

Effect of Mobile Health on Obese Adults: A Systematic Review and Meta-Analysis

Seong-Hi Park¹, Jeonghae Hwang², Yun-Kyoung Choi³

¹School of Nursing, Soonchunhyang University, Asan, Korea

²Department of Health Administration, Hanyang Cyber University, Seoul, Korea

³Department of Nursing, College of Natural Sciences, Korea National Open University, Seoul, Korea

Objectives: This study was conducted to examine the effects of mobile health (mHealth), using mobile phones as an intervention for weight loss in obese adults. **Methods:** An electronic search was carried out using multiple databases. A meta-analysis of selected studies was performed. The effects of mHealth were analyzed using changes in body weight and body mass index (BMI). **Results:** We identified 20 randomized controlled trials (RCTs) involving 2,318 participants who fit our inclusion criteria. The meta-analysis showed that body weight was reduced with a weighted mean difference (WMD) of -2.35 kg (95% confidence interval [CI], -2.84 to -1.87). An examination of the impact of duration of intervention showed that weight loss was greater after 6 months of mHealth (WMD = -2.66 kg) than between three and four months (WMD = -2.25 kg); it was maintained for up to 9 months (WMD = -2.62 kg). At 12 months, weight loss was reduced to a WMD of -1.23 kg. BMI decreased with a WMD of -0.77 kg/m² (95% CI, -1.01 to -0.52). BMI changes were not statistically significant at 3 months (WMD = -1.10 kg/m²), but they were statistically significant at 6 months (WMD = -0.67 kg/m²). **Conclusions:** The use of mHealth for obese adults showed a modest short-term effect on body weight and BMI. Although the weight loss associated with mHealth did not meet the recommendation of the Scottish Intercollegiate Guideline Network, which considers a reduction of approximately 5 to 10 kg of the initial body weight as a successful intervention. Well-designed RCTs are needed to reveal the effects of mHealth interventions.

Keywords: Adult, Obesity, Cell Phone, Mobile Applications, Meta-analysis

Submitted: December 16, 2018

Revised: January 19, 2019

Accepted: January 23, 2019

Corresponding Author

Jeonghae Hwang

Department of Health Administration, Hanyang Cyber University,
220, Wangsimni-ro, Seongdong-gu, Seoul 04763, Korea. Tel: +82-
2-2290-0811, E-mail: 1110006@hycu.ac.kr (<https://orcid.org/0000-0002-7428-5761>)

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/4.0/>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

© 2019 The Korean Society of Medical Informatics

1. Introduction

Overweight and obesity are defined as “abnormal or excessive fat accumulation resulting in health risks” [1]. In May 2004, the World Health Organization (WHO) declared war on obesity through its “Global Strategy on Diet, Activity, and Health” [2]. According to a study by the Non-Communicable Disease Risk Factor Collaboration (a network of scientists in 186 countries), one out of every five people in the world is now obese with a body mass index (BMI) greater than 30 kg/m² [3]. Obesity is not a cosmetic problem but a direct threat to survival. Fortunately, obesity is preventable.

Obesity is often associated with a variety of risk factors, such as age, race, genetic influences, diet, and lifestyle; it

cannot be explained by any one cause [4]. However, obese people tend to overeat and rarely engage in sufficient physical activity [5]. As these habitual behaviors play a major role in causing people to become overweight and obese, they are the main targets for preventive and therapeutic activities. The treatment of obesity begins by targeting weight loss through diet, exercise, and lifestyle changes, rather than medication [6]. However, changing a person’s lifestyle is not easy. Obesity treatment is perceived in a more distorted way than treatments for other diseases, so it is important for a patient to be actively motivated. In addition, since the health problems that result from obesity, as well as motivation and weight loss goals, vary from one person to the next, it is desirable to develop individualized treatment strategies tailored to the characteristics of individual patients [7].

Information and communication technologies have been using eHealth and uHealth to provide healthcare since the 1990s as a way of managing chronic diseases caused by multiple factors [8]. They provide interventions that aim to change the lifestyle of patients or prevent risky behavior through individually tailored contact [9]. Taken as a group, the functions of personal computers and digital devices as applied to health are described as mHealth or digital health [10]. Because of its portability, mHealth can provide life logging, feedback, and pervasive interaction and intervention anytime and anywhere [11]. Thus, mHealth can potentially provide customized treatment for individual patients at a low cost with minimum need for therapeutic intervention [12]. For these reasons, mHealth has been actively used in the treatment of chronic diseases, including heart disease, smoking, and obesity, which require timely intervention to change patients’ lifestyles [13,14]. A systematic review of mHealth’s effect on obesity was carried out [15,16], and the findings showed that the effect was insignificant. Since then, several published articles have explored the use of mHealth in 2014 with obese patients [1-7]. Moreover, mobile phones have become more widely available globally, and mHealth has become simpler to access and use. Therefore, this is an ideal time to add to the evidence base surrounding the impact of mHealth. In this context, mHealth can be a new alternative to play a key role in modern healthcare solutions.

Thus, the purpose of this study was to evaluate the effect of mHealth on the weight loss of adult obesity through a systematic review focusing on randomized controlled trials (RCTs) with a high methodological standard and to provide scientific evidence regarding mHealth.

Table 1. Search strategies used to search Ovid MEDLINE

Search strategies	
1	exp Obesity/ or obesity.mp.
2	obesity abdominal.mp. or exp Obesity, Abdominal/
3	overweight.mp. or Overweight/
4	weight gain.mp. or exp Weight Gain/
5	body mass index.mp. or exp Body Mass Index/
6	(overweight or over weight).mp.
7	fat overload syndrom\$.mp.
8	exp Metabolic Syndrome X/ or metabolic syndrome.mp.
9	(overeat or over eat).mp.
10	(overfeed or over feed).mp.
11	or/1-10
12	cellular phone.mp. or exp Cell Phones/
13	text messag\$.mp.
14	texting.mp.
15	short messag\$.mp.
16	mobile health.mp. or exp Telemedicine/
17	sms.mp.
18	(multimedia messag\$ or multi-media messag\$).mp.
19	mms.mp.
20	((cellular phone\$ or cell phone\$ or mobile phone\$) and (messag\$ or text\$)).mp.
21	(phone adj3 call*).mp.
22	((cell* or mobile or smart or google or nexus or iphone) adj3 (phone* or telephone*)).mp.
23	smartphone*.mp.
24	smart-phone*.mp.
25	((mobile or smartphone or smart-phone or phone or software) adj3 app*).mp.
26	multimedia messaging service.mp.
27	palmtop computer\$.mp.
28	(tablet adj3 (device? or comput\$)).mp.
29	(Blackberry or Nokia or Symbian or Samsun or iPhone or Ipad).mp.
30	(windows adj3 (mobile? or phone?)).mp.
31	smart?pad.mp.
32	bluetooth headset*.mp.
33	(smart adj (watch\$ or band\$ or shoe\$ or glasse\$)).mp.
34	(patch and tattoos).mp.
35	smart implant\$.mp.
36	fuelband.mp.
37	google glass\$.mp.
38	fitbit.mp.

Continued on next page.

Table 1. Continued

Search strategies	
39	fitness tracking.mp.
40	iBGstar.mp.
41	iRhythm.mp.
42	iRobot.mp.
43	or/12-42
44	11 and 43
45	Search filter of SIGN for randomized controlled trials
46	44 and 45

II. Methods

This study was conducted in accordance with guidelines provided in the Cochrane Handbook for Systematic Reviews of Intervention [17] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses [18].

1. Search Strategies

An electronic database search was executed on October 1, 2016, using the Ovid MEDLINE, EMBASE, Cochrane Library, and CINAHL Complete databases. The search strategy relied on Medical Subject Heading (MeSH) search terms, including ‘obesity’, ‘overweight’, ‘cellular phone’, and ‘mobile health’. To search for RCTs, we used the Scottish Intercollegiate Guidelines Network search filter [19] in the Ovid MEDLINE database. The combinations of search terms are shown in Table 1.

2. Eligibility Criteria

The selection criteria used to retrieve documents were the following: (1) study designs, RCTs; (2) participants, overweight or obese adults over 18 years of age with a BMI above 25 kg/m² [20]; (3) interventions, mobile healthcare programs providing health promotion services and health information through mobile phones (These included health management and personal guidance systems provided remotely via SMS, as well as applications connected to health-information devices); (4) comparators, no treatment or counseling providing educational materials not via mobile devices as a weight-loss interventions; and (5) outcomes, changes in body weight and BMI.

The exclusion criteria for the literature were the following: (1) non-original studies; (2) studies including adults within a normal range of BMI; (3) persons with specific illnesses; (4) non-mobile phone-based health programs; (5) studies that

did not report body weight or BMI among their results; and (6) non-RCTs. The language options were not limited.

3. Study Selection and Data Extraction

First, duplicate documents were eliminated. The title and abstract of each article were then reviewed. If an inclusion was still unclear following title/abstract screening, the full text was evaluated and exclusion criteria applied. Data were extracted after the evidence was reviewed in table form. The data extracted from the included literature related to study location, the randomized allocation method, blinding, subjects, selection criteria, age, sex ratio, BMI, mHealth programs, and research outcomes. All processes were independently carried out by the three authors, and the final selection was based on consensus. Disagreements were resolved through third party involvement.

4. Risk of Bias Assessment

The quality of the literature was assessed independently by the three authors using Cochrane’s risk of bias tool [17]. This is a quality assessment method for RCTs that includes the following seven items: random sequence generation, allocation concealment, the blinding of participants and personnel, the blinding of outcome assessments, incomplete outcome data, and other biases. In addition, each item was judged as having a high, low, or unclear risk of bias, depending on the content of the study.

5. Statistical Analysis

A meta-analysis of extracted data was carried out, using Cochrane’s Review Manager (RevMan) 5.3 program (The Nordic Cochrane Center, Copenhagen, Denmark). Because the estimated effect is a continuous variable, it was described as a weighted mean difference (WMD) and 95% confidence interval (CI) and analyzed using a random-effect model. The mean effect on the outcome variable and the 95% CI were based on the general inverse variance estimation method. For studies in which the standard deviation was not reported, these were converted and analyzed by the RevMan 5.3 program’s automatic calculation tool using the standard error or CI presented in the studies. Body weights reported in pounds were converted into kilograms; cases that cited a percentage of reduced body weight were also recalculated to reflect baseline body weights. The difference in effect between groups was analyzed at a 5% significance level. To measure the heterogeneity among the studies, a forest plot was initially used to visually identify the common factors in CI and effect estimates, and Cochran’s Q statistics and Hig-

gins’s I^2 statistics were used. Here, $I^2 \leq 25\%$ indicated low heterogeneity; $25\% < I^2 \leq 75\%$, medium heterogeneity; and $I^2 > 75\%$, high heterogeneity [17]. The presence of publication bias was confirmed through a funnel plot.

III. Results

1. Description of Included Studies

In total, 1,311 studies were retrieved from the following electronic databases: Ovid MEDLINE (477), EMBASE (617), Cochrane Library (145), and CINAHL Complete (72). Of these, 329 studies were excluded as duplicates. The titles and abstracts of 982 studies were screened using the specified selection and exclusion criteria, and 121 studies were reviewed based on their full texts. Finally, 962 studies (98.0%) were excluded, and 20 studies were selected for review. Full details of the literature review are shown in the flow diagram (Figure 1).

2. Methodological Quality of Included Studies

By evaluating the quality of the 20 selected studies (Appendix 1), we ensured that none showed a high risk of bias in any of the seven items. All of the chosen studies were RCTs. Concealment was performed using an opaque envelope or computerized number generator for 12 studies [A1, A3, A4, A7, A9, A10, A13, A14, A17–A20]. Some studies used strati-

fied randomized block design [A2, A15, A16] and minimization [A6, A12] for random allocation. Ten of the studies used blinding of either the participants or the assessors. Some studies [A12, A19, A20] suggested that the blinding of participants was not practicable in the research process. The lack of blinding may not have affected the results of these studies. There were seven studies that did not include a description of blinding [A1, A5, A7, A11, A15, A16, A18]. One study [A19] showed a dropout rate of more than 20% during the follow-up period, but this was a long-term follow-up period of 1 year. Six of the studies were of high quality and met all of the seven items [A2, A3, A6, A9, A14, A17]. There was no disagreement among the authors when it came to quality evaluation. The results are shown in Figure 2.

3. Characteristics of Selected Studies

The total number of subjects was 2,318 across the 20 included studies. Of the selected studies, 15 were performed in the United States, 2 each in the United Kingdom [A4, A12] and Australia [A2, A13], and 1 in China [A10]. All of the studies were published after 2011. There were seven large-scale RCTs with more than 100 subjects [A2, A4, A7–A10, A19] and two small studies [A6, A11] with fewer than 50 subjects. The average age of participants was in the 60s in only one study [A5], in the 20s in two studies [A7, A13], in the 30s in three studies [A2, A10, A18], and in the 50s in four stud-

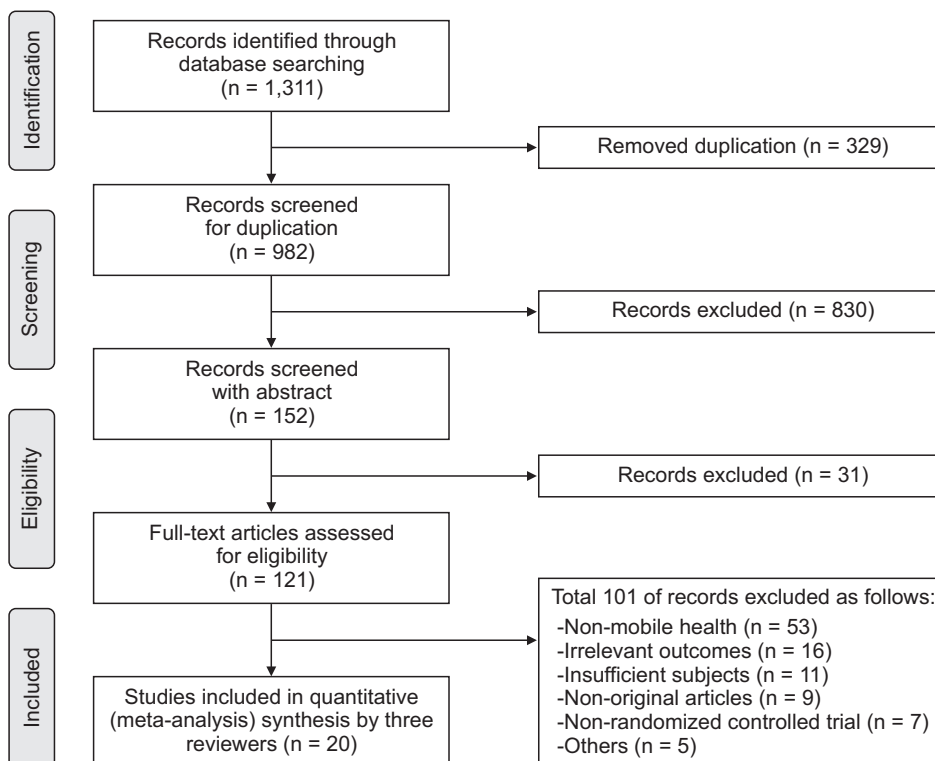


Figure 1. Flow diagram of study selection.

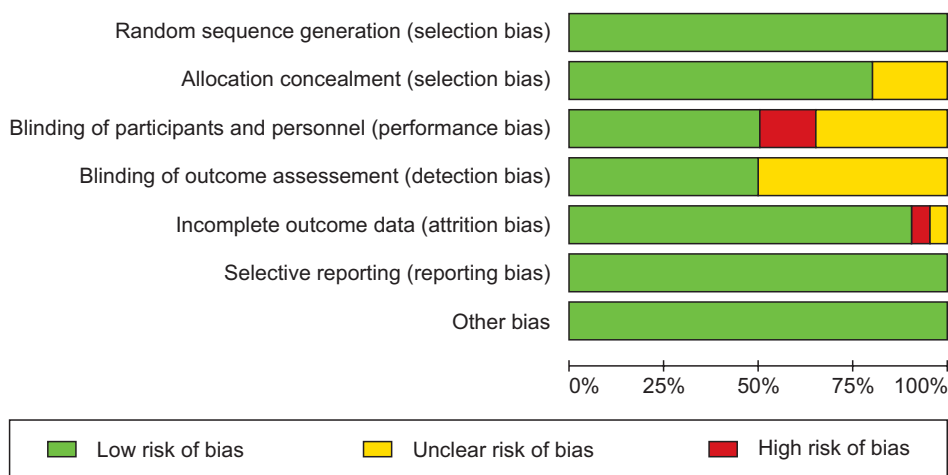


Figure 2. Risk of bias graph.

ies [A3, A9, A15, A16]. The majority of participants were in their 40s in 10 studies [A1, A4, A6, A8, A11, A12, A14, A17, A19, A20]. The subjects were pre-obese with BMI scores in the range of 25 to 30 kg/m² in three studies [A5, A10, A13], Class I obese with BMI scores in the range of 30.0 to 34.99 kg/m² in 10 studies [A1, A4, A6, A8, A11, A12, A14, A17, A19, A20], and Class II obese with BMI scores of 35.0 kg/m² or higher in five studies.

The mHealth program was relatively simple. In six studies [A1, A8, A13, A17, A19, A20], using a smartphone application, subjects were able to input their daily calories and various life activities such as exercise, providing information to be monitored. Seven studies [A6, A7, A9, A12, A14, A15, A18] were monitoring services that send and receive information with fixed times, and there were customized programs involving some devices, such as Fitbits or pedometers [A2, A3, A5], or personalized feedback like coaching was provided based on the monitored results [A4, A10, A11, A16]. The mHealth programs lasted for 3 months in five studies [A1, A2, A4, A6, A13], 4 months in three studies [A5, A14, A15], and 6 months in 10 studies [A3, A8–A12, A16–A18, A20]. One study ran for 12 months [A19] and another for 24 months [A7] (Table 2).

4. Effects of Mobile Health on Weight Loss

All of the studies measured weight loss (Figure 3). Analysis showed that body weight was reduced with a WMD of -2.35 kg (95% CI, -2.84 to -1.87) in obese adults, which was statistically significant ($Z = 9.53$, $p < 0.001$) in intervention groups in comparison to the control. However, heterogeneity among the studies was high, at 94% ($\chi^2 = 520.08$, $p < 0.001$). A detailed analysis of the length of intervention showed that mHealth could reduce body weight with a WMD of -2.25 kg (95% CI, -3.34 to -1.16) between 3 and 4 months, a WMD

of -2.66 kg (95% CI, -3.94 to -1.38) at 6 months, a WMD of -2.62 kg (95% CI, -4.81 to -0.43) at 9 months, and -1.23 kg (95% CI, -2.25 to -0.21) beyond 12 months. These results were statistically significant. However, the heterogeneity among the studies was higher than 85%, except in those that ran for 12 months or more ($I^2 = 0.0\%$, $\chi^2 = 1.49$, $p = 0.68$).

Because there was a high degree of heterogeneity among the studies, a sub-group analysis was performed, using the average age of the subjects, the type of obesity, BMI level, and the year of publication. However, this did not succeed in reducing the level of heterogeneity.

5. Effects of Mobile Health on BMI Changes

BMI changes were measured in six studies [A1, A10–A13, A18] (Figure 4). The meta-analysis showed that BMI decreased with a WMD of -0.77 kg/m² (95% CI, -1.01 to -0.52) in obese adults, which was statistically significant ($Z = 6.08$, $p < 0.001$); the heterogeneity among studies was 95% ($\chi^2 = 121.22$, $p < 0.001$). The mHealth program results varied by the length of intervention, decreasing BMI with a WMD of -1.10 kg/m² (95% CI, -2.79 to 0.59) at 3 months. There was a high level of heterogeneity among studies and no statistically significant difference in BMI ($I^2 = 95.0\%$, $\chi^2 = 36.90$, $p < 0.001$). At six months, the change in BMI was a WMD of -0.67 kg/m² (95% CI, -0.71 to -0.63); this was statistically significant. There was 0.0% heterogeneity ($\chi^2 = 1.00$, $p = 0.80$).

6. Publication Bias

The RevMan 5.3 program does not provide the statistical findings for the funnel plot. No distinct asymmetry was observed in the funnel plot, but there was mild publication bias shown in weight loss (Figure 5).

Table 2. Characteristics of selected studies

Study ^a	Year	Country	Method		Inclusion criteria	Participants			Follow-up		Outcomes				
			Concealment	Blinding		Group	Total	Anal-ysis	Sex (M:F)	Age (yr)	BMI (kg/m ²)	Interventions	Weight	BMI	
Hale et al. [A1]	2016	USA	List of random numbers		Overweight and obese adults; BMI 25.0–49.9 kg/m ²	Con. Exp.	25 26	21 21	5:20 4:22	43.9±12.9 48.4±11.9	33.2±5.3 36.2±6.3	3	Standard tracking app	○ ○	The Social Pound Off Digitally mobile app include diet, PA, and weight-tracking features, and calorie database with commonly consumed food and beverage for 3 months
Partridge et al. [A2]	2016	Australia	Stratified randomized block design	Subjects & researchers	Age 18–35 years with a high risk of weight gain; BMI 25.0–49.9 kg/m ²	Con. Exp.	125 123	46:79 50:73	- -	- -	3 & 9	Dietary guideline with 2 page handout	○	TXT2BFIT program; 8 weekly motivation text messages; 5 personalized coaching calls; weekly e-mail; education using mobile phone apps and support resources included diet, PA, meals, etc. for 3 months	
Ross & Wing [A3]	2016	USA	Computer generated	Researchers	Age 18–70 years; BMI 27–40 kg/m ²	Con. Exp.	26 27	4:22 4:23	54.2±9.5 52.9±0.3	- -	6	Traditional weight management	○	Phone based weight loss program; Fitbit Zip activity monitor and phone-based intervention contact for 6 months	

Table 2. Continued 1

Study ^a	Year	Country	Method		Inclusion criteria	Participants			Follow-up (mo)		Interventions	Outcomes		
			Concealment	Blinding		Group	Total	Anal-ysis	Sex (M:F)	Age (yr)		BMI (kg/m ²)	Weight	BMI
Sidhu et al. [A4]	2016	UK	Computer generated	Subjects assessors	Age ≥18 years	Con. Exp.	190 190	155 151	19:171 20:170	47.0±13.7 47.8±13.1	34.4±5.3 34.5±4.8	3 & 9	Usual care	○
													SMS-text based Lighten Up	
													Plus intervention; weekly texts asking for weight, advice diet and PA, etc. for 3 months	
Cadmus-Bertram et al. [A5]	2015	USA			Overweight, menopausal women with BMI ≥25 kg/m ²	Con. Exp.	26 25	0:26 0:25	61.3±7.5 58.6±6.5	29.1±3.2 29.2±3.8	4	Pedometer	○	
													Web-based tracking; Fitbit based PA intervention for 4 months	
Martin et al. [A6]	2015	USA	Minimization allocation method	Researchers	Overweight and obese adults; Age 18-65 years; BMI 25-35 kg/m ²	Con. Exp.	20 20	3:17 4:16	43.3±2.6 45.6±2.7	29.5±3.2 30.2±2.7	3	Health education	○	
													SmartLoss intervention by a smartphone (Blackberry VR Curve 8320; Waterloo, Ontario, Canada); provided weight graph and feedback for 3 months	
Svetkey et al. [A7]	2015	USA	Equal allocation		Overweight or obesity; Age 18-35 years; BMI ≥25 kg/m ²	Con. Exp.	123 121	38:85 38:84	29.6±4.3 29.2±4.2	35.1±7.5 35.7±8.2	6 & 12 & 24	Three handouts on healthy eating and PA	○	
													Personal coaching enhanced by smartphone self-monitoring; tracking weight, dietary intake and PA, etc. for 24 months	

Table 2. Continued 2

Study ^a	Year	Country	Method			Participants				Follow-up		Outcomes		
			Concealment	Blinding	Inclusion criteria	Group	Total	Anal-ysis (M:F)	Sex	Age (yr)	BMI (kg/m ²)	up (mo)	Interventions	Weight
Laing et al. [A8]	2014	USA		Researchers	Primary care patients; Age ≥18 years; BMI ≥25 kg/m ²	Con. Exp.	107	26:81	43:2±15.0	33.3±7.0	6	Usual primary care		○
Lin et al. [A9]	2014	USA	Web-based program	Researchers	Aged ≥21 years; BMI >27 kg/m ²	Con. Exp.	61	13:48	52.3±12.0	37.5±8.9	6	Standard care		○
Lin et al. [A10]	2014	China	Computer generated	Researchers	Overweight adults; Age 30–50 years; BMI ≥24 kg/m ²	Con. Exp.	60	24:36	38.1±8.1	28.4±0.5	6	Brief advice session		○
Allen et al. [A11]	2013	USA		Volunteers	Age 18–65 years; BMI ≥27 kg/m ²	Con. Exp.	18	4:14	42.5±12.1	34.1±4.1	6	Intensive counseling		○
Carter et al. [A12]	2013	UK	Minimization allocation method	Assessors	Age 18–65 years; BMI ≥27 kg/m ²	Con. Exp.	43	9:34	42.5±8.3	34.5±5.7	6	Paper food diary, calorie-counting book and calculator		○
						Exp.	43	10:33	41.2±8.5	33.7±4.2		My Meal Mate app; detailed self-monitoring (of diet, PA, and weight) and feedback for 6 months		○

Table 2. Continued 3

Study ^a	Year	Country	Method		Participants				Follow-up		Outcomes				
			Concealment	Blinding	Inclusion criteria	Group	Total	Anal-ysis	Sex (M:F)	Age (yr)	BMI (kg/m ²)	Interventions	Weight	BMI	
Hebden et al. [A13]	2013	Australia	Computer generated	Subjects	University students; Age 18–35 years; BMI 23–31.9 kg/m ²	Con. Exp.	25	6:19	23.1±3.7	27.2±2.5	3	Diet booklet	mHealth program; gender-specific SMS messages (4 weeks), e-mail (4 weeks) for 3 months	○	○
Norman et al. [A14]	2013	USA	Computer generated	Subjects and study staff	Overweight or obesity; Age 25–55 years; BMI 25–39.9 kg/m ²	Con. Exp.	33	13:52	46.0±7.0	32.8±3.9	4	Usual care using print materials	2–5 weight management text-message per day; Three 24-hour recalls assessed fruit/vegetable intake change for 4 months	○	○
Shaw et al. [A15]	2013	USA	Permuted block randomization	Participants on Duke Diet and Fitness Center	Participants on Duke Diet and Fitness Center	Con. Exp.	39	4:25	54.8±15.9	37.3±6.3	4	General health message	Received a daily mobile health message; PA, low-calories healthy diet and monitoring of body weight for 4 months	○	○
Spring et al. [A16]	2013	USA	Stratified randomization	Overweight and obese adults; BMI 25–40 kg/m ²	Overweight and obese adults; BMI 25–40 kg/m ²	Con. Exp.	35	30:5	57.7±10.2	35.8±3.8	3 & 6	Standard care	Mobile technology system; personal digital assistants to self-monitor diet and PA; biweekly coaching calls for 6 months	○	○

Table 2. Continued 4

Study ^a	Year	Country	Method		Inclusion criteria	Group	Participants			Follow-up (mo)	Interventions	Outcomes	
			Concealment	Blinding			Total	Anal-ysis (M:F)	Sex (M:F)			Age (yr)	BMI (kg/m ²)
Steinberg et al. [A17]	2013	USA	Blind randomization	Subjects and study staff	Age 18–60 years; BMI 25–40 kg/m ² and maximum weight of 330 lbs.	Con. Exp.	44 44	9:35	44.7±10.6	31.0±3.1	3 & 6	Delayed intervention	○
							47 45	14:33	43.0±11.4	33.2±4.0		Daily self-weighting weight loss intervention using smart scale and e-mail for 6 months	
Steinberg et al. [A18]	2013	USA	Computer generated		Age 25–50 years; BMI ≥25 kg/m ²	Con. Exp.	24 26	0:24 0:26	39.0±9.0 37.6±7.4	34.6±5.8 36.9±6.2	6	Education	○
												Daily text messaging for weight control; self-monitoring tailored behavioral goals along with feedback and tips for 6 months	
Shapiro et al. [A19]	2012	USA	Computer generated and sealed envelope	No	Age 21–65 years; BMI 25–39.9 kg/m ²	Con. Exp.	89 81	34:55 27:54	40.9±12.1 43.1±11.4	32.0±4.0 32.4±4.2	6 & 12	Monthly e-newsletter	○
												Text4Diet message include sugar-sweetened beverages, sedentary time, PA; daily step monitoring via pedometers, etc. for 12 months	
Turner-McGrievy & Tate [A20]	2011	USA	Computer generated	No	Overweight and obese adults; Age 18–60 years; BMI 25–45 kg/m ²	Con. Exp.	49 47	13:36 11:36	43.2±11.7 42.6±10.7	32.2±4.5 32.9±4.8	3 & 6	Podcast	○
												Podcast plus enhanced mobile media; monitoring apps (FatSecret's Calorie Counter) for 6 months	

BMI: body mass index, SMS: Short Message Service, PA: physical activity.

^a A list of studies is in Appendix 1.

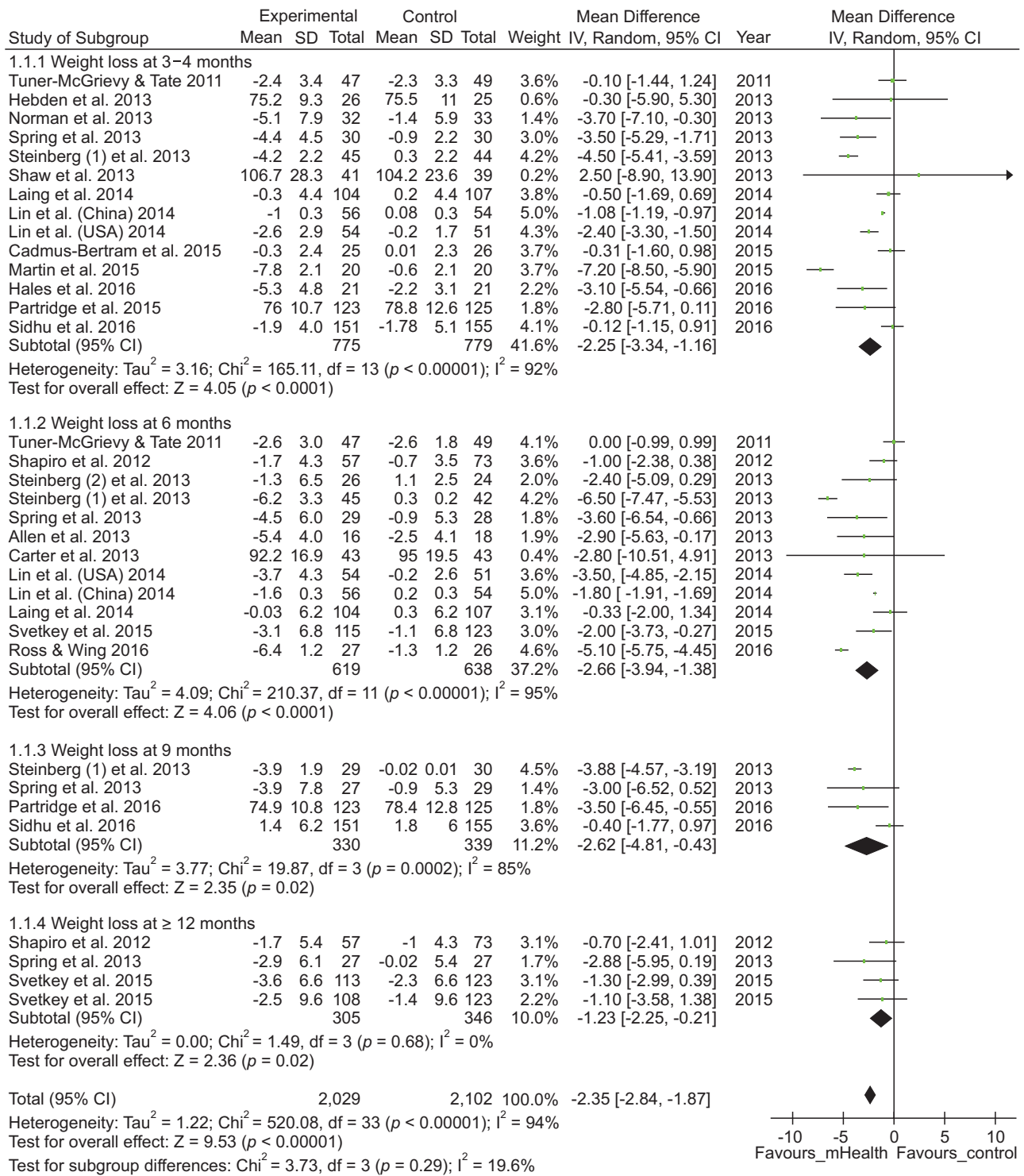


Figure 3. Weight-loss responses to mobile health.

IV. Discussion

This study examined the effects of mHealth, using mobile phones as a weight loss intervention for obese adults. The results obtained by the meta-analysis of 20 RCTs involving 2,318 obese adults provided scientific evidence that mobile

phone-based interventions have some effect in reducing body weight and BMI in the short term.

Of the 20 studies included in this study, 16 were conducted in the United States. This seems to be related to the spread of mobile phones. In July 2008, access to apps was revolutionized with the release of the App Store, which allows apps

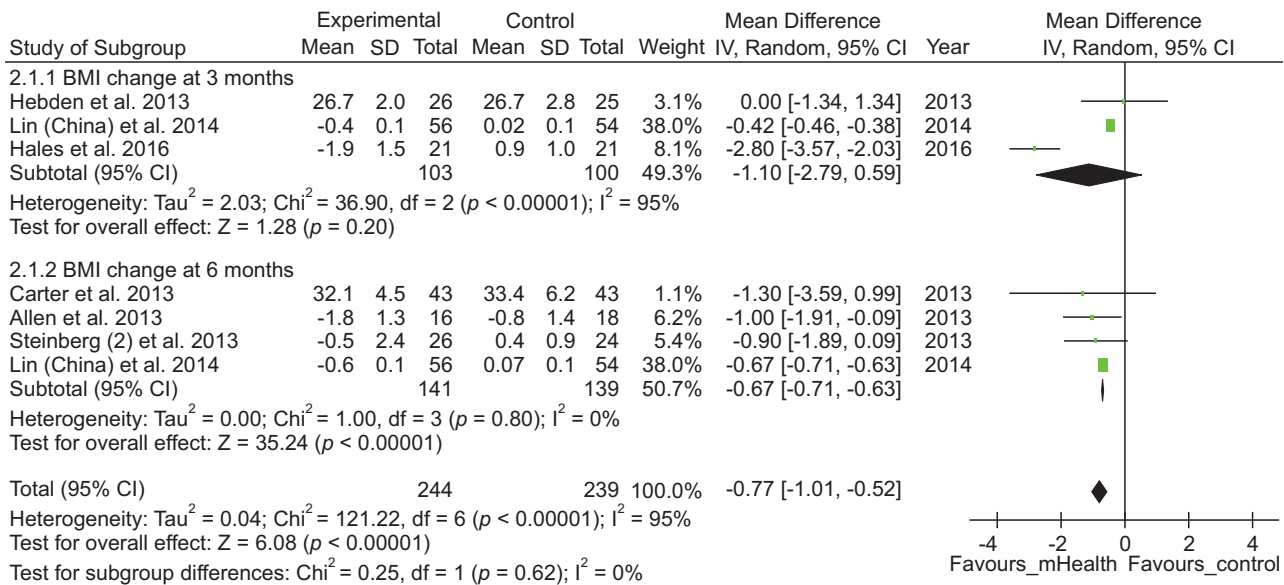


Figure 4. Body mass index (BMI) change responses to mobile health.

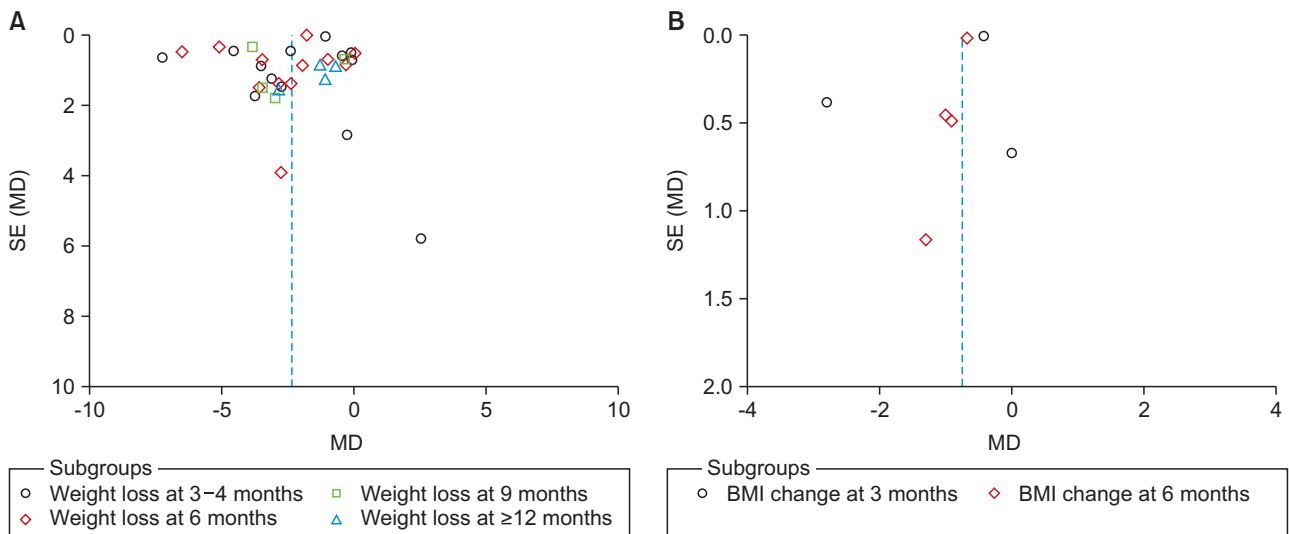


Figure 5. Funnel plots of weight loss (A) and BMI change (B). BMI: body mass index, SE: standard error, MD: mean difference.

to be downloaded from online marketplaces [21,22]. This technological advance has led to the development of apps for the prevention and management of chronic diseases, such as diabetes, obesity, and heart disease [23]. The 20 studies selected demonstrate that mHealth research using apps began in 2010 and gradually increased.

As a result, the body weight of obese adults has been reduced, with a WMD of -2.35 kg (95% CI, -2.84 to -1.87). According to the guideline for the management of obesity of SIGN [24], weight loss programs are successful when there is a decrease in weight by 5% to 10% (approximately 5 to 10 kg) minimum compared to the initial body weight. Therefore, a 2 kg weight loss in obese adults with a BMI of 25 kg/m² or

more is not sufficient to interpret as an effective result. However, the effect of mHealth on obese adults seems evident in comparison to the results of six weight loss studies (WMD -1.09 kg; 95% CI, -2.12 to -0.05) presented by Khokhar et al. [15]. It is worth noting that mHealth programs of different durations produced different results. Analyzing the weight-loss effect every 3 months for 1 year showed that the effect slightly increased at 6 months (WMD = -2.66 kg), in comparison to 3 months (WMD = -2.25 kg). At 9 months (WMD = -2.62 kg), the weight loss tended to be maintained, but at 12 months, the WMD decreased to -1.23 kg.

In addition, only six studies that reported changes in mHealth BMI were analyzed at the 3- and 6-month marks. A

meta-analysis showed that BMI decreased by -1.10 kg/m^2 at 3 months, but was not statistically significant. At 6 months, the reduction was -0.67 kg/m^2 , which was statistically significant; there was also no heterogeneity between studies (0.0%).

Therefore, combining these two results suggests that weight loss through the mHealth program shows a modest short-term effect among obese adults. However these results were analyzed according to the follow-up months presented in the included studies. In most studies [A1, A3, A5, A6, A8–A15], the duration of intervention and follow-up was the same. However, in some studies [A2, A4, A16], they were followed up either after intervention or showed outcomes like weight loss at some point during intervention [A7, A17, A19, A20]. Therefore, this may be the result of discrepancies between intervention periods and follow-up periods, and this is one of the limitations of this study.

Obesity is caused by an imbalance in dietary intake and energy consumption. The main interventions used to control obesity are diet, energy and nutrient balance, and exercise. At this point, mHealth should provide the necessary information to maximize the effects of diet and exercise, giving warning messages and feedback to prevent inappropriate behavior. In addition, it should actively intervene in real-time weight-loss programs by using devices connected to mobile phones. Among the advantages of mHealth are quick access to information and multimedia resources, flexible intercommunications, portability, and convenience [25].

The content of the mHealth programs covered in the 20 studies has evolved. In 2011 and 2012, these programs sent text messages, providing simple information about calories and daily life activities. These programs have now become monitoring services that send and receive fixation information as part of a customized program involving other devices, such as Fitbits and pedometers; they also provide feedback, such as coaching. This study has not analyzed versions of mHealth that use recently developed biosensor or wearable devices. It is therefore premature to argue that the effects of mHealth can be precisely determined. The types of mHealth intervention in the included studies were different. Therefore, this is one of the limitations of this study. Various recent advances in the program, coupled with the inefficiencies of users entering information, have not yet been analyzed through research. In the future, mHealth will not only measure and provide feedback on behavioral changes, it will also need to innovate by intervening more actively to determine the behavior of obese adults based on evidence, such as cognitive behavior theory.

There are few limitations in this study. The high heteroge-

neity among studies in this study remains a critical issue. In all of the studies, the results of weight change were analyzed and sub-group analyses were carried out, focusing on the mean age, type of obesity, the BMI levels of participants and so forth; this extra layer of analysis did not reduce heterogeneity. Therefore, we did not describe the results in detail in this paper. This may be the cause of the difference between the intervention period and the follow-up period, as mentioned above. This is because mHealth is not a mediator that directly affects weight loss, such as calorie restriction or exercise; rather, it acts as a mediator to stimulate dieting and exercise programs in obese adults. This may be attributed to the fact that the work was a pilot study with a small number of subjects. We therefore propose a large-scale RCT of the effect of duration in the mHealth program and on mHealth content for diverse age groups.

The results of this study showed that mHealth intervention for obese adults led to a modest short-term effect on body weight and BMI. The mobile phone provides convenience in everyday life; weight-loss options using mHealth have recently expanded. It is therefore difficult to definitively determine the effect of mHealth at this point. In the future, mHealth is expected to have a significant impact on reducing adult obesity, given improved service content available through mHealth, the convenience of the mobile phone, and mHealth's ability to actively intervene in the daily life of obese adults in real time. It is therefore necessary to expand studies applying mHealth interventions not only to obese adults but also to various age groups.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Acknowledgments

This study was funded by the Ministry of Health & Welfare (No. 11-1352000-001926-01) and the Soonchunhyang University.

ORCID

Seong-Hi Park (<https://orcid.org/0000-0002-5495-3291>)

Jeonghae Hwang (<https://orcid.org/0000-0002-7428-5761>)

Yun-Kyoung Choi (<https://orcid.org/0000-0001-7591-0277>)

References

1. World Health Organization. Obesity and overweight fact sheet [Internet]. Geneva, Switzerland: World Health Organization; 2018 [cited at 2019 Jan 10]. Available from: <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>.
2. World Health Organization. Global strategy on diet, physical activity and health [Internet]. Geneva, Switzerland: World Health Organization; 2004 [cited at 2019 Jan 10]. Available from: http://www.who.int/dietphysicalactivity/strategy/eb11344/strategy_english_web.pdf.
3. NCD Risk Factor Collaboration (NCD-RisC). Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19.2 million participants. *Lancet* 2016;387(10026):1377-96.
4. Rosenbaum M, Leibel RL, Hirsch J. Obesity. *N Engl J Med* 1997;337(6):396-407.
5. Wadden TA, Foster GD. Behavioral assessment and treatment of markedly obese patients. In: Wadden TA, Van Itallie TB, editors. *Treatment of the seriously obese patient*. New York (NY): Guilford Press; 1992. p. 290-330.
6. National Institutes of Health. Methods for voluntary weight loss and control: National Institutes of Health Technology Assessment Conference statement Mar 30-Apr 1, 1992. Bethesda (MD): National Institutes of Health; 1992.
7. Kim MK, Lee WY, Kang JH, Kang JH, Kim BT, Kim SM, et al. 2014 Clinical practice guidelines for overweight and obesity in Korea. *Korean J Obes* 2014;23(4):217-21.
8. Silva BM, Rodrigues JJ, de la Torre Diez I, Lopez-Coronado M, Saleem K. Mobile-health: a review of current state in 2015. *J Biomed Inform* 2015;56:265-72.
9. Vital Wave Consulting. *mHealth for development: the opportunity of mobile technology for healthcare in the developing world*. Washington (DC): Vodafone Foundation; 2009.
10. Woo HK, Sim EY, Cho YT. Big data and mobile health: public health values and future challenges. *Statistical Research* 2016;(special issue):96-111.
11. Boulos MN, Wheeler S, Tavares C, Jones R. How smartphones are changing the face of mobile and participatory healthcare: an overview, with example from eCAA-LYX. *Biomed Eng Online* 2011;10:24.
12. Lee MH, Kim J, Jee SH, Yoo SK. Integrated solution for physical activity monitoring based on mobile phone and PC. *Healthc Inform Res* 2011;17(1):76-86.
13. Ghorai K, Akter S, Khatun F, Ray P. mHealth for smoking cessation programs: a systematic review. *J Pers Med* 2014;4(3):412-23.
14. Cajita MI, Gleason KT, Han HR. A systematic review of mHealth-based heart failure interventions. *J Cardiovasc Nurs* 2016;31(3):E10-22.
15. Khokhar B, Jones J, Ronksley PE, Armstrong MJ, Caird J, Rabi D. Effectiveness of mobile electronic devices in weight loss among overweight and obese populations: a systematic review and meta-analysis. *BMC Obes* 2014;1:22.
16. Lyzwinski LN. A systematic review and meta-analysis of mobile devices and weight loss with an intervention content analysis. *J Pers Med* 2014;4(3):311-85.
17. Higgins JP, Green S; Cochrane Collaboration. *Cochrane handbook for systematic reviews of interventions*. Chichester, UK: John Wiley & Sons; 2011.
18. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Intern Med* 2009;151(4):264-9, W64.
19. Scottish Intercollegiate Guidelines Network. Search filters [Internet]. Edinburgh: Scottish Intercollegiate Guidelines Network; c2019 [cited at 2019 Jan 10]. Available from: <https://www.sign.ac.uk/search-filters.html#diag>.
20. Pi-Sunyer FX. Obesity: criteria and classification. *Proc Nutr Soc* 2000;59(4):505-9.
21. Murfin M. Know your apps: an evidence-based approach to evaluation of mobile clinical applications. *J Physician Assist Educ* 2013;24(3):38-40.
22. Payne KB, Wharrad H, Watts K. Smartphone and medical related app use among medical students and junior doctors in the United Kingdom (UK): a regional survey. *BMC Med Inform Decis Mak* 2012;12:121.
23. Robinson R. App revolution: avoiding the app trap. *PharmaVOICE* 2014;14(2):24-8.
24. Scottish Intercollegiate Guidelines Network. Management of obesity [Internet]. Edinburgh: Scottish Intercollegiate Guidelines Network; 2010 [cited at 2019 Jan 10]. Available from: <http://www.sign.ac.uk/sign-115-management-of-obesity.html>.
25. Ventola CL. Mobile devices and apps for health care professionals: uses and benefits. *P T* 2014;39(5):356-64.

Appendix 1. List of studies included in a systematic review

- A1. Hales S, Turner-McGrievy GM, Wilcox S, Fahim A, Davis RE, Huhns M, et al. Social networks for improving healthy weight loss behaviors for overweight and obese adults: a randomized clinical trial of the social pounds off digitally (Social POD) mobile app. *Int J Med Inform* 2016 Oct;94:81-90.
- A2. Partridge SR, McGeechan K, Bauman A, Phongsavan P, Allman-Farinelli M. Improved eating behaviours mediate weight gain prevention of young adults: moderation and mediation results of a randomised controlled trial of TXT2BFiT, mHealth program. *Int J Behav Nutr Phys Act* 2016;13:44.
- A3. Ross KM, Wing RR. Impact of newer self-monitoring technology and brief phone-based intervention on weight loss: a randomized pilot study. *Obesity (Silver Spring)* 2016;24(8):1653-9.
- A4. Sidhu MS, Daley A, Jolly K. Evaluation of a text supported weight maintenance programme 'Lighten Up Plus' following a weight reduction programme: randomized controlled trial. *Int J Behav Nutr Phys Act* 2016;13:19.
- A5. Cadmus-Bertram LA, Marcus BH, Patterson RE, Parker BA, Morey BL. Randomized trial of a Fitbit-based physical activity intervention for women. *Am J Prev Med* 2015;49(3):414-8.
- A6. Martin CK, Miller AC, Thomas DM, Champagne CM, Han H, Church T. Efficacy of SmartLoss, a smartphone-based weight loss intervention: results from a randomized controlled trial. *Obesity (Silver Spring)* 2015;23(5):935-42.
- A7. Svetkey LP, Batch BC, Lin PH, Intille SS, Corsino L, Tyson CC, et al. Cell phone intervention for you (CITY): a randomized, controlled trial of behavioral weight loss intervention for young adults using mobile technology. *Obesity (Silver Spring)* 2015;23(11):2133-41.
- A8. Laing BY, Mangione CM, Tseng CH, Leng M, Vaisberg E, Mahida M, et al. Effectiveness of a smartphone application for weight loss compared with usual care in overweight primary care patients: a randomized, controlled trial. *Ann Intern Med* 2014;161(10 Suppl):S5-12.
- A9. Lin M, Mahmooth Z, Dedhia N, Frutchey R, Mercado CE, Epstein DH, et al. Tailored, interactive text messages for enhancing weight loss among African American adults: the TRIMM randomized controlled trial. *Am J Med* 2015;128(8):896-904.
- A10. Lin PH, Wang Y, Levine E, Askew S, Lin S, Chang C, et al. A text messaging-assisted randomized lifestyle weight loss clinical trial among overweight adults in Beijing. *Obesity (Silver Spring)* 2014;22(5):E29-37.
- A11. Allen JK, Stephens J, Dennison Himmelfarb CR, Stewart KJ, Hauck S. Randomized controlled pilot study testing use of smartphone technology for obesity treatment. *J Obes* 2013;2013:151597.
- A12. Carter MC, Burley VJ, Nykjaer C, Cade JE. Adherence to a smartphone application for weight loss compared to website and paper diary: pilot randomized controlled trial. *J Med Internet Res* 2013;15(4):e32.
- A13. Hebden L, Cook A, van der Ploeg HP, King L, Bauman A, Allman-Farinelli M. A mobile health intervention for weight management among young adults: a pilot randomised controlled trial. *J Hum Nutr Diet* 2014;27(4):322-32.
- A14. Norman GJ, Kolodziejczyk JK, Adams MA, Patrick K, Marshall SJ. Fruit and vegetable intake and eating behaviors mediate the effect of a randomized text-message based weight loss program. *Prev Med* 2013;56(1):3-7.
- A15. Shaw RJ, Bosworth HB, Silva SS, Lipkus IM, Davis LL, Sha RS, et al. Mobile health messages help sustain recent weight loss. *Am J Med* 2013;126(11):1002-9.
- A16. Spring B, Duncan JM, Janke EA, Kozak AT, McFadden HG, DeMott A, et al. Integrating technology into standard weight loss treatment: a randomized controlled trial. *JAMA Intern Med* 2013;173(2):105-11.
- A17. Steinberg DM, Tate DF, Bennett GG, Ennett S, Samuel-Hodge C, Ward DS. The efficacy of a daily self-weighing weight loss intervention using smart scales and e-mail. *Obesity (Silver Spring)* 2013;21(9):1789-97.
- A18. Steinberg DM, Levine EL, Askew S, Foley P, Bennett GG. Daily text messaging for weight control among racial and ethnic minority women: randomized controlled pilot study. *J Med Internet Res* 2013;15(11):e244.
- A19. Shapiro JR, Koro T, Doran N, Thompson S, Sallis JF, Calfas K, et al. Text4Diet: a randomized controlled study using text messaging for weight loss behaviors. *Prev Med* 2012;55(5):412-7.
- A20. Turner-McGrievy G, Tate D. Tweets, apps, and pods: results of the 6-month mobile Pounds off digitally (mobile POD) randomized weight-loss intervention among adults. *J Med Internet Res* 2011;13(4):e120.