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Research Article

Using Mobile Health for Hypertension Self-Management in Adults: An Updated Systematic Review of Randmozed Controlled Trials

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Abstract

Background: The best application for self-management was the interactive mobile health (mHealth) where readings of the patient's blood pressure (BP) were transmitted to a website so that a follow-up could be achieved by supervising healthcare professionals. We aim to conduct a systematic review to study the effectiveness of mHealth for hypertension self-management in adults.

Methods: We systematically searched PubMed, Google scholar, SIGLE, metaRegister of Controlled Trials (mRCT), WHO Virtual Health Library (VHL), Cochrane Library, Scopus, EMBASE, Web of Science (WoS) through ISI to retrieve all the relevant Randomized controlled trials (RCTs) that investigated the effect of mHealth on hypertension control with the change in blood pressure (BP) as one of their outcomes between 2010 and August 15, 2020. Moreover, the risk of bias was assessed using the Cochrane Collaboration's proposal.

Results: We included 31 relevant studies, of which 17 RCTs reported changes in BP as their primary outcomes and five of them reported the effect of mHealth on hypertension control. Almost all the studies reported significant control of BP, and seven studies reported favorable outcomes with no significance and only one study reported a negative impact of mHealth on BP. Additionally, ten studies reported significance and another eight reported favorable outcomes (with no significance) in terms of medication adherence. Only one study reported adverse events with the self-management outcome. In terms of economic efficiency, three studies (out of seven that reported this outcome) reported that cost-saving with the mHealth intervention groups.

Conclusion: In general, our results indicated the fact mHealth intervention themes are effective in controlling BP, patients' self-care, and medication adherence. However, investigations are needed to determine the best and most economic intervention theme.

Keywords: *Hypertension; Compliance; Management; Device; Adherence; Blood Pressure*

Introduction

Hypertension is one of the most prevalent disorders globally and is estimated to affect > 1 in 4 people and the rate is rising [1]. By 2025, statisticians expect the prevalence rate will be 60% worldwide affecting 1.5 billion patients with a relatively huge mortality rate [2]. The major causes of hypertension are related to the patient's lifestyle [3]. Uncontrolled hypertension can lead to serious complications and is a major risk factor for many cerebrovascular and cardiac diseases [4,5]. Failure of diagnosis, insufficient management, and poor compliance leads to uncontrolled hypertension with possible complications [6].

Poor diagnosis leads to an underestimation of the prevalence rate as in poor-income countries where only 37% of patients with hypertension are diagnosed, including 29% being treated and 8% having controlled hypertension. In high-income countries, the rates are higher reaching as many as 67% diagnosed, 55% undergoing treatment, and 28% controlled [7]. Although antihypertensive drugs are

widely available, the rate of hypertension control is low [8]. A rate of 50 - 80% of patients on anti-hypertensive medications has been reported as having poor compliance to the treatment regimens with poor self-management [9,10]. Additionally, around US $370 is the estimated cost of hypertension globally adding another burden to the worldwide economy [11]. Therefore, establishing cheap and feasible ways of intervention is essential to lower such burdens.

Self-management has been reported to be effective in controlling hypertension and any improvement will lead to more enhanced outcomes [12-14]. Many approaches of self-management have been reported including supporting adherence to the prescribed medications, clinical data, and behavior monitoring, patients education, and management medical titration [15]. However, these protocols must be conducted under the supervision of a health-care professional as reported by randomized controlled trials (RCTs) that the effect of isolated patients' self-management (without supervision) will reduce the outcome [16-18]. The best application for self-management has been the interactive mobile health (mHealth) where readings of the patient's blood pressure (BP) are transmitted to a website so that a follow-up could be achieved by the supervising healthcare professionals. Several published RCTs have reported significant improvement of patients' BP after using mHealth approaches in hypertension self-management and intervention [19-24] while others found minimal/no improvement with no significance [25-30]. Previous reviews and met-analysis studies have been established to summarize the different outcomes of these studies [31-33], however, the limited number of such studies urges the need to develop further explorations on this topic. Additionally, due to a considerable number of recently published RCTs that were not included in these reviews is another factor for conducting this review. Consequently, we aim to conduct a systematic review to study the effectiveness of mHealth for hypertension self-management in adults and discover whether it can improve the rate of controlled hypertension, and assessing the degree of patients' education, the degree of delivery together with the reported economic evaluations.

Methods

Search strategy and study selection

In general, this systematic review was established following the Preferred Reporting Items for Systematic Review and Meta-analyses statement (PRISMA) guidelines and recommendations [34]. We conducted a thorough search strategy on the following electronic databases: PubMed, Google scholar, SIGLE, metaRegister of Controlled Trials (mRCT), WHO Virtual Health Library (VHL), Cochrane Library, Scopus, EMBASE, Web of Science (WoS) through ISI with the following search terms: (hypertension* or hypotension or hypertensive or "blood pressure"* or "elevated blood pressure" or "high blood pressure'") AND (self-management* or "self care"* or "self management" or "self monitoring" or self-monitoring or self-care) AND (telemedicine* or telehealth or eHealth* or "e health" or e-health or mHealth* or "m health" or m-health or "mobile application" or apps or "digital health" or "mobile health" or "message text"). A manual search in the relevant references of the included studies and similar reviews was also conducted to guarantee that all the eligible published studies have been added. The search was conducted to include studies published since 2010 and up to August 15, 2020.

After the search strategy and importing the results to find and exclude the duplicated results, we created a screening sheet in which two members of the investigating team carefully screened the imported studies. At first, title and abstract screening were performed followed by full-text screening. Any disagreement between the two reviewers were solved by discussion and referral to the study supervisor who shared his opinion. The screening was based on the following inclusion and exclusion criteria. Inclusion criteria included: (1) randomized controlled trials (RCTs) that recruited adult patients diagnosed with hypertension, (2) the use of app-based approaches in the intervention groups of the included studies as a measurement for controlling hypertension, and (3) investigated one of the following outcomes: changes in the systolic or diastolic blood pressure (SBP or DBP), and these concerning the patients' self-management and adherence to medications. Exclusion criteria were: (1) other study designs that are not RCTs, (2) the hypertensive population is not the main one, (3) hypertension with pregnancy or hypertension was not the primary diagnosis, (3) the assessment was conducted on physicians/health care practitioners, (4) non-original study data as thesis, abstracts, visual representations, editorials and letters to the editors.

Data extraction

After a final decision was made regarding the included studies, relevant data was extracted. At first, we have performed pilot sheet testing on a few numbers of the included studies to reach a suitable sheet design that suited all the included studies. Finally, data extraction was conducted by two independent study authors to extract the following information: reference IDs including study title, first author's name, year of publication, and country where the study was conducted, as well as the patient's characteristics including age, gender, other demographics, sample size, and baseline BP. Other information concerning the study outcomes included the different methods of intervention, changes in the SBP and DBP, patients' self-management, and follow-up durations.

Risk of bias assessment

Assessment of quality for the included studies was performed by three reviewers who discussed their differences and reached a final decision. We used the Cochrane Collaboration's proposal for the assessment of the risk of bias (RoB 2) for RCTs according to which the qualities of studies were marked as low, unclear, or high risk of bias [35]. The tool mainly assessed bias in selection, detection, performance, attrition and reporting.

Results

Search results

A generalized presentation of the search strategy is presented in figure 1. Briefly, title and abstract screening was performed for 3341 records after duplicates removal and resulted in 320 relevant studies. Following this, full-texts screening resulted in the inclusion of 29 records after screening against our inclusion and exclusion criteria. Moreover, manual searching resulted in other two relevant studies, and by which the total number of included studies is 31 relevant RCTs.

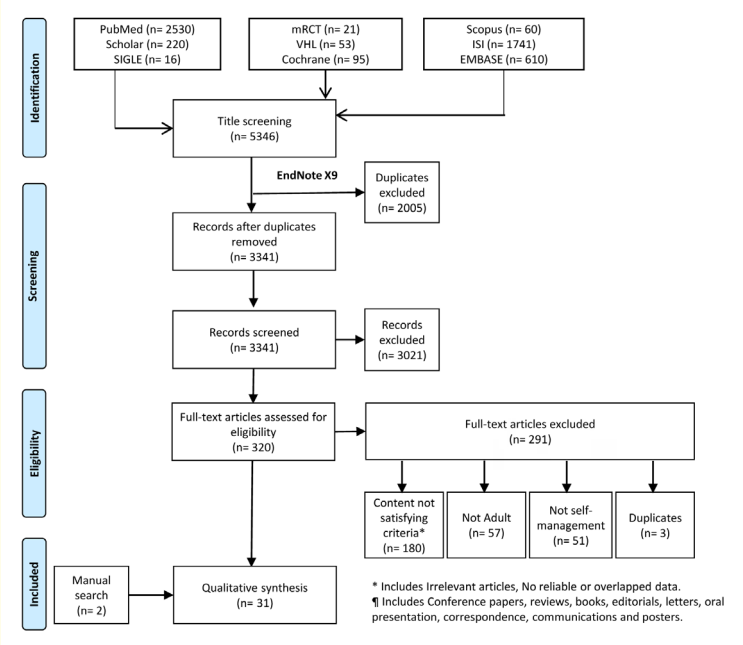


Figure 1: *PRISMA flowchart of the search and screening process.*

Study characteristics

A summary of the characteristics for all the 31 included studies is presented in table 1. The settings of the included studies were as follows: 12 in the United States, four in the United Kingdom, four in Canada, and one in each country of Palestine, Brazil, China, Korea, South Africa, Honduras, Chile, Taiwan, Iran and Spain. The majority of studies were conducted in urban areas, and only four studies [28,36-38] assessed patients from the rural population. The sample size ranged between 38 and 8642.

Study reference (First author, year)	Setting	Total sample size (n)	Population	Follow-up duration	Intervention content	Control content	Outcome measures	Blood pressure outcome	Self-management behavior outcome	Medication adherence outcome	Costs
Abu-El-Noor., *et al*. 2020 [39]	Palestine	218	Adults (over 18 years) who were diagnosed with hypertension at least one year before the time of data collection and were prescribed at least one antihypertensive drug	3 months	Using mobile phone apps for remonetizing patients of their medications	Usual care	Improve adherence to treatment regimens among hypertensive patients	NR	NR	Significant, better adherence in the intervention group (P=0.000)	NR
Bobrow., *et al*. 2015 [26]	South Africa	1372	Receiving antihypertensive medication, aged ≥21 years	12 months	Intervention 1: information-only adherence support Intervention 2: interactive support	Usual care	Primary: change in mean SBP Secondary: the proportion of BP control and health status	Significant (P=.05). The difference in SBP change of interactivity and information group compared with the control group was −2.2 mm Hg and −1.6 mm Hg	NR	A significant change between intervention and control groups (P<.001)	NR
Bosworth., *et al*. 2011 [27]	United States	591	Uncontrolled BP	18 months	Intervention 1: self-monitoring nurse-administered behavioral management and usual care Intervention 2: self-monitoring nurse-administered physician-directed management with a clinical decision support system and usual care Intervention 3: combined 1 and 2	Usual care	Primary: BP control Secondary: change of SBP and DBP	A significant difference in the rate of BP control in the 2 intervention groups relative to the control group (P=.03)	NR	NR	US $947 for behavioral management; US $1275 for medication management; US $1153 for the combined intervention arm

Bove., *et al*. 2013 [53]	United States	241	SBP of 140 mm Hg or above	6 months	BP education and monitoring and usual care	Usual care	Primary: the proportion of BP control; changes in BP Secondary: BMI[h]	Not significant. Greater reduction in SBP (P=.12) and DBP (P=.17) in the telemedicine group than the control	NR	No significant change in the 2 groups (P=.86)	NR
Brennan., *et al*. 2010 [49]	United States	638	African American	12 months	DMP[e] with nurse support and usual care	LSP[f] and usual care	Primary: SBP and DBP Secondary: frequency of BP monitoring; health care utilization	Significant. Lower SBP of the intervention group than the control group (123.6 vs 126.7 mm Hg; P=.03)	Significant. The intervention group is 46% more willing to report weekly BP monitoring than the control group (P=.02)	Significant. Better medication adherence in the intervention than the control group (P=.01)	NR
Chandler., *et al*. 2019 [50]	United States	54	Hispanic or Latino diagnosed, aged 21 to 65 years	9 months	Self-monitoring and electronic medication tray	ESC[g]	Primary: change in SBP Secondary: DBP and adherence	A significant difference for SBP control (P=.009); No significant difference of DBP change (P=.34) showed in the intervention group and the control group	Better protocol adherence showed in the intervention group	Significant. Greater increases in the intervention group than the control group (P<.001)	NR
Contreras., *et al*. 2019 [59]	Spain	148	Stage 1 or 2 hypertension	12 months	Self-monitoring and pharmacological support	Usual care	Primary: medication adherence Secondary: change of SBP and DBP	Significant. SBP (P<.001) and DBP (P<.001) in the intervention group are lower than in the control group	NR	Significant. Medication adherence is 86.3% in the intervention group and 62.66% in the control group (P<.001)	NR
Debon., *et al*. 2020 [54]	Brazil	39	Currently, ongoing medical monitoring and follow-up regarding hypertension treatment, have proven cognitive ability in the MMSE psychometric test15, be able to measure blood pressure periodically	3 months	E-lifestyle app and usual care	self-monitoring and usual care	The difference in BP measure	A significant improvement increased DBP and decreased SBP (p<0.05), with no significance in the control group.	Better with no significance (P=0.333)	Poor adherence which increased after education via specific workshops	NR

Frias., *et al*. 2017 [24]	United States	109	elevated systolic BP (SBP ≥140 mm Hg) and HbA1c (≥7%) failing antihypertensive (≥2 medications) and oral diabetes	12 weeks	Three interventions of digital medicine offering (DMO) that measures medication ingestion adherence, physical activity, and rest using digital medicines (medication taken with ingestible sensor)	Usual care	Primary: the effect of the DMO on BP Secondary: effect on glycemic and lipid control, engagement, and provider decision making	Significant reduction in BP and DPB in the DMO than the usual care group (P<0.05)	NR	Better by 4 times in the DMO group than the usual care group with no significance	NR
Davidson., *et al*. 2015 [51]	United States	38	Hispanic or Latino or African American or black, aged 21 to 65 years with uncontrolled BP	6 months	Medication adherence and BP monitoring at 4-month, 12-month, and combined follow-up periods.	Usual care	Primary: the proportion of SBP control Secondary: the proportion of DBP control; the total change of BP	Significant for SBP control (P=.003) and DBP control (P=.04). A higher proportion of SBP and DBP control in the intervention group than in the control group	NR	Higher medication adherence in the intervention group than in the control	Overall cost savings of US $23,692 in the intervention group; US $5,923 in the control group
Ghezeljeh., *et al*. 2018 [42]	Iran	100	Aged 35 to 80 years	1.5 months	Intervention 1: self-management without follow-up Intervention 2: telephone follow-up Intervention 3: smartphone-based social networking follow-up	Routine education	Self-management behavior	NR	Significant. Better self-management behavior in intervention groups than control (P<.001)	NR	NR
Gong., *et al*. 2020 [40]	China	480	Age 18–79 yr old with primary hypertension according to the diagnostic criteria in 2010 Chinese Guidelines for Hypertension Prevention and Treatment	6 months	Using mobile phone apps for remonetizing patients of their medications	Self-monitoring of blood pressure	Primary: SBP and DBP changes Secondary: Medication adherence	Significant reduction in SBP and DBP in values and control rate in the intervention group (P<0.05)	NR	Significant in the intervention (P<0.05)	NR

KIM 2019 [41]	Korea	124	Aged >65 years	2 months	Intervention 1: home-based health coaching	Usual care	Primary: self-management behavior; hypertension-related knowledge	Significant. More reduction of SBP (P<.001) and DBP (P=.02) in 3 intervention groups than the control group	Significant differences in self-management behavior (P<.001) hypertension knowledge (P<.001), between 4 groups	Significant. Better medication adherence in the coaching group than the other 3 groups (P<.001)	NR
					Intervention 2: information providing		Secondary: change in SBP and DBP				
					Intervention 3: information providing and coaching						
Lee., *et al*. 2016 [52]	Taiwan (China)	382	Aged 18 to 85 years	6 months	Self-monitoring and remonetizing intervention	Recording BP monitoring outcome and weekly remonetized	Primary: change of BP	Significant. The difference in SBP change between 2 groups by 0.69 mm Hg (P=.04); No significant difference in DBP (P=.35)	NR	NR	NR
							Secondary: the degree of BP control				
Liu., *et al*. 2018 [43]	Canada	128	Stage 1 or 2 hypertension, aged 35 to 74 years	4 months	Intervention 1: user-driven e-counseling[d]	Weekly email newsletter	Primary: SBP[b]	Significant for SBP (P<.001). A greater reduction of SBP in the expert-driven group. No significant difference for DBP (P=.07)	Significant. A greater improvement of daily steps and fruit consumption in the expert-driven group (P=.01)	NR	NR
					Intervention 2: Expert-driven e-counseling		Secondary: DBP[c], behavior				
Maciejewski., *et al*. 2013 [57]	United States	591	Uncontrolled BP	18 months	Intervention 1: self-monitoring nurse-administered behavioral management and usual care	Usual care	Primary: BP control	Significant (P<.001). Behavioral group (17.1%), medication management group (20.2%), and the combined group (20.4%) had greater SBP control compared with usual care	NR	NR	Estimate expenditures are similar
					Intervention 2: self-monitoring nurse-administered physician-directed management with a clinical decision support system and usual care		Secondary: change of SBP and DBP				
					Intervention 3: combined 1 and 2						

Margolis., *et al*. 2013 [23]	United States	450	Uncontrolled BP	12 months	Self-monitoring and phone visit of pharmacists	Usual care	Primary: the proportion of patients with controlled BP Secondary: change in SBP and DBP; patient satisfaction	Significant. The difference of SBP change between intervention and control group: −9.7 mm Hg (P<.001); Significant. The difference of DBP change between intervention and control group: −5.1 mmHg (P<.001)	NR	Difference between groups of self-reported medication adherence: 13.8%	Intervention cost US $1350 per patient
McKinstry., *et al*. 2013 [46]	United Kingdom	401	An adult patient with hypertension	6 months	Self-monitoring and closed-loop feedback	Usual care	Primary: mean SBP Secondary: mean DBP	Significant reduction of SBP (P<.001) and DBP (P=.002) in the telemonitoring group than the control group	No significant difference in lifestyle adjustment between groups (P=.79)	Better medication adherence in the intervention group	Costs in the intervention group is higher than in the control group by US $173.41
McManus., *et al*. 2010 [47]	United Kingdom	480	Receiving ≤2 antihypertensive drugs, aged 35 to 85 years	12 months	Self-monitoring and teleconnection with doctors	Usual care	Primary: change in mean SBP Secondary: antihypertensive drugs prescribed	A significant difference in SBP (P=.002). Reduction of SBP in the intervention group than in the control group by 5.4 mm Hg; No significant difference in DBP change between the groups (P=.09)	Quality of life increased in the intervention group	NR	NR
McManus., *et al*. 2018 [48]	United Kingdom	1182	Aged >35 years, taking ≤3 antihypertensive medicines	12 months	Intervention 1: telemonitoring and send readings Intervention 2: self-monitoring and record BP on paper	Usual care	Primary: change of SBP Secondary: self-reported adherence	Significant. Lower SBP in the telemonitoring group than in the control group (P<.001); non-significant difference between the 2 intervention groups (P=.18)	No significant difference in self-reported adherence between 3 groups (P=.83)	NR	NR

Meurer., *et al*. 2019 [55]	United States	55	Emergency department with a systolic stage 2 or more hypertension	4 months	Medication and health behavior intervention	Usual care	Primary: the proportion of BP control Secondary: change in SBP	SBP of the intervention group had a mean drop of 9.1 mmHg	NR	NR	NR
Migneault., *et al*. 2012 [44]	United States	337	African American, aged >34 years	8 months	Behavioral intervention and usual care	Usual care	Primary: change in behavior, medication adherence Secondary: change in BP[a]	Larger reduction of SBP[a] and DBP[b] in the intervention group than the control group	Dietary: significant improvement in the intervention group (P=.02); activity: significantly (P=.02)	Not significant (P=.25). Higher medication adherence in the intervention group than in the control group	NR[c]
Moore., *et al*. 2014 [58]	United States	44	Receiving ≤1 medication	12 months	Technology-supported health coach	Usual care	Primary: decrease in SBP and DBP; the proportion of BP control Secondary: the change in medication load and weight	A significant difference in SBP change (P=.009). No significant difference in DBP change (P=.054). All of the participants achieved BP[e] control	NR	NR	Intervention: US $67.50 per patient/year; Control: US $248 per patient/year
Morawski., *et al*. 2018 [18]	United States	412	Aged 18 to 75 years	3 months	Medication adherence intervention	Usual care	Primary: medication adherence and change of SBP Secondary: the proportion of controlled BP	No difference in DBP change between the groups (P=.78)	NR	Significant. Higher in the intervention than control (P=.01)	NR
Nolan., *et al*. 2012 [36]	Canada	387	Stage 1 or 2 hypertension, aged 45 to 74 years	4 months	E-counseling intervention	Usual care	Primary: change of SBP and DBP	Significant. Lower SBP pressure in the e-counseling group with 1-7 emails (P=.03); Significant. DBP differed	NR	NR	NR
Nolan., *et al*. 2018 [45]	Canada	264	Stage 1 or 2 hypertension, aged 35 to 74 years	12 months	E-counseling intervention	Self-monitoring and basic self-management education	Primary: decrease of SBP, DBP Secondary: other clinical data	Significant. A greater reduction of SBP for e-counseling (P=.02). No significant difference in DBP between e-counseling versus control (P=.17)	NR	NR	NR

Peiris., *et al*. 2019 [38]	India	8,642	aged 40 years or older, classified at high CVD risk and indicated for BP-lowering medication based on WHO and NPCDCS guidelines	6 months	self-monitoring nurse-administered physician-directed management with a clinical decision support system	Usual care	Primary: proportion meeting systolic blood pressure (SBP) targets Secondary: difference in mean BP levels, the difference in the proportion reporting use of BP medicines; the difference in other CVD risk factors (body mass index; current smoking; self-reported dietary intake and physical activity levels); the difference in the quality of life (EQ-5D); and the difference in the number of self-reported new CVD events	No significance in proportion and control	A small increase in self-reported physical activity with no significance	NR	NR
Piette., *et al*. 2012 [28]	Honduras and Mexico	200	Aged 18 to 80 years	1.5 months	Self-monitoring and structured email alerts and family members' help	Usual care	Primary: SBP Secondary: depressive symptoms, medication-related problems, satisfaction	Significant. 57% of intervention, 38% of the control group had controlled BP (P = .006); No significant decrease in SBP among intervention and control group (P=.74)	NR	NR	NR

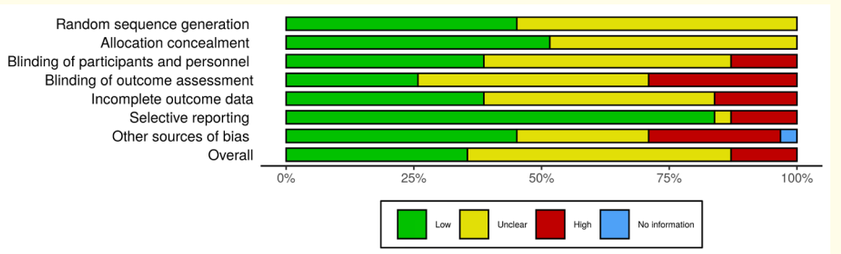
Salisbury., *et al*. 2016 [22]	United Kingdom	641	adults aged 40 to 74 years with a 10-year cardiovascular disease risk of 20% or more, no previous cardiovascular event, at least one modifiable risk factor (systolic blood pressure ≥140 mm Hg, body mass index ≥30, current smoker	12 months	Healthline service (alongside usual care), comprising regular telephone calls from trained lay health advisors following scripts generated by interactive software	Usual care	Primary: Lowering cardiovascular diseases risk Secondary: Engagement and patient safety	Nonsignificant but intervention was associated with lower levels in BP, SPB, DPB	Small non-significant improvements in the intervention group	Small non-significant improvements in the intervention group	After 12 months the incremental cost-effectiveness ratio was estimated to be £10859
Tobe., *et al*. 2019 [37]	Canada	142	Hypertensive Canadian First Nations people from six rural and remote communities	12 months	Hypertension specific management SMS	Health behaviors SMS alone	Primary: The difference in systolic and diastolic BP from the baseline period to the last 2 months of measurement between randomized groups Secondary: proportion with controlled BP	Overall reduction but no significance in SBP, DPB, (P=0.05, 0.06, respectively)	NR	Equal effect	NR
Varleta., *et al*. 2017 [56]	Chile	314	Aged 30 to 80 years	6 months	Education and usual care	Usual care	Primary: antihypertensive therapy adherence Secondary: change in SBP and DBP	Not enough power to make statistical comparisons	NR	Significant. Adherence improved in the intervention group from 49% to 62.3% (P=.01)	NR

Table 1: *Characteristics of the included studies.*

[a]BP: Blood Pressure; [b]SBP: Systolic Blood Pressure; [c]DBP: Diastolic Blood Pressure; [d]E-counseling: Electronic Counseling; [e]DMP: Disease Management Program; [f]LSP: Light Support Education Program; [g]ESC: Enhanced Standard Care; [h]BMI: Body Mass Index.

Risk of bias

The overall risk assessment is presented in figure 2A and 2B. Among all the studies that were assessed for risk of bias, 11 of them [22,24,36,38-45] had a low risk while four [27,46-48] had a high risk of bias. The highest rate of bias (29%) was recorded with the item performance bias as nine studies [23,26,27,44,46-50] generated bias in blinding of participants and personnel. The lowest rate of bias (83.9%) was recorded in the item selective reporting while four articles had a high risk of reporting bias (22, 39, 51, 52). Incomplete outcome data was found in four studies [36,37,45,52,53] and the data was unclear in 14 of the included studies [18,23,26,28,40,43,44,46,47,49,50,54-56].



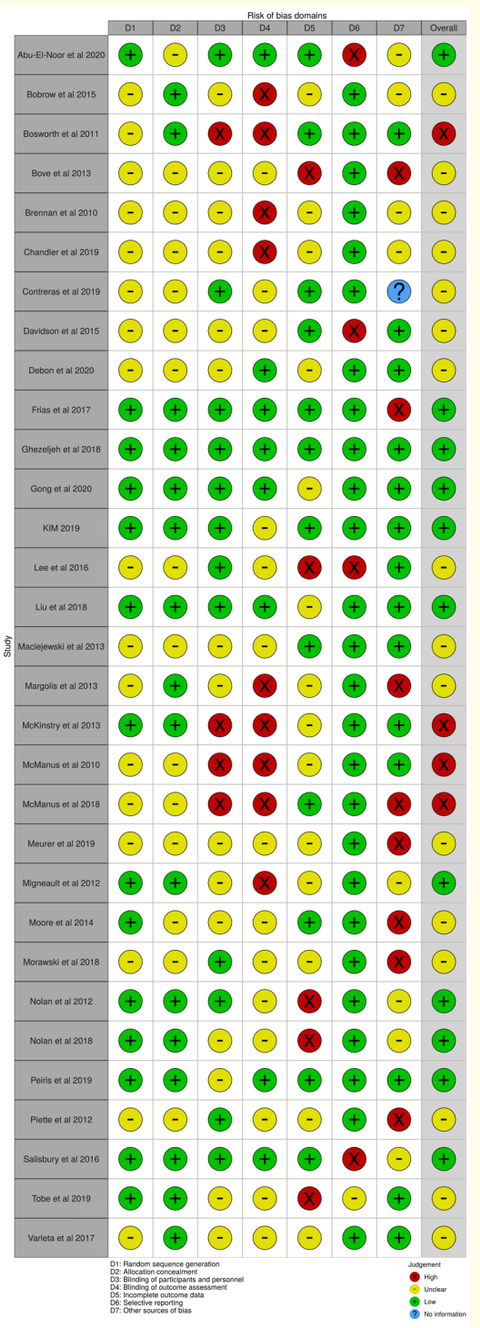


Figure 2: *Quality of the included studies. A: Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies; B: Risk of bias summary: review authors' judgements about each risk of bias item for each included study.*

Outcomes and Discussion

In this systematic review, we found 31 relevant studies that studied the effect of mHealth intervention procedures on adult hypertensive patients.

Reporting changes in blood pressure

Among these studies, 17 studies [18,23-28,36-38,40,41,43-53,55-59] reported changes in BP as their primary outcome and five of them [23,27,51,53,57] reported the effect of mHealth intervention as their main outcome. Almost all of the included studies reported positive improvements in the BP in the intervention groups and all of the reported results were significant except in seven studies [22,37,38,44,53,55,56] which reported a favorable reduction but with no statistical significance while Morawski., *et al*. [18] was the only study that did not find any changes between the intervention and control groups. A previously published meta-analysis of 21 RCTs reported that more total reductions in SBP and DBP were noticed after pooling the results in the intervention group than the control ($P < 0.001$) [33]. In general, better outcomes were noticed in studies that used high-frequency reminders, high interaction between the patients and health-care professionals, and the use of plans that have multifaceted functions and are more satisfactory for the patients.

Other outcomes included medication adherence which was reported in 19 included studies [18,22,24,26,37-41,44,46,49-51,53,54,56,59], changes in self-management and self-monitoring outcomes which was reported by 12 studies [22,38,41-44,46-49,54], changes in economics related to the potentially improved management of hypertension which was reported in seven studies [22,23,27,46,51,57,58] and patients' satisfaction and their feedback on the experience which was reported in eight studies [22,24,26,28,44,46,50,58]. It is worth mentioning that reporting self-management was in various forms among the included studies which reported changes in the quality of life, patients' preparedness to change their behaviors, and adhering to the pre-specified plan.

Intervention characteristics and delivery

All the procedures and design of the intervention and control groups are presented in table 1. Many intervention approaches were noticed across the selected studies, and included education about hypertension, education about healthy lifestyles, plan self-setting, self-monitoring of blood pressure and how to record it, self-monitoring of habitual and behavior changes, social supporting, setting reminders to increase the rate of medication adherence, and behavior change, pharmacological supporting, general action plans, motivational support, and management of stress where every intervention group depended mostly on at least two of these approaches. Moreover, all studies used education about hypertension as a basic approach where patient to doctor, community education, and educational workshops were used to raise awareness and therefore had better outcomes. Furthermore, self-monitoring of BP was reported in 20 studies [22,23,27,28,36,39,40,42,45-53,55,57,59], education about improving the quality of life as diet improvement with salt restrictions and performing exercises was reported in 21 studies [22,24,27,28,36-39,41-46,49,54-59], setting reminders to improve medication adherence was reported in 16 studies [18,22,24,27,28,38-40,47,50,53-55,57-59], motivational events to increase patients' adherence to the specified regimen was reported in six studies [22,24,36,47,48,58], while stress management was reported in two studies only [39,41]. It was reported that interventions trying to improve behavioral habits are significantly better than motivations and knowledge in improving adherence to medications [60-62]. Additionally, seven articles [24,26,27,41,43,48,57] divided their intervention into three groups to compare interactive self-management with healthcare personnel and user-based self-management [26,27,43].

As for the delivery of the chosen intervention theme, 12 studies [26,37,39,41,46,48,50,51,55,56,58,59] were conducted via SMS messaging to their patients, with half of theses services being sent to patients randomly while others depended on feedback from the patient's status. Also, 10 studies [18,24,39,40,48,50,51,54,58,59] developed suitable apps for doctor-patient interaction, while Peiris., *et al*. [38] provided tablet devices where doctors can record patients' information easily. Reminding through automated e-mails was done in seven studies [22,28,36,43,52,53,58]. Additional interventional devices included the wireless BP monitors to transmit the readings easily, voice

calls, digital and electronic medications. The increased frequency of reminding patients about their exposure wasreported with better outcomes [49], however, other reports stated that it can induce fatigue and yield in adverse effects [63]. As for the control group, usual care was the major theme used in 24 studies [18,22-24,26-28,36,38-41,44,46-48,51,53-59] while different themes of texting from the intervention group were used in seven studies [37,42,43,45,49,50,52].

Adherence to medications and patients' self-management

Among all of the included RCTs, only 10 of them [18,22,26,39-41,49,50,56,59] reported statistical significance in medication adherence in the intervention groups of patients on antihypertensive medications. Moreover, Frias., *et al*. [24] reported a high rate of medication adherence in the intervention group (≥ 80%) which was as four times that of the control group after a 4-month follow-up period. However, the authors did not report statistical significance. Similarly, another seven studies [38,44,46,49,51,53,54] stated that mHealth interventions were associated with better adherence, but they did not report any significance. On the other hand, Bove., *et al*. [53] showed that medication adherence was not always associated with using mHealth intervention as using it did not always improve BP control.

As for self-management behavior, all studies that reported this outcome showed positive responses from the patients by improving their lifestyle and especially the quality of food they ate. However, all the reported adverse effects as medication and cardiovascular events were most probably associated with the used drug and not the action of self-care, besides, these events occurred in both the intervention and control groups. McKinstry., *et al*. [46] was the only study that reported self-monitoring induced anxiety in three of their patients. Furthermore, eight studies [22,24,26,28,44,46,50,58] even qualitatively assessed the degree of participants' satisfaction (including patients and doctors) and the results of which were indicative of high levels of satisfaction among all participants.

Economic evaluation

Among the included studies, only seven of them [22,23,27,46,51,57,58] reported the economic evaluation and the difference in costs for the intervention and control groups (Table 1). Of these studies, only three of them [22,23,46] stated that cost-saving was much higher when applying measures of intervention, while two studies [51,58] found the opposite to be true. It is noteworthy that the overall costs were mainly from nurse support, connection charges, using mobile phones, and approaches of monitoring including the periodical visits. This will remain an area of debate as a previous systematic review of 20-years reported that mHealth is not cost-effective [64]. Besides, estimation of the cost is multi-factorial; in rural areas, high costs of mHealth might be a greater factor than the high costs of medical professionals in urban areas. The variations in costs among different countries is another factor. Therefore, costs cannot be avoided, but a middle-ground option should be investigated.

Limitations to our study included the short periods of follow-up as two studies only lasted for more than one year. Another limitation was the small sample in most of the included studies and the various intervention themes that were used without clear definitions and this makes understandingunclear. Additionally, mHealth intervention details were not reported by some studies. Moreover, the settings were in high-middle or high-income countries and were usually held in urban areas which reduces the variations in the targeted populations.

Conclusion

The results of our systematic review indicated the fact that mHealth largely led to BP control as indicated by most of the included studies. Moreover, wee found it can improve patients' compliance and adherence to medications and improve their quality of life in terms of physical health and improved quality of food chosen. Such interventions have also proven to be cost-effective, however, this was a controversial point and should be the aim of future investigations.

Bibliography

1. Duan Y., *et al.* "Effectiveness of home blood pressure telemonitoring: a systematic review and meta-analysis of randomised controlled studies". *Journal of Human Hypertension* 31.7 (2017): 427-437.

2. Kumara WA., *et al.* "Prevalence and risk factors for resistant hypertension among hypertensive patients from a developing country". *BMC Research Notes* 6 (2013): 373.

3. Warburton DER and Bredin SSD. "Health benefits of physical activity: a systematic review of current systematic reviews". *Current Opinion in Cardiology* 32.5 (2017): 541-556.

4. Kearney PM., *et al.* "Global burden of hypertension: analysis of worldwide data". *Lancet* 365.9455 (2005): 217-223.

5. Egan BM., *et al.* "Improving Hypertension Control in Primary Care With the Measure Accurately, Act Rapidly, and Partner With Patients Protocol". *Hypertension* 72.6 (2018): 1320-1327.

6. Palafox B., *et al.* "Wealth and cardiovascular health: a cross-sectional study of wealth-related inequalities in the awareness, treatment and control of hypertension in high-, middle- and low-income countries". *International Journal for Equity in Health* 15.1 (2016): 199.

7. Mills KT., *et al.* "Global Disparities of Hypertension Prevalence and Control: A Systematic Analysis of Population-Based Studies From 90 Countries". *Circulation* 134.6 (2016): 441-450.

8. Pickering TG., *et al.* "Call to action on use and reimbursement for home blood pressure monitoring: executive summary: a joint scientific statement from the American Heart Association, American Society Of Hypertension, and Preventive Cardiovascular Nurses Association". *Hypertension* 52.1 (2008): 1-9.

9. Elliott WJ. "What factors contribute to the inadequate control of elevated blood pressure?" *Journal of Clinical Hypertension* 10.1-1 (2008): 20-26.

10. Burnier M and Egan BM. "Adherence in Hypertension". *Circulation Research* 124.7 (2019): 1124-1140.

11. Frieden TR and Jaffe MG. "Saving 100 million lives by improving global treatment of hypertension and reducing cardiovascular disease risk factors". *Journal of Clinical Hypertension* 20.2 (2018): 208-211.

12. Leon N., *et al.* "Improving treatment adherence for blood pressure lowering via mobile phone SMS-messages in South Africa: a qualitative evaluation of the SMS-text Adherence SuppoRt (StAR) trial". *BMC Family Practice* 16 (2015): 80.

13. Kamal AK., *et al.* "A randomized controlled behavioral intervention trial to improve medication adherence in adult stroke patients with prescription tailored Short Messaging Service (SMS)-SMS4Stroke study". *BMC Neurology* 15 (2015): 212.

14. Petrella RJ., *et al.* "Mobile health, exercise and metabolic risk: a randomized controlled trial". *BMC Public Health* 14 (2014): 1082.

15. Bodenheimer T., *et al.* "Patient self-management of chronic disease in primary care". *The Journal of the American Medical Association* 288.19 (2002): 2469-2475.

16. Agarwal R., *et al.* "Role of home blood pressure monitoring in overcoming therapeutic inertia and improving hypertension control: a systematic review and meta-analysis". *Hypertension* 57.1 (2011): 29-38.

17. Bray EP., *et al.* "Does self-monitoring reduce blood pressure? Meta-analysis with meta-regression of randomized controlled trials". *Annals of Medicine* 42.5 (2010): 371-386.

18. Morawski K., *et al.* "Association of a Smartphone Application With Medication Adherence and Blood Pressure Control: The MedISAFE-BP Randomized Clinical Trial". *JAMA Internal Medicine* 178.6 (2018): 802-809.

19. Artinian NT., *et al.* "Effects of nurse-managed telemonitoring on blood pressure at 12-month follow-up among urban African Americans". *Nursing Research* 56.5 (2007): 312-322.

20. Green BB., *et al.* "Effectiveness of home blood pressure monitoring, Web communication, and pharmacist care on hypertension control: a randomized controlled trial". *The Journal of the American Medical Association* 299.24 (2008): 2857-2867.

21. Stoddart A., *et al.* "Telemonitoring-based service redesign for the management of uncontrolled hypertension (HITS): cost and cost-effectiveness analysis of a randomised controlled trial". *BMJ Open* 3.5 (2013): e002681.

22. Salisbury C., *et al.* "Telehealth for patients at high risk of cardiovascular disease: pragmatic randomised controlled trial". *British Medical Journal* 353 (2016): i2647.

23. Margolis KL., *et al.* "Effect of home blood pressure telemonitoring and pharmacist management on blood pressure control: a cluster randomized clinical trial". *The Journal of the American Medical Association* 310.1 (2013): 46-56.

24. Frias J., *et al.* "Effectiveness of Digital Medicines to Improve Clinical Outcomes in Patients with Uncontrolled Hypertension and Type 2 Diabetes: Prospective, Open-Label, Cluster-Randomized Pilot Clinical Trial". *Journal of Medical Internet Research* 19.7 (2017): e246.

25. Carrasco MP., *et al.* "Impact of patient-general practitioner short-messages-based interaction on the control of hypertension in a follow-up service for low-to-medium risk hypertensive patients: a randomized controlled trial". *IEEE Transactions on Information Technology in Biomedicine: A Publication of the IEEE Engineering in Medicine and Biology Society* 12.6 (2008): 780-791.

26. Bobrow K., *et al.* "Mobile Phone Text Messages to Support Treatment Adherence in Adults With High Blood Pressure (SMS-Text Adherence Support [StAR]): A Single-Blind, Randomized Trial". *Circulation* 133.6 (2016): 592-600.

27. Bosworth HB., *et al.* "Home blood pressure management and improved blood pressure control: results from a randomized controlled trial". *Archives of Internal Medicine* 171.13 (2011): 1173-1180.

28. Piette JD., *et al.* "Hypertension management using mobile technology and home blood pressure monitoring: results of a randomized trial in two low/middle-income countries". *Telemedicine Journal and E-Health: The Official Journal of the American Telemedicine Association* 18.8 (2012): 613-620.

29. Buis L., *et al.* "Abstract 20109: Impact of Text Message Medication Reminders on Medication Adherence and Blood Pressure in a High Risk Urban Emergency Department Population". *Circulation* 130.2 (2014): A20109-A.

30. Rubinstein A., *et al.* "Effectiveness of an mHealth intervention to improve the cardiometabolic profile of people with prehypertension in low-resource urban settings in Latin America: a randomised controlled trial". *The Lancet Diabetes and Endocrinology* 4.1 (2016): 52-63.

31. Alessa T., *et al.* "Mobile Apps to Support the Self-Management of Hypertension: Systematic Review of Effectiveness, Usability, and User Satisfaction". *JMIR Mhealth and Uhealth* 6.7 (2018): e10723.

32. Lu X., *et al.* "Interactive Mobile Health Intervention and Blood Pressure Management in Adults". *Hypertension* 74.3 (2019): 697-704.

33. Li R., *et al.* "The Effectiveness of Self-Management of Hypertension in Adults Using Mobile Health: Systematic Review and Meta-Analysis". *JMIR Mhealth and Uhealth* 8.3 (2020): e17776.

34. Moher D., *et al.* "Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement". *Plos Medicine* 6.7 (2009): e1000097.

35. Higgins JPT., *et al.* "The Cochrane Collaboration's tool for assessing risk of bias in randomised trials". *British Medical Journal* 343 (2011): d5928.

36. Nolan RP., *et al.* "Therapeutic benefit of internet-based lifestyle counselling for hypertension". *The Canadian Journal of Cardiology* 28.3 (2012): 390-396.

37. Tobe SW., *et al.* "Diagnosing hypertension in Indigenous Canadians (DREAM-GLOBAL): A randomized controlled trial to compare the effectiveness of short message service messaging for management of hypertension: Main results". *Journal of Clinical Hypertension* 21.1 (2019): 29-36.

38. Peiris D., *et al.* "SMARThealth India: A stepped-wedge, cluster randomised controlled trial of a community health worker managed mobile health intervention for people assessed at high cardiovascular disease risk in rural India". *Plos One* 14.3 (2019): e0213708.

39. Abu-El-Noor NI., *et al.* "Impact of a mobile phone app on adherence to treatment regimens among hypertensive patients: A randomised clinical trial study". *European Journal of Cardiovascular Nursing: Journal of the Working Group on Cardiovascular Nursing of the European Society of Cardiology* (2020): 1474515120938235.

40. Gong K., *et al.* "Mobile health applications for the management of primary hypertension: A multicenter, randomized, controlled trial". *Medicine* 99.16 (2020): e19715.

41. Kim M. "Effects of Customized Long-Message Service and Phone-Based Health-Coaching on Elderly People with Hypertension". *Iranian Journal of Public Health* 48.4 (2019): 655-663.

42. Najafi Ghezeljeh T., *et al.* "Comparing the effects of education using telephone follow-up and smartphone-based social networking follow-up on self-management behaviors among patients with hypertension". *Contemporary Nurse* 54.4-5 (2018): 362-373.

43. Liu S., *et al.* "Effectiveness of User- and Expert-Driven Web-based Hypertension Programs: an RCT". *American Journal of Preventive Medicine* 54.4 (2018): 576-583.

44. Migneault JP., *et al.* "A culturally adapted telecommunication system to improve physical activity, diet quality, and medication adherence among hypertensive African-Americans: a randomized controlled trial". *Annals of Behavioral Medicine: A Publication of the Society of Behavioral Medicine* 43.1 (2012): 62-73.

45. Nolan RP., *et al.* "Randomized Controlled Trial of E-Counseling for Hypertension: REACH". *Circulation Cardiovascular Quality and Outcomes* 11.7 (2018): e004420.

46. McKinstry B., *et al.* "Telemonitoring based service redesign for the management of uncontrolled hypertension: multicentre randomised controlled trial". *British Medical Journal* 346 (2013): f3030.

47. McManus RJ., *et al.* "Telemonitoring and self-management in the control of hypertension (TASMINH2): a randomised controlled trial". *Lancet* 376.9736 (2010): 163-172.

48. McManus RJ., *et al.* "Efficacy of self-monitored blood pressure, with or without telemonitoring, for titration of antihypertensive medication (TASMINH4): an unmasked randomised controlled trial". *Lancet* 391.10124 (2018): 949-959.

49. Brennan T., *et al.* "Disease management to promote blood pressure control among African Americans". *Population Health Management* 13.2 (2010): 65-72.

50. Chandler J., *et al.* "Impact of a Culturally Tailored mHealth Medication Regimen Self-Management Program upon Blood Pressure among Hypertensive Hispanic Adults". *International Journal of Environmental Research and Public Health* 16.7 (2019): 1226.

51. Davidson TM., *et al.* "Evaluation of an mHealth Medication Regimen Self-Management Program for African American and Hispanic Uncontrolled Hypertensives". *Journal of Personalized Medicine* 5.4 (2015): 389-405.

52. Lee P., *et al.* "Cloud-based BP system integrated with CPOE improves self-management of the hypertensive patients: A randomized controlled trial". *Computer Methods and Programs In Biomedicine* 132 (2016): 105-113.

53. Bove AA., *et al.* "Managing hypertension in urban underserved subjects using telemedicine--a clinical trial". *American Heart Journal* 165.4 (2013): 615-621.

54. Debon R., *et al.* "Effects of using a mobile health application on the health conditions of patients with arterial hypertension: A pilot trial in the context of Brazil's Family Health Strategy". *Scientific Reports* 10.1 (2020): 6009.

55. Meurer WJ., *et al.* "Feasibility of Emergency Department-initiated, Mobile Health Blood Pressure Intervention: An Exploratory, Randomized Clinical Trial". *Academic Emergency Medicine: Official Journal of the Society for Academic Emergency Medicine.* 26.5 (2019): 517-527.

56. Varleta P., *et al.* "Mobile phone text messaging improves antihypertensive drug adherence in the community". *Journal of Clinical Hypertension* 19.12 (2017): 1276-1284.

57. Maciejewski ML., *et al.* "Do the benefits of participation in a hypertension self-management trial persist after patients resume usual care?" *Circulation Cardiovascular Quality and Outcomes* 7.2 (2014): 269-275.

58. Moore JO., *et al.* "Technology-supported apprenticeship in the management of hypertension: A randomized controlled trial". *Journal of Clinical Outcomes Management* 21 (2014): 110-112.

59. Márquez Contreras E., *et al.* "Specific hypertension smartphone application to improve medication adherence in hypertension: a cluster-randomized trial". *Current Medical Research and Opinion* 35.1 (2019): 167-173.

60. Conn VS., *et al.* "Medication adherence interventions that target subjects with adherence problems: Systematic review and meta-analysis". *Research in Social and Administrative Pharmacy: RSAP* 12.2 (2016): 218-246.

61. Gwadry-Sridhar FH., *et al.* "Impact of interventions on medication adherence and blood pressure control in patients with essential hypertension: a systematic review by the ISPOR medication adherence and persistence special interest group". *Value in Health: The Journal of the International Society for Pharmacoeconomics and Outcomes Research* 16.5 (2013): 863-871.

62. De Jongh T., *et al.* "Mobile phone messaging for facilitating self-management of long-term illnesses". *The Cochrane Database of Systematic Reviews* 12.12 (2012): Cd007459.

63. Finitsis DJ., *et al.* "Text message intervention designs to promote adherence to antiretroviral therapy (ART): a meta-analysis of randomized controlled trials". *Plos One* 9.2 (2014): e88166.

64. Mistry H. "Systematic review of studies of the cost-effectiveness of telemedicine and telecare. Changes in the economic evidence over twenty years". *Journal of Telemedicine and Telecare* 18.1 (2012): 1-6.

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