Using Mobile Health for Hypertension Self-Management in Adults: An Updated Systematic Review of Randomized 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 meta-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.
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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.

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.

<table>
<thead>
<tr>
<th>Study reference (First author, year)</th>
<th>Setting</th>
<th>Total sample size (n)</th>
<th>Population</th>
<th>Follow-up duration</th>
<th>Intervention content</th>
<th>Control content</th>
<th>Outcome measures</th>
<th>Blood pressure outcome</th>
<th>Self-management behavior outcome</th>
<th>Medication adherence outcome</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abu-El-Noor, et al. 2020 [39]</td>
<td>Palestine</td>
<td>218</td>
<td>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</td>
<td>3 months</td>
<td>Using mobile phone apps for reminding patients of their medications</td>
<td>Usual care</td>
<td>Improve adherence to treatment regimens among hypertensive patients</td>
<td>NR</td>
<td>NR</td>
<td>Significant, better adherence in the intervention group (P=0.000)</td>
<td>NR</td>
</tr>
<tr>
<td>Bobrow, et al. 2015 [26]</td>
<td>South Africa</td>
<td>1372</td>
<td>Receiving antihypertensive medication, aged ≥21 years</td>
<td>12 months</td>
<td>Intervention 1: information-only adherence support</td>
<td>Usual care</td>
<td>Primary: change in mean SBP</td>
<td>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</td>
<td>NR</td>
<td>A significant change between intervention and control groups (P&lt;0.001)</td>
<td>NR</td>
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<tr>
<td>Bosworth, et al. 2011 [27]</td>
<td>United States</td>
<td>591</td>
<td>Uncontrolled BP</td>
<td>18 months</td>
<td>Intervention 1: self-monitoring nurse-administered behavioral management and usual care</td>
<td>Usual care</td>
<td>Primary: BP control</td>
<td>A significant difference in the rate of BP control in the 2 intervention groups relative to the control group (P&lt;.03)</td>
<td>NR</td>
<td>NR</td>
<td>US $947 for behavioral management; US $1275 for medication management; US $1153 for the combined intervention arm</td>
</tr>
<tr>
<td>Study</td>
<td>Country</td>
<td>Sample Size</td>
<td>Race/Ethnicity</td>
<td>Duration</td>
<td>Intervention Details</td>
<td>Primary Outcomes</td>
<td>Secondary Outcomes</td>
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<tr>
<td>Bove., et al. 2013 [53]</td>
<td>United States</td>
<td>241</td>
<td>SBP of 140 mm Hg or above</td>
<td>6 months</td>
<td>BP education and monitoring and usual care</td>
<td>Not significant. Greater reduction in SBP (P=.12) and DBP (P=.17) in the telemedicine group than the control.</td>
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<tr>
<td>Brennan., et al. 2010 [49]</td>
<td>United States</td>
<td>638</td>
<td>African American</td>
<td>12 months</td>
<td>DMP with nurse support and usual care</td>
<td>Significant. Lower SBP of the intervention group (123.6 vs 126.7 mm Hg; P=.03)</td>
<td>Significant. The intervention group is 46% more willing to report weekly BP monitoring than the control group (P=.02)</td>
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<tr>
<td>Chandler., et al. 2019 [50]</td>
<td>United States</td>
<td>54</td>
<td>Hispanic or Latino diagnosed, aged 21 to 65 years</td>
<td>9 months</td>
<td>Self-monitoring and electronic medication tray</td>
<td>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.</td>
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<tr>
<td>Contreras., et al. 2019 [59]</td>
<td>Spain</td>
<td>148</td>
<td>Stage 1 or 2 hypertension</td>
<td>12 months</td>
<td>Self-monitoring and pharmacological support</td>
<td>Significant. SBP (P&lt;.001) and DBP (P&lt;.001) in the intervention group are lower than in the control group.</td>
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<tr>
<td>Debon., et al. 2020 [54]</td>
<td>Brazil</td>
<td>39</td>
<td>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</td>
<td>3 months</td>
<td>E-lifestyle app and usual care</td>
<td>A significant improvement increased DBP and decreased SBP (p&lt;0.05), with no significance in the control group.</td>
<td>Better with no significance (P=0.333) Poor adherence which increased after education via specific workshops</td>
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</table>

<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Number</th>
<th>Patient Details</th>
<th>Intervention Details</th>
<th>Usual Care</th>
<th>Primary</th>
<th>Secondary</th>
<th>Significance</th>
<th>Cost Savings</th>
<th>Other Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frias., et al. 2017 [24]</td>
<td>United States</td>
<td>109</td>
<td>Elevated systolic BP (SBP ≥140 mm Hg) and HbA1c (≥7%) failing antihypertensive (≥2 medications) and oral diabetes</td>
<td>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)</td>
<td>Usual care</td>
<td>Primary: the effect of the DMO on BP Secondary: effect on glycemic and lipid control, engagement, and provider decision making</td>
<td>Significant reduction in BP and DBP in the DMO compared to the usual care group (P&lt;0.05)</td>
<td>NR</td>
<td>Better by 4 times in the DMO group than the usual care group with no significance</td>
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<tr>
<td>Davidson, et al. 2015 [51]</td>
<td>United States</td>
<td>38</td>
<td>Hispanic or Latino or African American or black, aged 21 to 65 years with uncontrolled BP</td>
<td>6 months Medication adherence and BP monitoring at 4-month, 12-month, and combined follow-up periods.</td>
<td>Usual care</td>
<td>Primary: the proportion of SBP control Secondary: the proportion of DBP control; the total change of BP</td>
<td>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</td>
<td>NR</td>
<td>Higher medication adherence in the intervention group than in the control group Overall cost savings of US $23,692 in the intervention group; US $5,923 in the control group</td>
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<td>Ghezeljeh., et al. 2018 [42]</td>
<td>Iran</td>
<td>100</td>
<td>Aged 35 to 80 years</td>
<td>1.5 months Intervention 1: self-management without follow-up Intervention 2: telephone follow-up Intervention 3: smartphone-based social networking follow-up</td>
<td>Routine education</td>
<td>Self-management behavior</td>
<td>Significant. Better self-management behavior in intervention groups than control (P&lt;.001)</td>
<td>NR</td>
<td>NR</td>
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<tr>
<td>Gong, et al. 2020 [40]</td>
<td>China</td>
<td>480</td>
<td>Age 18–79 yr old with primary hypertension according to the diagnostic criteria in 2010 Chinese Guidelines for Hypertension Prevention and Treatment</td>
<td>6 months Using mobile phone apps for remonitoring patients of their medications</td>
<td>Self-monitoring of blood pressure</td>
<td>Primary: SBP and DBP changes Secondary: Medication adherence</td>
<td>Significant reduction in SBP and DBP in values and control rate in the intervention group (P&lt;0.05)</td>
<td>NR</td>
<td>Significant in the intervention (P&lt;0.05)</td>
<td></td>
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<tr>
<td>Study</td>
<td>Country</td>
<td>Sample Size</td>
<td>Age</td>
<td>Duration</td>
<td>Intervention 1</td>
<td>Usual Care</td>
<td>Primary Outcome</td>
<td>Secondary Outcome</td>
<td>Findings</td>
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<td>KIM 2019 [41]</td>
<td>Korea</td>
<td>124</td>
<td>Aged &gt;65 years</td>
<td>2 months</td>
<td>Home-based health coaching</td>
<td>Usual care</td>
<td>Significant reduction in SBP (P&lt;.001) in intervention vs control group</td>
<td>Change in SBP and DBP</td>
<td>Not reported</td>
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<tr>
<td>Lee, et al. 2016 [52]</td>
<td>Taiwan (China)</td>
<td>382</td>
<td>Aged 18 to 85 years</td>
<td>6 months</td>
<td>Self-monitoring and remote monitoring intervention</td>
<td>Usual care</td>
<td>Significant improvement in self-management behavior (P&lt;.001)</td>
<td>Change in SBP and DBP</td>
<td>Significant difference in self-management behavior (P&lt;.001)</td>
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<tr>
<td>Liu, et al. 2018 [43]</td>
<td>Canada</td>
<td>128</td>
<td>Stage 1 or 2 hypertension, aged 35 to 74 years</td>
<td>4 months</td>
<td>User-driven e-counseling</td>
<td>Usual care</td>
<td>Significant reduction of SBP (P&lt;.001) in expert-driven group</td>
<td>Change in SBP and DBP</td>
<td>Significant improvement of daily steps and fruit consumption (P=.01)</td>
<td></td>
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<tr>
<td>Maciejewski, et al. 2013 [57]</td>
<td>United States</td>
<td>591</td>
<td>Uncontrolled BP</td>
<td>18 months</td>
<td>Self-monitoring nurse-administered behavioral management and usual care</td>
<td>Usual care</td>
<td>Significant reduction of SBP (P&lt;.001) in expert management group (17.1%), medication management group (20.2%), and combined group (20.4%) compared with usual care</td>
<td>Change in SBP and DBP</td>
<td>Estimate expenditures are similar</td>
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</tbody>
</table>

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<table>
<thead>
<tr>
<th>Study Authors</th>
<th>Country</th>
<th>Sample Size</th>
<th>Setting</th>
<th>Duration</th>
<th>Intervention Details</th>
<th>Usual Care Details</th>
<th>Primary Outcomes</th>
<th>Secondary Outcomes</th>
<th>Cost in US Cost per Patient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Margolis, et al. 2013</td>
<td>United States</td>
<td>450</td>
<td>Uncontrolled BP</td>
<td>12 months</td>
<td>Self-monitoring and phone visit of pharmacists</td>
<td>Usual care</td>
<td>Significant change in SBP between intervention and control group: −9.7 mm Hg (P&lt;.001)</td>
<td>Difference between groups of self-reported medication adherence: 13.8%</td>
<td>NR</td>
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<td>Secondary: change in SBP and DBP; patient satisfaction</td>
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<td>McKinstry, et al. 2013</td>
<td>United Kingdom</td>
<td>401</td>
<td>An adult patient with hypertension</td>
<td>6 months</td>
<td>Self-monitoring and closed-loop feedback</td>
<td>Usual care</td>
<td>Significant reduction of SBP (P&lt;.001) and DBP (P=.002) in the telemonitoring group than the control group</td>
<td>No significant difference in lifestyle adjustment between groups (P=.79)</td>
<td>NR</td>
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<td>Primary: mean SBP</td>
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<td>Secondary: mean DBP</td>
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<tr>
<td>McManus, et al. 2010</td>
<td>United Kingdom</td>
<td>480</td>
<td>Receiving ≤2 antihypertensive drugs, aged 35 to 85 years</td>
<td>12 months</td>
<td>Self-monitoring and teleconnection with doctors</td>
<td>Usual care</td>
<td>A significant difference in SBP (P=.002). Reduction of SBP in the intervention group than the control group by 5.4 mm Hg; No significant difference in DBP change between the groups (P=.09)</td>
<td>Quality of life increased in the intervention group</td>
<td>NR</td>
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<td>Primary: change in mean SBP</td>
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<td></td>
<td>Secondary: antihypertensive drugs prescribed</td>
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<tr>
<td>McManus, et al. 2018</td>
<td>United Kingdom</td>
<td>1182</td>
<td>Aged &gt;35 years, taking ≤3 antihypertensive medicines</td>
<td>12 months</td>
<td>Intervention 1: telemonitoring and send readings</td>
<td>Usual care</td>
<td>Significant. Lower SBP in the telemonitoring group than in the control group (P&lt;.001); non-significant difference between the 2 intervention groups (P=.18)</td>
<td>No significant difference in self-reported adherence between 3 groups (P=.83)</td>
<td>NR</td>
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<td>Intervention 2: self-monitoring and record BP on paper</td>
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<td></td>
<td>Primary: change of SBP</td>
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</tbody>
</table>

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<table>
<thead>
<tr>
<th>Authors, Year</th>
<th>Country</th>
<th>Sample Size</th>
<th>Age/Stage</th>
<th>Intervention Duration</th>
<th>Type of Intervention</th>
<th>Usual Care</th>
<th>Primary Effect</th>
<th>Secondary Effect</th>
<th>SBP of the Intervention Group</th>
<th>Control</th>
<th>NR</th>
<th>NR</th>
<th>NR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meurer, et al. 2019 [55]</td>
<td>United States</td>
<td>55</td>
<td>Emergency department with a systolic stage 2 or more hypertension</td>
<td>4 months</td>
<td>Medication and health behavior intervention</td>
<td>Usual care</td>
<td>Primary: the proportion of BP control</td>
<td>Secondary: change in SBP</td>
<td>SBP of the intervention group had a mean drop of 9.1 mmHg</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Migneault, et al. 2019 [44]</td>
<td>United States</td>
<td>337</td>
<td>African American, aged &gt;34 years</td>
<td>8 months</td>
<td>Behavioral intervention and usual care</td>
<td>Usual care</td>
<td>Primary: change in behavior, medication adherence</td>
<td>Secondary: change in BP</td>
<td>Larger reduction of SBP and DBP in the intervention group than the control group</td>
<td>Dietary: significant improvement in the intervention group (P=.02); activity: significantly (P=.02)</td>
<td>Not significant (P=.25). Higher medication adherence in the intervention group than in the control group</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Moore, et al. 2014 [58]</td>
<td>United States</td>
<td>44</td>
<td>Receiving ≤1 medication</td>
<td>12 months</td>
<td>Technology-supported health coach</td>
<td>Usual care</td>
<td>Primary: decrease in SBP and DBP, the proportion of BP control</td>
<td>Secondary: the change in medication load and weight</td>
<td>A significant difference in SBP change (P=.009). No significant difference in DBP change (P=.054). All of the participants achieved BP control</td>
<td>NR</td>
<td>NR</td>
<td>Intervention: US $67.50 per patient/year; Control: US $248 per patient/year</td>
<td>NR</td>
</tr>
<tr>
<td>Morawska, et al. 2018 [19]</td>
<td>United States</td>
<td>412</td>
<td>Aged 18 to 75 years</td>
<td>3 months</td>
<td>Medication adherence intervention</td>
<td>Usual care</td>
<td>Primary: medication adherence and change of SBP</td>
<td>Secondary: the proportion of controlled BP</td>
<td>No difference in DBP change between the groups (P=.78)</td>
<td>NR</td>
<td>Significant. Higher in the intervention than control (P=.01)</td>
<td>NR</td>
<td>NR</td>
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<tr>
<td>Nolan, et al. 2012 [36]</td>
<td>Canada</td>
<td>387</td>
<td>Stage 1 or 2 hypertension, aged 45 to 74 years</td>
<td>4 months</td>
<td>E-counseling intervention</td>
<td>Usual care</td>
<td>Primary: change of SBP and DBP</td>
<td></td>
<td>Significant. Lower SBP pressure in the e-counseling group with 1–7 emails (P=.03); Significant. DBP differed</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
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<tr>
<td>Nolan, et al. 2018 [45]</td>
<td>Canada</td>
<td>264</td>
<td>Stage 1 or 2 hypertension, aged 35 to 74 years</td>
<td>12 months</td>
<td>E-counseling intervention</td>
<td>Self-monitoring and basic self-management education</td>
<td>Primary: decrease of SBP, DBP</td>
<td>Secondary: other clinical data</td>
<td>Significant. A greater reduction of SBP for e-counseling (P=.02). No significant difference in DBP between e-counseling versus control (P=.17)</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
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<tr>
<td>Citation</td>
<td>Country</td>
<td>Sample Size</td>
<td>Duration</td>
<td>Intervention</td>
<td>Usual care</td>
<td>Primary:</td>
<td>Secondary:</td>
<td>Outcome</td>
<td>Notes</td>
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<tr>
<td>Peiris., et al 2019 [38]</td>
<td>India</td>
<td>8,642</td>
<td>6 months</td>
<td>self-monitoring nurse-administered physician-directed management with a clinical decision support system</td>
<td>Usual care</td>
<td>No significance in proportion and control</td>
<td>A small increase in self-reported physical activity with no significance</td>
<td>NR</td>
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<td>Piette., et al 2012 [28]</td>
<td>Honduras and Mexico</td>
<td>200</td>
<td>1.5 months</td>
<td>Self-monitoring and structured email alerts and family members’ help</td>
<td>Usual care</td>
<td>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)</td>
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<tr>
<td>Study</td>
<td>Country</td>
<td>Sample Size</td>
<td>Population Details</td>
<td>Duration</td>
<td>Intervention Details</td>
<td>Primary Outcomes</td>
<td>Secondary Outcomes</td>
<td></td>
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<td>Salisbury, et al. 2016 [22]</td>
<td>United Kingdom</td>
<td>641</td>
<td>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)</td>
<td>12 months</td>
<td>Healthline service (alongside usual care), comprising regular telephone calls from trained lay health advisors following scripts generated by interactive software</td>
<td>Nonsignificant but intervention was associated with lower levels in BP, SBP, DBP</td>
<td>Small nonsignificant improvements in the intervention group</td>
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<td>Tobe., et al. 2019 [37]</td>
<td>Canada</td>
<td>142</td>
<td>Hypertensive Canadian First Nations people from six rural and remote communities</td>
<td>12 months</td>
<td>Hypertension specific management SMS</td>
<td>Overall reduction but no significance in SBP, DBP, (P=0.05, 0.06, respectively)</td>
<td>NR</td>
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<td>Varleta, et al. 2017 [56]</td>
<td>Chile</td>
<td>314</td>
<td>Aged 30 to 80 years</td>
<td>6 months</td>
<td>Education and usual care</td>
<td>Primary: antihypertensive therapy adherence</td>
<td>Not enough power to make statistical comparisons</td>
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Table 1: Characteristics of the included studies.

*B: Blood Pressure; **SBP: Systolic Blood Pressure; **DBP: Diastolic Blood Pressure; *E-counseling: Electronic Counseling; *DMP: Disease Management Program; *LSP: Light Support Education Program; *ESC: Enhanced Standard Care; *BMI: Body Mass Index.

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**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 [36,37,52,53] 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.
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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 [22,24,27,28,36-39,41-46,49-54,55-59], 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 these 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
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calls, digital and electronic medications. The increased frequency of reminding patients about their exposure was reported 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 understanding unclear. 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, we 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


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