12) The SA group lost 2.9 kg more weight than the W group and 1.3 kg more weight than the PD group. The SP group also had the greatest decrease in BMI (SP 1.6 kg/m^2, PD 1.1 kg/m^2,0.5 kg/m^2,P= <0.001)and body fat (SP 1.2, PD 0.9, W 0.4, P= 0.02) compared to the other two groups.	
Wharton et al (2014),[25] Phoenix, AZ	Inclusion Criteria: Aged between 18 and 65 years old, BMI between 25-40 kg/m^2, participants had to own a smartphone, Participants had to be free from unresolved	Participants were stratified by age, BMI, and gender and randomized into 1 of 3 methods for weight loss: the smartphone application "Lose It!" (SA), the memo feature on a smartphone (M), or a paper diary method (PD). The smartphone app Lose It! allowed users to set weight loss goals at the beginning of the study, and it was able to	Primary Outcomes: Consistency of daily dietary tracking. Secondary Outcomes: Weight change and dietary quality. Consistency of daily dietary tracking was	Outcome measures were normally distributed, and mean comparisons across time and between groups were assessed using univariate analysis and repeated measures ANOVA. The chi-square test was used to assess relationships among	1. The smartphone app tracked exercise and was able to adjust daily allotted calorie consumption accordingly. This may have led to a

	medical conditions, and not currently taking medications or supplements that are known to affect body weight, participants also had to report no changes in weight greater than 5 pounds in the past 3 months. 57 participants were randomized at baseline, while 47 participants completed the trial at 6 weeks. The study consisted of 75% females with an average age of 41.	track exercise and calculate daily caloric allotments that could be consumed by the individuals to meet their goal. The app also provided immediate feedback regarding caloric intake when dietary data was entered. The participants in the paper diary and memo groups received one-on-one counseling before the start of the study and weekly emails of encouragement during the study. The memo feature functions as an electronic diary with no feedback or additional information. The duration of the study was 8 weeks. The purpose of the study was to assess weight loss and self-monitoring via a popular smartphone app compared to tradition counseling and entry methods.	determined by reviewing the dietary logs from each participant and analyzing the number of completed days. A completed day was characterized by ≥800 kcal of food intake in a 24 hour period. Dietary quality was assessed by using the Healthy Eating Index-2005 (HEI-05). Outcomes were assessed at the 8th week.	nominal variables. The app group recorded significantly more completed days (43 days) compared to the memo group (30.7 days) (P= 0.024) but not the paper group (34.8 days) (no P value given). The memo and paper groups both recorded a significantly greater number of incomplete days than the app group (21 days, 21.3 days, and 10.3 days, respectively) (P= 0.04). All groups had a significant reduction in weight (SA 3.5 kg, M 6.5 kg, PD 4.4 kg), but they did not significantly differ between the groups (P= 0.36). The SA group lost 3.0 kg less weight than the M group and 0.9 kg less than the PD group. Although the HEI score for the app group fell the most (6%), there was no significant difference between the groups (M increase of 3%, PA increase of 9%) (P= 0.29).	more modest weight loss compared to the other groups because they lacked this function. 2. Short duration of only 8 weeks. 3. Possibility of bias because there was a significant difference in attrition between the groups (P= 0.05).

Brindal et al (2013),[26] Australia	Inclusion Criteria: women, adults (age not specified), BMI >25 kg/m^2, had to own an iphone, had to be willing to participate, needed ability to weigh self at home. Exclusion Criteria: could not have a medical condition that would interfere with the ability to undertake the meal replacement program: including pregnancy, breastfeeding active cancer, gastrointestinal disorders, and type 1 diabetes. 58 participants were randomized to participate in the study, and 44 participants finished the 8 week study. The majority of the women were professionals with an average age of 42.	The participants were randomly assigned to a meal replacement program group or to a meal replacement program plus a mobile app group by a computer-generated random sequence. The control group received an app as well, but it lacked any features that would aid in the trial. Both groups received the same commercially available meal replacement program. The study was conducted in two phases. During the first phase (the feasibility phase), the meal replacement program was provided to the participants. During the second phase (free-living phase), the continuation of the program was at the discretion of each participant. The app provided information, allowed for easier intake record keeping, displayed positive support and feedback, and prompted users to record data. No weight management advice was given to participants of either group. The duration of the study was 8 weeks. The purpose of this study was to evaluate an evidence based weight loss intervention that was supported by a smartphone app.	Primary Outcomes: Percent weight loss from baseline and engagement of the intervention. Secondary Outcomes: behavioral outcomes. Engagement was mainly determined by the frequency of weighing by the participants. The behavioral outcomes were determined using the positive and negative affect (PANAS) using subscales of positive and negative effects.	Outcomes were assessed using mixed models with an unstructured covariance matrix. This method uses all available data and is an intention to treat analysis. Both groups lost weight over the course of the study. The intervention group lost an average of 3.18% of their body weight, while the control group lost 2.22% of their body weight (kg of weight loss was not reported). This difference, however, was not significant (P= 0.08). 23% of the participants in the intervention group, and 21% in the control group, lost a clinically significant 5% of their initial body weight (difference between the groups P= 0.86). The intervention group weighed themselves significantly more frequently than the control group (3.9 times, 2.7 times respectively) (P= 0.001). The intervention group had a more significant change in positive affect compared to the control (0.48 and -0.01, respectively) (P= 0.012), while there was not a significant change in negative affect between the smartphone and control groups (-0.06 and -0.12, respectively) (P= 0.76).	1. The trial included only women. 2. The study was 8 weeks in duration.

Table 2. Weight loss in each included study

Article	Laing et al (2014)[21]	Allen et al (2013)[22]	Turner-McGrievy (2011)[23]	Carter et al (2013)[24]	Wharton et al (2014)[25]	Brindal et al (2013)[26]
Duration of study	6 months	6 months	6 months	6 months	8 weeks	8 weeks
Weight change in intervention group(s) and control group	Primary care plus smartphone app: -0.03 kg Primary care alone: +0.27 kg	Intensive counseling plus smartphone: -5.4 kg Less intensive counseling plus smartphone: -3.3 kg Smartphone only: -1.8 kg Intensive counseling only: -2.5 kg	Podcast plus mobile group: -2.4kg Podcast only: -2.3kg	Smartphone app: -4.2 kg Website group: -1.3 kg Paper diary group: -2.9 kg	Smartphone app: -3.5 kg Memo feature on a smartphone: -6.5 kg Paper diary: -4.4 kg	Meal replacement plus app: -3.18% (of body weight) Meal replacement program alone: 2.22% (of body weight) Note: kg of weight loss not reported.
Difference between groups (p value)	P= 0.63	P= 0.89	P= 0.98	P= 0.004, between the smartphone and website groups P= 0.12, between the smartphone and paper diary groups.	P= 0.36	P= 0.08
Effect Sizes (in kg weight loss)	Smartphone app in addition to primary care increased weight loss by 0.3kg	When app added to counseling, weight loss increased by 2.9kg and 0.8kg. App alone was less effective then counseling alone by 0.7kg.	Addition of app to the podcast intervention increased weight loss by 0.1kg.	App alone increased weight loss from the website group by 2.9kg, and the paper diary group by 1.3kg.	App alone group was less effective than the memo feature on a smartphone by 3.0kg, and less effective than paper diary alone by 0.9kg.	App added to a meal replacement program increased percentage of body weight lost by 0.96%. Note: kg weight loss not reported.

Chapter 4 Discussion

The results of this systematic review demonstrate that smartphone apps may assist in weight reduction, but they may only increase weight loss by 0.5kg.

Although most of the results were not statistically significant, there does seem to be some emerging trends in the data. When a smartphone is added to an existing weight loss intervention as an adjunct, there is a trend for increased weight loss.[21,22,23] The beneficial weight loss that can be seen by the addition of a smartphone intervention, however, is minimal. The average increase in weight loss seen when a smartphone app is an adjunct is 1.025kg (median 0.55kg).[21, 22, 23] Even though the weight loss seen is minimal, the articles in this review support the use of a smartphone app to increase weight loss. Another interesting (and unexpected) trend is demonstrated by two out of three studies that analyze stand-alone smartphone interventions.[22,25] These two studies demonstrate a decrease in weight loss when compared to the control/another intervention.[22,25] In the study by Allen et al, there was a 0.7kg decrease in weight loss.[22] In the study by Wharton et al, there was a similar trend of decreased weight loss by 3.0kg and 0.9kg in the smartphone app only groups.[25] These studies do not support the theory that smartphone applications as a stand-alone intervention are effective for weight loss. Future studies that are investigating the use of smartphone applications for weight loss interventions should focus on smartphone apps as an adjunct, and not a stand-alone intervention.

The results also demonstrate that smartphones are a well-accepted tool for weight loss interventions. Five out of six included articles found that utilization of the intervention was highest amongst the participants who were allocated a smartphone

application.[22, 23, 24, 25, 26] Two of these articles statistically assessed for participation by comparing the number of completed records in each group.[24, 25] The articles found that the records in the smartphone app groups had significantly more completed records. The increase in dietary record keeping seen in this review is likely related to ease of use when compared to a paper diary. Not only do most Americans keep a smartphone with them at all times (allowing them to carry their diary with them and fill it out at their convenience), but many of the smartphone applications were designed with ease of use in mind. [25, 26] This increase in dietary record keeping likely has an increase in dietary accuracy as well. Many articles support the idea that mobile dietary record keeping is more accurate than a paper a diary. [27, 28]

One recent study by Spring and colleges assesses the use of frequent weight loss coaching sessions with and without the addition of a personal digital assistant (PDA).[29] Both groups received the same weight loss coaching sessions delivered by nutritionists and psychologists with the only difference being the utilization of the PDA. The study found that the addition of the PDA resulted in significant weight loss compared to the coaching session only group. The study also showed that the odds of reaching a clinically significant weight loss (≥5% body weight) were significantly higher in the PDA group.[29] More articles that evaluate the efficacy of a smartphone application in conjunction with a sufficient weight loss intervention, instead of a stand-alone intervention, are needed.

Obesity is a huge burden to the American people, but a recent article indicates that the prevalence of obesity is significantly higher in rural compared to urban areas.[30] The article by Spring and colleges demonstrates a possible solution to the rural obesity problem. In that study, the coaching intervention that was utilized was entirely over the

phone without in-person contact. Again, this study resulted in significant and sustained weight loss over 12 months.[29] These results may be adopted by health care professionals to institute an effective weight loss coaching program that augments treatment with a smartphone application. More rural Americans who are most in need of obesity interventions could be reached because the distance barrier can be overcome.

There are some limitations to this systematic review. Because this review article only searched from published articles in MEDLINE, PsycInfo, and CINAHL, there is likely publication bias present. Also, this review article had two of six studies performed outside of the United States. This is detrimental to the generalizability and application of the results to the American public. Generalizability will also be limited to only those who can afford to have a smartphone.

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Appendix A:

MEDLINE search:

1 exp Mobile Applications/ (276)

2 (mobile adj (app or apps or application$)).mp. [mp=title, abstract, original title, name of substance word,

subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept

word, unique identifier] (655)

3 (portable software adj (app or apps or application$)).mp. [mp=title, abstract, original title, name of substance

word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary

concept word, unique identifier] (0)

4 (portable electronic adj (app or apps or application$)).mp. [mp=title, abstract, original title, name of substance

word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary

concept word, unique identifier] (1)

5 ((app or apps or application$) and (smartphone$ or smart phone$ or tablet$)).mp. [mp=title, abstract, original

title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare

disease supplementary concept word, unique identifier] (3612)

6 1 or 2 or 3 or 4 or 5 (4083)

7 exp Weight Loss/ (29356)

8 exp Diet, Reducing/ (9559)

9 exp Weight Reduction Programs/ (667)

10 exp Obesity/pc, th [Prevention & Control, Therapy] (25250)

11 exp Body Weight/ (356711)

12 exp Overweight/ (148403)

13 exp Body Mass Index/ (84291)

14 7 or 8 or 9 or 10 or 11 or 12 or 13 (399091)

15 6 and 14 (59)

16 exp Cell Phones/ (5359)

17 exp Software/ (113910)

18 16 and 17 (653)

19 14 and 18 (30)

20 15 or 19 (75)

21 limit 20 to english language (71)

22 exp Computers, Handheld/ (2408)

23 14 and 22 (58)

24 limit 23 to english language (57)

25 exp Waist Circumference/ (5168)

26 6 and 25 (5)

27 limit 26 to english language (5)

28 21 or 24 or 27 (119)

29 remove duplicates from 28 (107)

CINAHL search:

Search ID# Search Terms Search Options Last Run Via Results

S25 S22 OR S24 Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 130

S24 S19 AND S23 Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 3

S23 MH "Mobile Applications" Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 76

S22 S11 AND S19 Limiters - Published Date: 20080101-20151231; English Language

Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 130

S21 S11 AND S19 Limiters - Published Date: 20080101-20151231; English Language

Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 130

S20 S11 AND S19 Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 153

S19 S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 141,089

S18 (MH "Eating Behavior+") OR (MH "Food Habits") Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 21,890

S17 (MH "Waist Circumference") OR (MH "Waist-Hip Ratio") Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 3,680

S16 (MH "Body Mass Index") Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 49,494

S15 (MH "Body Weight+") OR (MH "Body Weight Changes+") OR (MH "Weight Control") Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 92,841

S14 (MH "Obesity+") Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 58,430

S13 (MH "Diet, Reducing") OR (MH "Restricted Diet+") Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 11,214

S12 (MH "Weight Loss+") OR (MH "Weight Reduction Programs") OR (MH "Weight Control") Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 19,871

S11 S1 OR S2 OR S3 OR S4 OR S6 OR S10 Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 5,735

S10 S5 AND S9 Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 1,966

S9 S7 OR S8 Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 259,371

S8 (MH "World Wide Web Applications+") Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 11,253

S7 (MH "Software+") Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 250,046

S6 (MH "Computers, Hand-Held") Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 3,167

S5 (MH "Wireless Communications") Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 9,288

S4 (app or apps or application*) and (smartphone* or smart phone* or tablet* or mobile technolog* or pda or pda's or personal digital assistant*) Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 636

S3 (portable electronic N1 (app or apps or application* or technolog*)) Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 1

S2 (portable software N1 (app or apps or application* or technolog*)) Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 0

S1 (mobile N1 (app or apps or application* or technolog*)) Search modes - Boolean/Phrase Interface - EBSCOhost Research Databases

Search Screen - Advanced Search

Database - CINAHL Plus with Full Text 811

PsycInfo search:

1 (mobile adj (app or apps or application$)).mp. [mp=title, abstract, heading word, table of contents, key concepts,

original title, tests & measures] (213)

2 (portable software adj (app or apps or application$)).mp. [mp=title, abstract, heading word, table of contents,

key concepts, original title, tests & measures] (0)

3 (portable electronic adj (app or apps or application$)).mp. [mp=title, abstract, heading word, table of contents,

key concepts, original title, tests & measures] (0)

4 ((app or apps or application$) and (smartphone$ or smart phone$ or tablet$ or pda or pda's or personal digital

assistant$)).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]

(567)

5 exp mobile devices/ (2791)

6 exp Computer Applications/ (31513)

7 computer software/ (4207)

8 6 or 7 (34469)

9 5 and 8 (339)

10 mobile technolog$.mp. (621)

11 1 or 2 or 3 or 4 or 9 or 10 (1477)

12 exp Weight Loss/ (1807)

13 exp dietary restraint/ (960)

14 exp weight control/ (2403)

15 exp Obesity/ (12818)

16 exp Body Weight/ (25162)

17 exp Body Mass Index/ (3108)

18 exp Body Size/ or exp Body Fat/ (26812)

19 overweight/ (2550)

20 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 (29151)

21 11 and 20 (24)

22 limit 21 to english language (24)

Vita

Taylor Alloway was born on 3/19/1987 in Austin, Texas to Parents Harley and Katherine Alloway. He graduated from Henderson State University with a bachelors degree in biology, and he received his MD from The University of Texas Medical branch in Galveston, Texas. He is currently an internal medicine resident at the University of Tennessee Health Science Center in Memphis, Tennessee.

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