Nurse Media JOURNAL OF NURSING

Nurse Media Journal of Nursing
e-ISSN: 2406-8799, p-ISSN: 2087-7811
https://ejournal.undip.ac.id/index.php/medianers
12(1):133-150, April 2022
https://doi.org/10.14710/nmjn.v12i1.41139

REVIEW

Digital Health Interventions to Improve Cardiometabolic Risk Profile among Adults with Obesity and Chronic Diseases: A Systematic Review

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Article Info

Article History:
Received: 2 September 2021
Revised: 23 March 2022
Accepted: 29 March 2022
Online: 27 April 2022

Keywords:
Adults, cardiometabolic risk, chronic disease, digital health

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Abstract

Background: The prevalence of chronic diseases is rapidly increasing globally. Ubiquitous digital technologies give an opportunity for digital health intervention to improve cardiometabolic risk (CMR) profile that may consequently decrease the risk of chronic diseases. However, evidence on digital health associated with chronic disease interventions remains controversial.
Purpose: This systematic review aimed to determine the association of digital health intervention with improving CMR profile of adults with obesity and chronic diseases.
Methods: A comprehensive search of Medline, CINAHL, Embase, and PubMed was performed using the following criteria: publication between 2016-2021, using digital health tools as interventions, adults with obesity or chronic diseases, cardiometabolic profile as outcomes, and randomized controlled trial (RCT) as the design. The search yielded 548 articles of which 13 studies met the inclusion criteria. The Joanna Briggs checklist for RCT was used to assess the quality of the studies. Data analysis was conducted according to the guidance for synthesis without meta-analysis.
Results: There were 8 (61.5%) out of 13 studies assessed the relationship between digital health interventions and weight, of which 7 studies (88%) found positive findings. The association between digital health intervention and blood pressure were assessed in 7 (53.8%) out 13 studies, of which only two studies had positive findings related with systolic blood pressure. The intervention modalities included m-Health (apps) in 2 studies, text-messaging in 4 studies, and combinations of modalities in 8 studies. The interventions used different strategies, including education, self-management, and social support. More than a half of the studies (54%) were about weight-loss interventions and 10 (76.9%) studies used education for intervention components.
Conclusions: Digital health intervention may be associated with decreased weight and BMI; however, only a few studies assessed other CMR profile, and the findings were inconsistent. Additional studies are needed to assess digital health interventions targeting other CMR profile, including blood pressure, glucose, and cholesterol level.

How to cite: Nisa H., & Barsbay, F. (2022). Digital health interventions to improve cardiometabolic risk profile among adults with obesity and chronic diseases: A systematic review. *Nurse Media Journal of Nursing, 12*(1), 133-150. https://doi.org/10.14710/nmjn.v12i1.41139

1. Introduction

Chronic diseases are the largest cause of death globally (Bennett et al., 2018a). The leading chronic diseases such as cardiovascular diseases (CVDs), cancer, chronic lung disease, and diabetes collectively caused 32.8 million deaths worldwide, of which 77% occur in low- and middle-income countries (WHO, 2021). Adoption of modern lifestyles affects morbidity and mortality of the chronic diseases (Patterson et al., 2018). Many studies have shown that interventions targeting cardiometabolic risk (CMR) profile were associated with the reduce risk of chronic diseases (Pereira et al., 2020; Ralston et al., 2019; Sundfør et al., 2018).

CMR profile refers to conditions that increases the likelihood of developing of common chronic diseases, such as CVDs or type-2-diabetes mellitus (T2DM). CMR, mostly prevalent in patients with metabolic syndrome (Aghakhanian et al., 2019), is a group of metabolically interrelated risk factors indicating high level of blood pressure, fasting blood sugar, cholesterol, obesity, and triglycerides (Ruilope, 2007). The strong associations of CMR with diabetes and cardiovascular health provide a convincing reason to reduce CMR events through early assessment and targeted interventions (Wilson et al., 2005). Thus, innovative method of cost-effective strategy targeting high-risk individuals, primarily adults with obesity or chronic diseases, is important to prevent further deterioration of health (Milani et al., 2017). Recently, many studies have integrated digital technology as one of the modalities in intervention program for people with obesity (Bennett et al., 2018b; Liyana et al., 2018; Lugones-Sanchez et al., 2020; Senecal et al., 2020a) or chronic diseases (Jahan et al., 2020; Toro-Ramos et al., 2020; Wang et al., 2020) .

Digital health is defined as technology used for improving the public's health and health services through mobile computing of clinical and genetic data (Fatehi et al., 2020). Digital health includes mobile health, mobile applications, health information technology, wearable devices, telehealth and telemedicine, social media, and website (Ronquillo et al., 2021). These technologies offer to educate patients by providing awareness into their behaviors and opportunities to practice new skills (Kuwabara et al., 2020). A systematic review demonstrated that women with diabetes receiving preconception care education through eHealth had significant improvements in knowledge and attitudes toward preconception care. In addition, intervention using eHealth showed a significant improvement in glycosylated hemoglobin levels with fewer preterm deliveries and adverse fetal outcomes (Nwolise et al., 2016). Multiple studies have suggested that mobile health (m-Health) interventions could be effective to promote healthy lifestyles and to support behavior change to smoking cessation, physically active, and less alcohol drink (Ek et al., 2020; Ludwig et al., 2018; Thomas et al., 2016; Whittaker et al., 2019). A meta-analysis of 13 studies among smokers of any age, primarily in high-income countries, showed that mobile text-based smoking cessation interventions resulted in a high likelihood of smoking cessation compared with less smoking cessation support; however, a smoking cessation smartphone apps with lower-intensity smoking cessation support was less likely to improve smoking cessation (Whittaker et al., 2019).

In recent decades, the transformation of digital health tools has enabled a rapidly increasing new field of digital public health (Conard, 2019). The WHO Global Observatory for eHealth assessed the evolution of digital health and its impact in 114 countries through a survey in 2009 (Ryu, 2012). The results showed that at least one type of m-Health service offered in majority of countries (83%). M-Health activity was found more in higher-income countries than in lower-income countries, whereas the greatest barrier to m-Health adoption by responding countries was the problem of competing health system priorities. Result-based evaluations of m-Health implementations were not routinely conducted, reporting an only 12% of countries had evaluating m-Health services. In addition, the survey underlined that the dominant form of m-Health was characterized by small-scale pilot projects that focused on single issues related to information sharing and access (Ryu, 2012).

The innovative approach of digital health may improve the individual's participation in promoting health and improving CMR profile (Burke et al., 2015). The increased use of digital health permits for modifying interventions suitable with each person, as the results from innovations in data analytics and health informatics. Digital health tools do not only help communication but also allow patients to better track and monitor their own health and wellness. A web-based self-management intervention for people with T2DM in the UK primary care has been shown to lower HbA1c over 12 months (Murray et al., 2017) and be cost-effective compared to usual care (Li et al., 2018). Several studies have shown the implementation strategy for a such digital health intervention in routine healthcare to improve glycemic control (Khunti et al., 2012; Ross et al., 2018). Furthermore, digital health interventions have been reported to change multiple-lifestyle health behavior including control obesity, encourage increased physical activity, healthy diet, smoking cessation, and control alcohol drinking. A randomized controlled trial including an intervention group (n=403) and a control group (n=387) among adults interested in reducing their cardiovascular risks showed that an 8-week web-based computer-tailored multiple-lifestyle interventions was associated with an increasing self-reported habit for physical activity and fruit and vegetable consumption (Storm et al., 2016). The effectiveness of health behavior change interventions using social networking cites was also reported in a meta-analysis of 21 studies, but the effects were moderated by health topic, methodological features, and participant features (Yang, 2017).

As the prevalence of chronic diseases continues to increase globally, digital tools as means for health intervention are necessary to reduce CMR profile. The results in a review that examined the effectiveness of m-Health interventions in patients with diabetes, hypertension, and dyslipidemia was inconsistent among different outcomes, suggesting an uncertainty regarding the effectiveness of different m-Health interventions (Cajita et al., 2021). However, the review was based on narrative syntheses with a lack of description of the methods used; unclear links between the included data, the synthesis, and the conclusions; as well as inadequate reporting of the limitations of the synthesis (Cajita et al., 2021). Digital health tools will continue to grow as they are becoming more ubiquitous with technological advances. According to the International Telecommunications Union (ITU), the mobile phone subscriptions worldwide increased in 2021 with a record 110 subscriptions per 100 inhabitants (ITU, 2021). This growth potentially benefits the use of digital tools for health intervention as cardiometabolic disorder continue to be the leading causes of morbidity and mortality worldwide (WHO, 2021). While digital health technology continues to change, we require a better understanding of digital health interventions with of chronic diseases. Therefore, it is important to review the evidence from studies on interventions using digital health tools to improve CMR risk profile. This systematic review aimed to determine whether digital health interventions was associated with improving CMR profile of adults with obesity and chronic diseases.

2. Methods

2.1 Research design

This systematic review was performed based on the Cochrane library guideline and PRISMA criteria (Rethlefsen et al., 2021).

2.2 Search methods

The articles' search was conducted by the second author (FB) to include articles published in English language within the years of 2016-June 2021, as digital health intervention studies were more available in this period. The final searches were conducted on June 5, 2021. Through the duration of the systematic review, the following databases and search engines were used: Embase, Medline, CINAHL, and PubMed. The search aimed to retrieve articles on digital health interventions to improve CMR profiles (Spaulding et al., 2021). The search keywords were informed by the search query of a recently published systematic review (Spaulding et al., 2021). In addition to the search query, the following terms were used to return articles of cardiometabolic lipid profile and smoking behavior: cholesterol OR lipid OR hyperlipid* AND smok*. The following keywords were used to identify candidate studies of other cardiometablic profiles and lifestyle factor: obesity OR overweight OR weight loss OR weight reduction OR weight loss maintenance OR weight control OR body weight maintenance OR weight regain OR body weight changes OR weight reduction programs OR weight reduction diets OR obes* OR Heart Diseases OR Vascular Diseases OR Cardiovascular Diseases OR Coronary Artery Diseases OR heart failure OR hypertens*, OR high blood pressure OR Diabetes Mellitus OR Exercise OR diabete* OR exercis* OR physical activity. In addition, the following terms were also used to return articles of digital health and design study: (Mobile Applications OR Computers, Handheld OR iphone* OR android OR smart phone OR smart phones OR smartphone OR mobile app OR mobile apps OR mHealth OR mobile health) AND (Randomized Controlled Trial OR mixed-methods).

2.3 Inclusion and exclusion criteria

Articles were eligible for inclusion if the use of digital health intervention was evaluated in those with obesity or chronic diseases. To be included, interventions should be published between January 2016 and June 2021, involved adult populations age of 19-64 years, used digital technology, focused on modifying lifestyle behaviors (smoking, alcohol intake, diet, weight, physical activity, and sedentariness), assessed cardiometabolic profile as outcomes, and having a randomized controlled trial (RCT) as study. Articles were excluded if interventions did not involve adults or were not required engagements. Studies with the sample size of less than 50 participants in intervention group were also excluded to minimize obtaining conclusions from underpower studies. Further, articles were excluded if not in English language.

2.4 Screening of articles

Each retrieved title and abstract were screened by the first author (HN) to determine articles' eligibility for full-text review after duplicate removal. The articles identified for full-text review were independently examined for inclusion by the two authors (HN and FB). Any discrepancies were discussed between the two authors. A consensus was reached on all the articles eligible for inclusion. The PRISMA flowchart was used for articles screening (Figure 1).

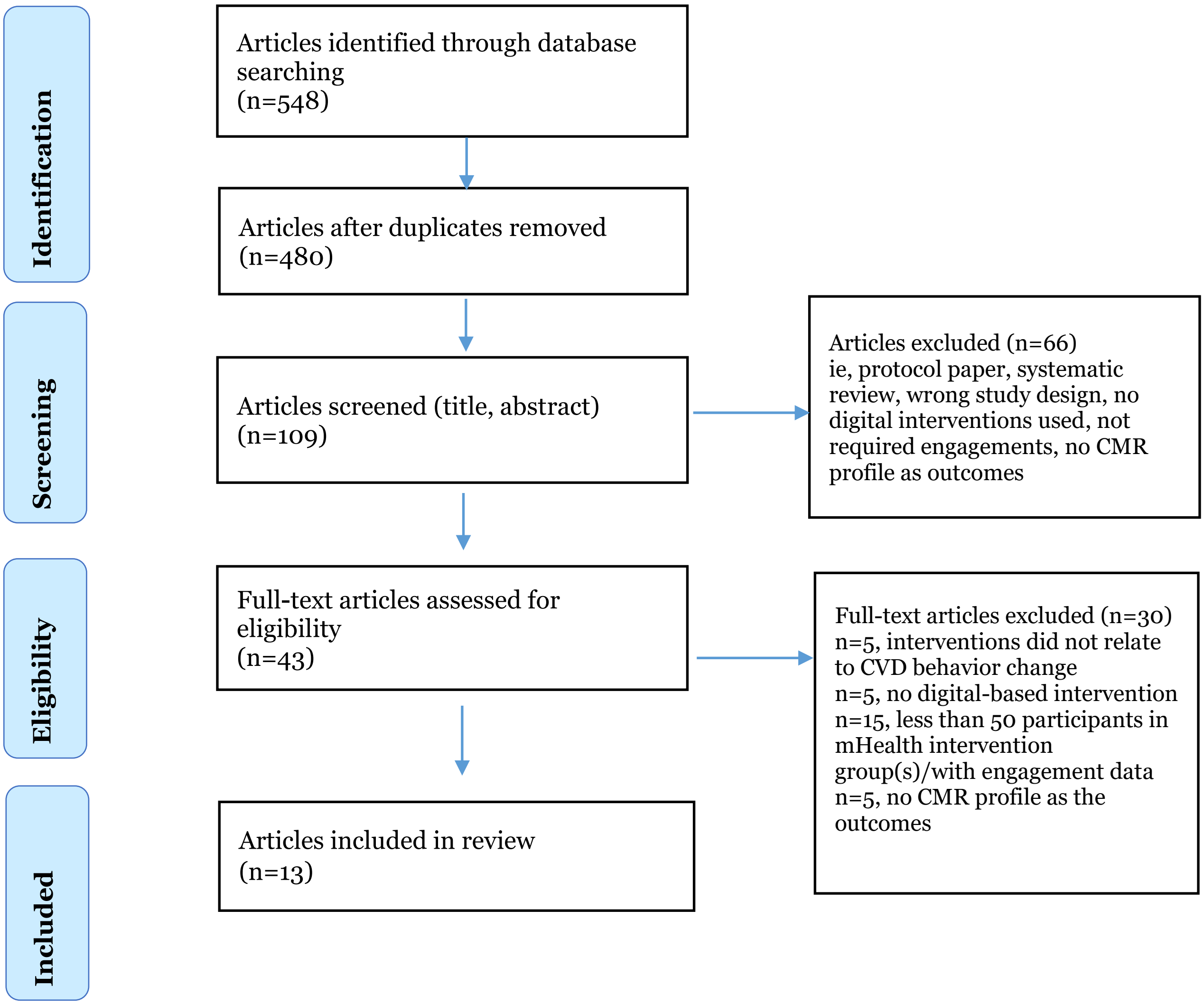

Figure 1. Diagram of search strategy

2.5 Data extraction

Data were extracted into a table to summarize the findings for the narrative results of this review (Table 1, Appendix 1). The first author (HN) extracted data on study population and setting, intervention and control description, and results regarding the relationship between using digital tools for health intervention and CMR profile.

2.6 Quality appraisal

Two authors (HN and FB) independently assessed the quality of each included study using the Joanna Briggs checklist for randomized controlled trials (JBI, 2017). The assessment consists of 13 predefined criteria with 4 options for the answer: yes, no, unclear, and not applicable. The rating of each criterion was 1 point if present or 0 point if absent or unclear or inadequately described. Potential scores ranged from 0 to 13, with scores of 0 to 4 indicating high risk, 5 to 8 indicating medium risk, and 9 to 13 indicating low risk. Appraisal results are presented in Table 2 (Appendix 2). Out of the 13 studies, there were none of the studies with high-risk bias, 10 studies with medium risk bias, and 3 studies with low-risk bias. The questions that the studies met all criteria on the Joanna Briggs Checklist for RCT studies were question 1 ("Was true randomization used for assignment of participants to treatment groups?"), question 10 ("Were outcomes measured in the same way for treatment groups?"), question 11 ("Were outcomes measured in a reliable way?"), and question 12 ("Was appropriate statistical analysis used?"). A few studies poorly performed (absent or unclear or inadequately described) on question 13 ("Was the trial design appropriate, and any deviations from the standard RCT design--individual randomization, parallel groups-- accounted for in the conduct and analysis of the trial?") in which 7.7% (1/13) of the studies received a score of yes, question 7 ("Were treatment groups treated identically other than the intervention of interest ?") in which 15.4% (2/13) of the studies received a score of yes, question 9 ("Were participants analyzed in the groups to which they were randomized?") in which 15.4% (2/13) of the studies received a score of yes, and question 4 ("Were participants blind to treatment assignment?") in which 23.1% (3/13) of the studies received a score of yes.

2.7 Data analysis

Data analysis was performed according to the guidance for synthesis without meta-analysis (SWiM) which consists of 9 items of guideline (Campbell et al., 2020). The first step was evaluating each article retrieved at the title/ abstract to assess their eligibility by grouping the studies (SWiM item 1). The selected articles were grouped into author and year, country, study design, study population and setting, intervention, comparator, and outcomes. Replicated studies were then omitted. Review of full-text articles were then performed for all included studies to address the review questions (SWiM items 2-6). Further, extracted data were shown in tables to present the findings of the association between digital health and CMR profile, including limitations of the studies (SWiM items 7-9).

Finding was categorized as a positive finding if studies showed a statistically significant association between digital health intervention and CMR profile. On contrary, finding was categorized as a negative finding if a non-statistically significant association reported. Intervention components and modalities were also summarized from review articles. In this review, if the relationship between digital health intervention and CMR profile was reported at multiple time points, the end of the intervention time point was used to conclude digital tools for health intervention was or was not significantly associated with the CMR profile of interest.

3. Results

3.1 Characteristics of the selected studies

At the initial search results, a total of 548 articles emerged as can be seen from Figure 1. Then, 68 replicated articles were removed. The remaining 480 articles were screened according to the titles and abstracts, resulting in 109 articles for review. Further, a total of 66 articles were excluded after full-text review, and overall, 13 articles were considered eligible for inclusion in this systematic review (Bennett et al., 2018b; Godino et al., 2016; Jahan et al., 2020; Lin et al., 2015; Lugones-Sanchez et al., 2020; Muralidharan et al., 2019; Newton et al., 2018; Svetkey et al., 2015; Tobe et al., 2019; Toro-Ramos et al., 2020; Wang et al., 2020; Yu et al., 2020; Zheng et al., 2019). Of the 13 studies included in this review, 85% articles were published in medical or clinical journals (Bennett et al., 2018b; Godino et al., 2016; Jahan et al., 2020; Lin et al., 2015; Muralidharan et al., 2019; Newton et al., 2018; Svetkey et al., 2015; Tobe et al., 2019; Wang et al., 2020; Yu et al., 2020; Zheng et al., 2019), and the remaining articles (15%) were published in m-Health journals (Lugones-Sanchez et al., 2020; Toro-Ramos et al., 2020). These results are more likely showing journal preferences of medical and clinical journals. Studies with clinical outcomes were generally the focus in those journals, while technology used for interventions in the studies was published infrequently.

Most of the studies were performed in high-income countries, including the United States (n=7) (Bennett et al., 2018b; Godino et al., 2016; Lin et al., 2015; Lugones-Sanchez et al., 2020; Newton et al., 2018; Svetkey et al., 2015; Toro-Ramos et al., 2020), and Canada (n=1) (Tobe et al., 2019). Other studies were performed in Asian countries (n=5) (Jahan et al., 2020; Muralidharan et al., 2019; Wang et al., 2020; Yu et al., 2020; Zheng et al., 2019). All studies included both male and female participants, but one study was conducted only in female (Lugones-Sanchez et al., 2020). Figure 2 shows the participants were properly selected at high-risk individuals to evaluate the effect of interventions. A total of 7 studies involved obesity participants (Bennett et al., 2018b; Godino et al., 2016; Lin et al., 2015; Lugones-Sanchez et al., 2020; Newton et al., 2018; Svetkey et al., 2015), and 3 studies involved participants with pre-diabetes or type-2 diabetes (Muralidharan et al., 2019; Toro-Ramos et al., 2020; Wang et al., 2020). The other two studies involved participants with hypertension (Jahan et al., 2020; Tobe et al., 2019) and coronary heart disease (Yu et al., 2020; Zheng et al., 2019). All studies involved participants aged 19-64 years. Duration of interventions in the included studies for this review was from 2 (Tobe et al., 2019) to 12 months (Bennett et al., 2018b; Godino et al., 2016; Toro-Ramos et al., 2020).

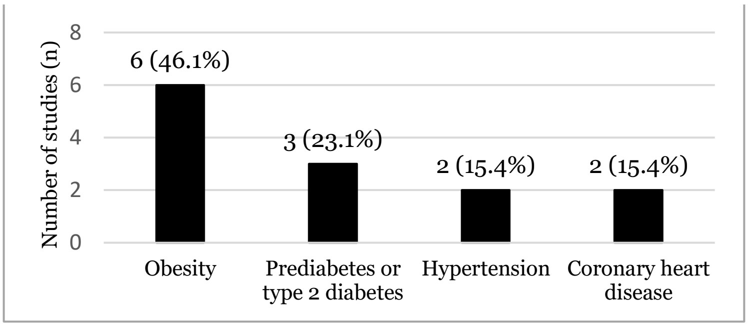

Figure 2. Frequency of studies based on participants

3.2 Digital health intervention modalities

Table 3 presents the frequency of studies according to intervention modalities. The use of m-Health (apps) as an intervention modality was reported in 1 (7.7%) study (Yu et al., 2020), and text-messaging (SMS) was used in 4 (30 .8%) studies (Lin et al., 2015; Newton et al., 2018; Tobe et al., 2019; Zheng et al., 2019). In addition, there were 4 combinations of digital health intervention modalities reported in the studies, including combinations of mHealth (apps), text messaging (SMS), telehealth, social media, and web-based computer. The use of mHealth (apps) and personal coach for intervention was found in 4 (30.8%) studies (Jahan et al., 2020; Svetkey et al., 2015; Toro-Ramos et al., 2020; Wang et al., 2020), and 2 (15.4%) studies used the combinations of mHealth (apps) and telehealth (Bennett et al., 2018b; Muralidharan et al., 2019). There was one study (7.7%) used the combination of mHealth (apps) and smart band (Lugones-Sanchez et al., 2020), and one study (7.7%) used an integrative intervention modality (Godino et al., 2016). Digital health intervention modalities and CMR profile were very heterogenous across the studies, confining to perform a quantitative review of the association between type of digital health intervention modalities and CMR profile.

Table 3. Frequency of studies based on intervention modalities

Participants	f	%
m-Health (apps)	1	7.7
Text messaging (SMS)	4	30.8
m-Health (apps) and telehealth	2	15.3
m-Health (apps) and smart band	1	7.7
m-Health (apps) and personal coach	4	30.8
m-Health (apps), SMS, social media, telehelath, and web-based computer	1	7.7

3.3 Components of digital health intervention

The interventions used a variety of strategies, including education, self-management, and social support. Half of the studies (54%) were about weight loss interventions (Bennett et al., 2018b; Godino et al., 2016; Lin et al., 2015; Lugones-Sanchez et al., 2020; Muralidharan et al., 2019; Newton et al., 2018; Svetkey et al., 2015), and 10 (76.9%) studies used education for intervention component (Godino et al., 2016; Jahan et al., 2020; Lin et al., 2015; Lugones-Sanchez et al., 2020; Muralidharan et al., 2019; Newton et al., 2018; Tobe et al., 2019; Toro-Ramos et al., 2020; Wang et al., 2020; Zheng et al., 2019). Table 4 shows frequency of studies according to intervention components.

Table 4. Frequency of studies based on intervention components

Participants	f	%
Education	10	76.9
Self-management progress	6	46.2
Structured telephone support	2	15.4

3.4 The associations of digital health interventions with CMR profile

Table 5 provides the number of studies reporting the relationship between the use of digital interventions and CMR profile. A positive finding was a statistically significant association between digital intervention and the CMR profile, whereas a negative finding was a non-statistically significant association between digital intervention and the CMR profile.

Of 13 studies in this review, a total of 8 (61.5%) studies measured weight as an outcome (Godino et al., 2016; Lin et al., 2015; Lugones-Sanchez et al., 2020; Muralidharan et al., 2019; Newton et al., 2018; Svetkey et al., 2015; Toro-Ramos et al., 2020; Wang et al., 2020), of which 7 studies (88%) found positive association between the digital health intervention use and weight change (Godino et al., 2016; Lin et al., 2015; Lugones-Sanchez et al., 2020; Muralidharan et al., 2019; Newton et al., 2018; Svetkey et al., 2015; Wang et al., 2020). In addition, there were 7 (53.8%) out of 13 studies assessed blood pressure (Bennett et al., 2018b; Godino et al., 2016; Jahan et al., 2020; Newton et al., 2018; Tobe et al., 2019; Yu et al., 2020; Zheng et al., 2019), of which only two studies had positive findings related with systolic blood pressure (Godino et al., 2016; Jahan et al., 2020). Most studies in this review rarely assessed others CMR profile.

Table 5. Findings for the relationship between using digital interventions and CMR profile in adults with obesity or chronic diseases

CMR Profile	Number of studies f	Positive findings f (%)	Negative findings f (%)
BMI[a]	4	2 (50)	2 (50)
Weight (kg)	8	7 (88)	1 (12)
Systolic blood pressure	7	2 (29)	5 (71)
Diastolic blood pressure	7	1 (14)	6 (86)
Serum glucose	2	1 (50)	1 (50)
HbA1c	2	0 (0)	2 (100)
LDL cholesterol[b]	2	0 (0)	2 (100)
HDL cholesterol[c]	2	1 (50)	1 (50)
Triglyceride	1	0 (0)	1 (100)
Total cholesterol	2	0 (0)	1 (100)

[a]BMI: Body mass index; [b]LDL cholesterol: Low density lipoprotein cholesterol; [c]HDL: High density lipoprotein cholesterol.

4. Discussion

A total of 13 studies included in this systematic review to determine whether digital health intervention was associated with improving CMR profile of adults with obesity and chronic diseases. This systematic review found that digital health interventions may be associated with CMR profile among adults, particularly a reduction in weight and BMI. Almost all studies included in this systematic review showed that digital health intervention led to weight loss. The association was replicated across digital health intervention modalities. For instance, an RCT study on 741 adults who were at high risk for T2DM in three cities in India showed that a 12-week use of mHealth (apps) was significantly associated with a moderate weight loss, whereas those who viewed videos through apps had a greater weight loss (2.4 kg) than those who only attended coach calls (0.9 kg) (Muralidharan et al., 2019). The use of text messaging (SMS) as a digital health intervention modality was also significantly associated with weight loss in two studies (Lin et al., 2015; Newton et al., 2018). In addition, 4 studies found a significant weight loss using different combinations of digital intervention modalities (Godino et al., 2016; Lugones-Sanchez et al., 2020; Svetkey et al., 2015; Wang et al., 2020). However, there was one study reported no association between an integrative digital intervention modality with weight loss among those who had pre-diabetes (Toro-Ramos et al., 2020). The observed associations could be explained by short duration of interventions, whereas intervention duration in the studies included in this review was limited only to a less than a year. This main finding supports the conclusions from previous reviews focused on both paper-based (Burke et al., 2011) and digital-based (Patel et al., 2021) self-monitoring in weight loss intervention among adults. Although a previous review suggested that engagement was a major issue in digital-based interventions (O'Connor et al., 2016), many studies reported digital health interventions implicated a short-term weight loss in overweight and obese adults (Beleigoli et al., 2019; Senecal et al., 2020a; Senecal et al., 2020b). For example, a systematic review of 11 RCT studies showed that web-based digital interventions led to greater short-term (<6 months follow-up) but not long-term weight loss than offline interventions in overweight and obese adults (Beleigoli et al., 2019). In addition, two retrospective observational analysis on 8,275 individual (Senecal et al., 2020a) and 251,718 individuals (Senecal et al., 2020b) with severe obesity suggested that the use of m-Health combining with weight-loss program resulted in the weight loss after 120 days follow-up.

Weight loss intervention among overweight and obese adults could improve others CMR profile (Liyana et al., 2018; Morris et al., 2021), suggesting that obesity management should be an integral part to modify the risk of cardiometabolic disorders (Iwamoto et al., 2021). However, this review found that digital-based intervention was not associated with decrease in others CMR profile, such as blood pressure, HbA1c, HDL cholesterol, triglyceride, and total cholesterol. The negative findings for associations of digital health intervention with many CMR profile in the studies included in this review could be explained by lack of power to detect a significance. In fact, an RCT study performed on 822 patients with coronary heart disease could not detect significant associations between mobile health intervention through text messaging with systolic blood pressure and BMI (Zheng et al., 2019), although adequate power was considered to identify statistically significant associations. Further, some studies (Godino et al., 2016; Newton et al., 2018; Yu et al., 2020) did not consider power calculations for blood pressure, serum glucose and cholesterol as they are secondary outcomes and viewed as exploratory findings.

Intervention components may also be important to persuade participant's adherence in medication. In fact, a recent qualitative study conducted on 20 patients with hypertensions in Belitung, Indonesia reported one of the barriers for managing hypertension was due to lack of a regular health monitoring and education from public health center (Aungsuroch et al., 2021). Interestingly, positive findings were found in studies that integrated telephone consultation with nurses, clinical dietitians, and other health specialists in their intervention (Muralidharan et al., 2019; Wang et al., 2020). However, the effect of frequency of telephone consultation was not discussed as a part of interventions. It is likely that the lifestyle interventions mainly focused on diet and physical activity, resulting insufficiency to significantly reduce blood pressure and cholesterol level (Godino et al., 2016; Newton et al., 2018). Further studies are needed to assess how digital health intervention may affect other CMR profile such as blood pressure, glucose, and cholesterol, as many digital health intervention studies have focused on weight management.

5. Implications and limitations

The result of this review implies the use of digital health intervention in clinical practices for managing and improving CMR profile of adults with obesity and chronic diseases. Components of digital health intervention, such as education, regular self-monitoring, or telephone support, may effectively provide patients with awareness into their health behaviors that can bring them closer to their health goals. Digital health is a proper measure to anticipate the trend of out-of-hospital care for patients with chronic diseases and disabilities. Using digital health intervention for chronic diseases potentially enhances the quality of health care services. Several reasons for digital health effectiveness include education and counseling related with disease control, face-to-face visits with health care professionals, and data collected on medical parameters. The engagement of patients in their own health care can also be improved using digital health tools. Moreover, the Coronavirus (COVID-19) pandemic has led to an inevitable surge in the use of digital health technologies due to the physical-distancing norms.

The strengths of this systematic review were each study conducted with a large sample size in the intervention group and performed based on guideline designed for this systematic review. Also, the study findings were reported on the associations of both general use and self-management progress with the CMR profile. The description of the number of studies with positive or negative associations was presented. However, there were also limitations that should be considered in this systematic review. First, effectiveness of digital health intervention was not assessed because this systematic review was aimed to determine whether digital health intervention was associated with improvement in CMR profile outcomes. Second, digital health intervention modalities and CMR profile were very different across the studies. This precluded us to perform a quantitative review of the association between type of digital health intervention modalities and CMR profile. Third, hand searching to find eligible articles was not performed. In addition, evidence in this systematic review may not fully inclusive as digital health intervention in this review were limited. Finally, most of the studies were from the USA and high-income countries, limiting the evidence from other countries.

6. Conclusion

This systematic review found that digital health interventions may be associated with CMR profile among adults, particularly a reduction in weight and BMI. However, only a few studies assessed other CMR profile, and the findings were inconsistent. Digital health intervention modalities and CMR profile were very heterogenous across the studies, hindering us to examine the association of intervention modalities and CMR profile. Additional studies are needed to assess digital health interventions targeting other important CMR profile, including blood pressure, glucose, and cholesterol level. In addition, future studies should examine the effectiveness of specific digital modalities or intervention components in improving CMR profile. Finally, further studies are needed to explore the effectiveness of digital health interventions in improving CMR profile in other countries.

Acknowledgment

The author is grateful to the UIN Jakarta Research Center for cordial support.

Author contribution

HN was responsible for the concept, design, data analysis, writing, and revision of the manuscript. HN and FB were responsible for data screening process, data extraction, and quality appraisal. All authors give final approval of the version submitted in this journal.

Conflict of interest

The authors declare no conflicts of interest.

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Appendix 1

Table 1. Data extraction for included studies

No	Author/ Year	Country	Study design	Study population & setting	Intervention (n)	Comparator (n)	Main results
1	Bennet et al. (2018b)	USA	Two-arm RCT with 12 months intervention duration; 6- and 12-months follow-ups	351 patients with obesity & diagnose of HTN, DM, or hyperlipidemia enrolled via primary care electronic health record. Age: 21-65 y Sex: 68% male Race: 52% Black	App for self-monitoring of behavior change goals with tailored feedback, smart scale, dietitian-delivered counseling calls, & clinician counseling at regular medical visits informed by app data. (n=176)	Usual care offered by clinician, self-help info., list of community resources for weight management, and newsletter. (n=175)	At both 6 and 12 months, a significantly larger proportion of intervention participants lost >5% of their initial weight, compared with usual care, at 6 (43% vs 6%, estimated RR = 6.8, 95% CI = 3.6, 12.7, p< 0.001) and 12 months (40.4% vs 16.7%, estimated RR = 2.4, 95% CI = 1.6, 3.5, p<0.001). There were no between-group differences in blood pressure, glucose, HbA1c, and blood lipids at 12 months, except for high-density lipoprotein cholesterol.
2	Godino et al. (2016)	USA	Parallel-group RCT 24 months intervention duration; 6, 12, 18, and 24- months follow-ups	404 college students with overweight/ obesity enrolled on college campuses Age: 18-35 y Sex: 70% female Race: 42% White	Social mobile approaches to reduce weight with PA/diet goals, tracking, & feedback via integrated Facebook, 3 apps, SMS, emails, blog posts, & health coach. (n=202)	Different website on weight loss and email newsletters. (n=202)	Weight was significantly less in the intervention group compared to the control group at 6 months (−1.33 kg, p=0.011) and 12 months (−1.33 kg, p=0.008). There was a significant difference between groups in systolic blood pressure at 24 months. There was no statistically significant difference between groups in diastolic blood pressure.
3	Jahan et al. (2020)	Bangladesh	Parallel-group RCT 5 months intervention duration;	420 individuals with HTN in rural community enrolled via a tertiary level health facility and through door-to-door visits by community health workers. Age: 35-71 y Sex: 86% female	Health education of behavior change via integrated in-person health education and SMS. (n=204)	Received only in-person health education (n=208)	SBP and DBP were significantly decreased in both groups (p<0.001). The mean SBP and DBP dropped between the groups over the study period, more in the intervention group, and the changes were statistically significant (p=0.04 and p=0.02, respectively).
4	Lugones et al. (2020)	USA	Multicenter RCT 3 months intervention duration.	440 individuals with overweight/obese enrolled via primary care centers. Age: 20-65 y Sex: 69% female	A mobile app and a smart band for self-monitoring of losing weight and changing body composition goals with tailored feedback, and counseling about healthy diet and PA. (n=231)	Counseling about healthy diet and PA. (n=209)	Weight was significantly less in the intervention group compared to the control group at 3 months (−0.84 kg, p<0.05)

Table 1. Continued

No	Author/ Year	Country	Study design	Study population & setting	Intervention (n)	Comparator (n)	Main results
5	Lin et al. (2015)	USA	Two-arm RCT 6 months intervention duration with a follow-up period of 12 months.	124 individuals with overweight/obese enrolled on 6 churches. Age: ≥21 y Sex: 85% female Race: 100% African American	Standard care and daily tailored text messages pertaining to targeted behaviors of participants' selection to lose weight, and customized to each participants' wake, lunch, and sleep times. (n=63)	Standard care included one-on-one counselling sessions with a dietitian and a physician. (n=61)	Mean weight loss at 3 months was 2.5 kg greater in the intervention group compared with standard care (95% CI, -4.3 to -0.6; *p*<0 .001), and 3.4 kg greater (95% CI, -5.2 to -1.7; *p*<0 .001) at 6 months.
6	Muralid haran et al. (2019)	India	RCT 12 weeks intervention duration.	561 individuals with prediabetes, overweight/obese enrolled via community-based screening and clinics. Age: >18 y Sex: 57% male	Mobile phone application for tracking weight, physical activity, and diet along with video lessons on T2D prevention and weekly coach calls. (n=271)	Usual care (n=290)	The intervention group experienced a significant 1 kg weight loss while the control group lost 0.3 kg (P < 0.05).
7	Newton et al.(2018)	USA	Cluster RCT 6 months intervention duration.	97 individuals with obesity or T2D enrolled participating churches. Age:18-7 y Sex: 91.8% female Race: African American.	Group sessions and received automated SMS text messages designed to reinforce behavioral strategies. (n=68)	Received SMS text messages related to health conditions including stroke prevention, lupus and CVD. (n=29)	There was a significant difference in weight loss (*P*=0.04) between participants in the intervention (–1.5 (SE 0.5) kg) and control (0.11 (SE 0.6) kg) groups. No significant between-group differences in the systolic or diastolic blood pressure, glucose, or cholesterol levels (*p*>0.356).
8	Svetkey et al. (2015)	USA	RCT 24 months intervention duration.	365 individuals with overweight/obesity enrolled by advertisings and mass mailings. Age: 18-35 y. Sex: 69.6% female Race: 56.2% White	Smartphone for self-monitoring and personal coaching of moderate calorie restriction, healthy dietary pattern, moderate PA, limited alcohol intake, and frequent self-monitoring of weight, diet, and PA. (n=122)	Received three hand-outs on healthy eating and PA and not asked to self-monitor. Use of these materials was not monitored. (n=123)	Intervention group lost the least weight at all measurement points (-0.87,-1.48, and -0.99 kg at 6, 12, and 24 months, respectively), and these values were not significantly different from Control (-1.14,-2.25, and -1.44 kg, respectively).
9	Toro-Ramos et al. (2020)	USA	RCT 20 weeks intervention duration; 6 and 12	202 individuals with prediabetes enrolled on clinics. Age:>18 y Sex: 71.2% female.	A mobile-delivered, coach-guided Diabetes Prevention Program (DPP, Noom), an interactive coach-to-participant	Received regular medical care including a paper based DPP curriculum (n=99)	Changes in the participants' weight and BMI were significantly different at 6 months between the intervention and control groups, but there was no difference in HbA levels (mean difference 0.004%, SE 0.05; *p*=0.94).

Table 1. Continued

No	Author/ Year	Country	Study design	Study population & setting	Intervention (n)	Comparator (n)	Main results
			months follow-ups.		interface and group messaging, daily challenges for behavior change, DPP-based education articles, food logging, and automated feedback. (n=101)		Weight and BMI were lower in the intervention group by -2.64 kg (SE 0.71; p<.001) and -0.99 kg/m2 (SE 0.29; P=.001), respectively.
10	Tobe et al. (2019)	Canada	Multicenter RCT 2 months intervention duration.	122 individuals with uncontrolled hypertension, and on or off medications enrolled from six communities. Age: >18 y Sex: 51% male	Received SMS pertaining information on the management of hypertension, advice to follow-up with the participants' health care provider if the measured BP was above target. (n=64)	Received SMS regarding healthy lifestyle and behavior changes. (n=58)	There was no statistically significant difference between groups in SBP and DBP.
11	Wang et al. (2020)	Mongolia	Two-arm RCT 12 months intervention duration.	171 patients with T2D enrolled on hospital. Age: 55.1 (10.8) Sex: 57% male	Received evaluated text messages twice a week, and telephone follow-up after each stage of the intervention. (n=74)	Received regular education. (n=72)	Compared with the control group, the decrease in the FPG (1.5 vs. 0.4, p=0.011), and the PPG (5.8 vs. 4.2, p=0.009) were better in the intervention group. Improvements in weight control (49.3% vs. 28.2%, p=0.031) was better in intervention group than in the control group.
12	Yu et al. (2020)	China	Multicenter RCT 6 months intervention duration.	1000 patients with coronary heart disease underwent isolated CABG enrolled on 4 teaching hospitals. Age: >18 y Sex: 85.5% male	Advanced smartphone application of self-management designed specifically to improve medication adherence after surgical coronary revascularization, the application automatically reminded the participants application, receive feedback, encouragement, and advice about their secondary prevention status and performance. (n=493)	Received standard post-CABG care, including cardiology education, instruction on CABG secondary prevention, and promotion of self-care management from research nurses and physicians during the inpatient stay after randomization. (n=494)	There was no statistically significant difference between groups in SBP, DBP, and BMI.

Table 1. Continued

No	Author/ Year	Country	Study design	Study population & setting	Intervention (n)	Comparator (n)	Main results
13	Zheng et al. (2019)	China	Multi-center RCT 6 months intervention duration.	822 patients with coronary heart disease and without diabetes mellitus enrolled from 37 hospitals. Age: 56.4 (SD 9.5) Sex: 14.1% female.	Text messaging by an automated computerized system provided educational and motivational information related to disease-specific knowledge, risk factor control, physical activity, and medication adherence. (n=402)	Usual care (n=404)	There were no significant differences in the change in SBP, LDL-C level, and BMI between the 2 groups.

Appendix 2

Table 2. Quality assessment of studies included in this systematic review using the Joanna Briggs Checklist for RCT studies

Quality assessment criteria	Bennet et al. (2018b)	Godino et al. (2016)	Jahan et al. (2020)	Lugones et al. (2020)	Lin et al. (2015)	Muralidharan et al. (2019)	Newton et al. (2018)	Svetkey et al. (2015)	Toro-Ramos et al. (2020)	Tobe et al. (2019)	Wang et al. (2020)	Yu et al. (2020)	Zheng et al. (2019)	Total studies meeting criterion
1. Was true randomization used for assignment of participants to treatment groups?	1	1	1	1	1	1	1	1	1	1	1	1	1	13
2. Was allocation to treatment groups concealed?	0	1	0	1	1	1	1	0	1	0	1	0	1	8
3. Were treatment groups similar at the baseline?	0	0	1	1	1	0	0	0	0	0	1	1	0	5
4. Were participants blind to treatment assignment?	0	1	0	0	0	0	0	0	1	0	1	0	0	3
5. Were those delivering treatment blind to treatment assignment?	0	0	0	1	1	0	0	0	1	0	1	0	1	5
6. Were outcomes assessors blind to treatment assignment?	0	1	0	1	1	0	0	0	1	0	1	0	1	6
7. Were treatment groups treated identically other than the intervention of interest?	0	0	0	0	0	0	0	0	0	0	0	1	1	2
8. Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?	1	1	1	0	1	0	1	1	1	1	1	0	0	8
9. Were participants analyzed in the groups to which they were randomized?	0	0	0	0	0	1	0	0	1	0	0	0	0	2
10. Were outcomes measured in the same way for treatment groups?	1	1	1	1	1	1	1	1	1	1	1	1	1	13
11. Were outcomes measured in a reliable way?	1	1	1	1	1	1	1	1	1	1	1	1	1	13
12. Was appropriate statistical analysis used?	1	1	1	1	1	1	1	1	1	1	1	1	1	13
13. Was the trial design appropriate, and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?	0	0	0	0	0	0	1	0	0	0	0	0	0	1
[a]Number of criteria met	5	8	6	8	9	6	7	5	10	5	10	6	8	

[a]Risk of Bias Total Score: 0-4 = high risk; 5-8 = medium risk; 9-13 = low risk.
Note. Rating of Each Criterion: 1 = present; 0 = absent or unclear or inadequately described.