Use of Short Messaging Service for Hypertension Management
A Systematic Review

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Background: Mobile phone Short Message Service (SMS) is a tool now used by the health research community, providing the capability for instant communication between patients and health professionals. Greater understanding of how to best use SMS as a means to improve healthcare delivery and outcomes will foster innovation in research and provide an opportunity to progress as a public health community. Purpose: The purposes of this systematic review are 2-fold: (1) to provide insight on the most used mobile phone SMS practices and characteristics in hypertension (HTN) outcome-focused publications and (2) to critically evaluate empirical evidence associated with SMS utilization and BP outcomes. Methods: Two independent systematic literature searches were completed. The final selected studies each then underwent data extraction and quality-rating assessment, followed by an evaluation for a meta-analysis to measure mean difference of the change in BP. Results: A total of 6 studies meeting the inclusion criteria were included in the review. Feasibility assessment for a meta-analysis was found unfavorable because of the variation among studies. Short Message Service interventions focused on BP management were most effective in studies featuring 2-way communication and individual patient-tailored content, and guided by evidence-based HTN management practices. Implications: Short Message Service interventions for HTN management were supported through evidence provided by the studies reviewed. Short Message Service holds strong potential to bring greater innovation to HTN management and care, especially in racial/ethnic minority populations that face psychosocial and structural barriers in healthcare access and utilization.

KEY WORDS: hypertension, mHealth, short messaging system

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communication sent from one mobile phone user to another with messaging applications.”6 This recent yet overwhelmingly popular technological innovation falls within the domain of mobile health (mHealth). The World Health Organization defines mHealth as “a medical and public health practice supported by mobile devices,” including mobile phones.7 The opportunity that SMS can provide as an effective health communication and data-tracking tool in health management has already been demonstrated for a number of diseases and health topics.8 This opportunity may be related to global availability and access to mobile phones—the United Nations’ International Communication Union reported that at the end of 2014, mobile phone subscriptions globally approached an astounding 7 billion, drawing near to the entire human population.9 Specifically within the United States, recent studies indicate that in 2013, 91% of all adults owned and used a mobile phone, and of those, 81% used SMS.10

Short Message Service is becoming a transformational tool for the public health community to use in the delivery of better quality care and health promotion, including within the realms of prevention and management of chronic diseases such as HTN. Consequently, identifying the most effective uses of SMS for any particular health issue or target population is essential to future mHealth research programming. Systematic reviews and meta-analysis on SMS-based interventions provide researchers useful insight on the most promising uses of SMS in supporting healthcare and disease prevention and management. Although much of the literature focused on CVD prevention that uses SMS has been on diabetes mellitus management,11 there is limited study of BP outcomes,12 despite the fact that HTN and diabetes mellitus are both recognized as significant CVD risk factors that require chronic management.2 To our knowledge, this review is the first specifically focused on SMS use for HTN management. This study was designed to systematically review and conduct a meta-analysis of interventions that used SMS to improve BP control among their participants and to provide recommendations for SMS utilization within HTN care.

Methods

This study used guidelines for primary process and reporting methods outlined by The Cochrane handbook for systematic reviews of interventions13 and The Preferred Reporting Items for Systematic Reviews and Meta-analyses: the PRISMA statement.14 Supplemental information pertaining to the initial steps that were carried out for a meta-analysis was also reported to provide further insight into the overall state of the research literature to date.

Eligibility Criteria

The following inclusion and exclusion criteria were set for the search and selection of literature to systematically review and assess for meta-analysis. Publications had to (a) describe either a quasi-experimental or randomized controlled trial, (b) target an adult population (≥18 years old), (c) integrate HTN prevention or management, (d) evaluate BP as outcome measures, and (e) use SMS as an intervention component. To avoid discrepancy, we defined SMS as a mobile phone’s text message service with sending and receiving message capability, typically under 160 alphanumeric characters in length, to either another mobile phone or a web-based system; this designation excluded mobile phone communication using applications or e-mail. Short message service also did not need to be the primary component used in a study to be included. Publications had to be available in (f) full-text and (g) English, Korean, or Spanish, the languages fluently spoken by our author team. There were no limits on year published, as SMS is a relatively new technology, with earliest publication involving a health intervention appearing in 2002.15 Studies using SMS that primarily addressed CVD such as stroke, metabolic syndrome, kidney disease, heart failure, or acute coronary syndrome were excluded, regardless of whether BP was an outcome measure, as these diseases can independently impact BP outcomes.

Sources of Information and Search Strategy

Two reviewers (E.W. and M.I.C.) conducted independent systematic literature searches using PubMed, CINAHL, Embase, Cochrane, Scopus, and PsycINFO for articles that were published as of July 2015. A medical librarian assisted in the creation of database search terms. The following Mesh terms were used in multiple combinations: text messaging, text message, text messages, texts, texted, texting, SMS, short message service, short messaging service, hypertension, high blood pressure, essential hypertension, diabetes mellitus, diabetes mellitus, cholesterol, tobacco smoking, passive smoking, smoking, smoker, smokers, diet, obesity, motor activity, physical activity, exercise, aerobic exercise, weight lifting, yoga (see Document, Supplemental Digital Content 1, http://links.lww.com/JCN/A19, for a full electronic search strategy). To reinforce search quality, the team completed 2 additional unique searches. A review of previously published mHealth or SMS-focused systematic review articles was completed to follow a cross-reference search for articles that fit our review’s inclusion criteria. Finally, a search on ClinicalTrials.gov for relevant completed studies pending publication was completed. If a study fit the inclusion criteria, its respective principal investigator was contacted for a copy of the study methods and results.

Screening, Data Extraction, and Critical Appraisal

Upon finalization of the articles for this systematic review, the data extraction and quality ratings were
performed. The following items were extracted from each article: author, year, country, target behavior, study design, aims, intervention, duration, sample size, and evaluation method and outcome measures. Data on SMS-specific intervention were collected separately, including SMS type, dosage, frequency, transmission, examples, and any relevant evaluation. A quality rating assessment using a bias rating tool was then completed for each study. E.W. and M.I.C. independently assessed and rated each study based on the quality criteria. Any discrepancies were reconciled by a team consensus.

**Statistical Analysis**

We worked toward completing a meta-analysis to assess the pooled effect size of the selected studies. The primary outcome was the mean difference in the change in BP measurement from baseline at the final time point between the intervention and control groups. In the case of any unreported data required for the meta-analysis, communicating efforts with the study’s corresponding author were made. Afterward, any data that were not able to be obtained was estimated using conservative calculation recommended in a report by the Agency for Healthcare Research and Quality (United States). Meta-analysis calculations were completed using STATA (College Station, Texas) with the “metan” command. The forest plots of the pooled mean differences of changes in systolic and diastolic BP from baseline were presented using 95% confidence intervals. Using the I² statistic, the clinical and methodological heterogeneity (eg, participants, interventions, designs, outcomes, or quality ratings) among the studies was assessed to determine the feasibility of meta-analysis. If substantial variances resulted (ie, I² values >50%), studies could not be pooled and each study would have to be separately reviewed and summarized.

**Results**

**Search Results**

The initial independent database searches identified over 3000 related articles for each reviewer. After duplicates were removed and article titles were screened, E.W. and M.I.C. examined abstracts for 493 and 352 articles, respectively. From these articles, the full-text review for inclusion criteria yielded E.W. with 29 articles and M.I.C. with 18 articles, respectively. The two reviewers met and reached a consensus on 15 of the articles. The whole team then met and conducted another round of full-text reviews on the 15 articles. After further discussion, 11 of the articles were removed for failing to meet all inclusion criteria, such as having targeted individuals with CVD, lacked clarity whether the study included participants with CVD, failed to measure BP outcomes, or been labeled a nonresearch study. A cross-reference search on 17 SMS-focused systematic reviews yielded 1 additional eligible article. Similarly, the search on ClinicalTrials.gov resulted in 1 additional clinical trial study that met the inclusion criteria. Figure 1 provides a search tree describing the steps taken to reach final consensus of the total studies selected.

**Summary of Studies**

A total of 6 studies were included to complete a systematic review and be assessed for meta-analysis. A summary of the studies’ characteristics can be found Table 1. Five studies identified as randomized controlled trial, 1 as quasi-experimental. All studies took place internationally, more specifically, 2 in Spain, 1 in Russia, 1 in China, 1 in South Korea, and 1 in the Philippines. The studies’ targeted behaviors included a partial or sole focus on HTN management, whereas 2 of the studies also focused on weight loss. Each study’s intervention and control groups’ systolic and diastolic BP outcomes were collected and reported in Table 1 using the baseline and difference from baseline at final point measurements. Intervention duration ranged from 2 to 12 months. A total of 1466 study participants (949 after attrition) were included in this review. The target population was limited to patients, although 1 study also chose to enroll general providers. Participants were recruited based on the presence of a specific disease (ie, HTN) or health behavior (ie, weight loss). The average age of the patient-participants was 53.6 years, and 55.3% were female.

**Short Message Service Characteristics**

The studies’ SMS characteristics are summarized in Table 2. The SMS component of each study was classified as either the main or a supplemental component of the intervention. Only 1 study integrated SMS into its intervention as a supplemental component, whereas the other 5 used SMS as the main component, with or without non-SMS supplemental components. For example, the Lin study integrated a supplemental SMS component, sending patient-participants daily SMS to track their weight loss goal progress, with supporting education sessions and telephone coaching call components. Two studies restricted SMS transmission to 1-way communication (only the study team sending the SMS). The other 4 studies allowed for 2-way communication, with the study teams always initiating the SMS communication with participants. Frequency of SMS communication also varied, with SMS being sent daily in 2 studies, weekly in 4 studies, and specific event-initiated (eg, unstable BP measurements were noted) in 1 study. Of
the studies where SMS was sent daily, in only 1 study was multiple SMS sent per day.20

The SMS types used among the studies varied both within and between the studies and were sorted into 5 categories: (1) SMS that provided medication reminders was used in 3 studies,18,19,22 sent daily in 1 study19 and 2 days per week in the 2 other studies18,22; (2) SMS to schedule clinic appointments was used in 1 study,19 sent during specific events such as when a participant had unstable self-reported BP; (3) SMS to disseminate educational information (eg, good health and dietary habits) was sent 2 days per week in 2 studies18,22; (4) SMS to provide self-report measurements and progress to the research team, sent by the participants themselves, was used in 4 studies.17,19–21

The types of self-reported information sent by participants included BP,17,19,21 heart rate,17 weight,17,19,21 number of cigarettes smoked,19 medication intake record,21 and behavioral goal progress.20 The SMS to self-report information were sent by participants on a daily basis in 1 study,20 and on a weekly basis in 3 studies17,19,21; finally, (5) all 4 studies using SMS to self-report information also used SMS to provide individualized feedback and commentary on behalf of the research teams or general providers,17 which was sent in response to the SMS with self-report information provided by participants.

**Effects of Short Message Service Intervention**

Evaluation of the effects of SMS was primarily based on the studies’ BP outcomes and then supported by other clinical and behavioral outcome measures. Measurements of BP used to calculate outcomes were collected in clinical settings and by trained researchers. The BP data that were self-reported by participants (via SMS) were only used to develop the individualized feedback and commentary content and/or were evaluated as a

**FIGURE 1. Flow chart of the literature search and selection process. BP indicates blood pressure; CVD, cardiovascular disease; HTN, hypertension.**
<table>
<thead>
<tr>
<th>First Author (Year), Country</th>
<th>Target Behavior</th>
<th>Study Design and Duration</th>
<th>Sample N = Baseline Evaluation</th>
<th>Intervention</th>
<th>Outcome Measures and Evaluation</th>
<th>Principal Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrasco (2008), Spain</td>
<td>HTN</td>
<td>RCT 6 mo</td>
<td>Sample size: N = 285 → 273 (IG: 142 → 131, CG: 143 → 142) Mean age: IG: 62.1 y, CG: 62.8 y Female: IG: 39.7%, CG: 40.8%</td>
<td>IG: reported BP, HR, and weight to their GP weekly via SMS + (GP feedback optional) CG: self-measured BP, HR, and weight weekly + reported their measures in-person during routine visits</td>
<td>Primary: degree of HTN control and uncontrolled HTN at 6 mo Secondary: BP, HR, quality of life, anxiety survey scores, number of consultation visits, and hospital admissions Evaluation: baseline and 6 mo</td>
<td>No significant difference in percentage with controlled BP at 6 mo No significant BP decreases from baseline for both groups No significant difference in quality of life and anxiety survey scores No significant median difference in number of hospital admissions Evaluation: baseline and 6 mo</td>
</tr>
<tr>
<td>Kiselev (2012), Russia</td>
<td>HTN</td>
<td>RCT 12 mo</td>
<td>Sample size: N = 199 → 164 (IG: 97 → 62, CG: 102) Mean age: IG: 49 y, CG: 51 y Female: IG: 45%, CG: 50%</td>
<td>IG and CG (at baseline): prescribed medication, encouraged to measured BP at home, and received informational brochures IG: daily/weekly SMS for 12 mo CG: standard care</td>
<td>Primary: BP goal of 135/85 mmHg Secondary: weight loss and smoking cessation Evaluation: baseline and 6 and 12 mo</td>
<td>77% (IG) vs 12% (CG) reached BP goal at 12 mo</td>
</tr>
<tr>
<td>Lin (2014), China</td>
<td>Weight loss</td>
<td>RCT 6 mo</td>
<td>Sample size: N = 123 → 110 (IG: 63 → 56, CG: 60 → 54) Mean age: IG: 38.35 y, CG: 38.07 y Female: IG: 60.32%, CG: 60%</td>
<td>IG: daily SMS + goal setting + 3 group education sessions + 5 coaching calls CG: brief education information at baseline</td>
<td>Primary: weight change Secondary: BP, BMI, waist circumference, body fat (%), dietary intake, physical activity, and psychosocial factors Evaluation: baseline and 6 mo</td>
<td>Significant difference in mean weight change at 6 mo (IG: −1.6 kg, CG: +0.24 kg) Significant difference in mean BP change (IG: −1.71/−3.24 mm Hg, CG: +2.34/+1.2 mm Hg) Significant difference in mean BMI change (IG: −0.61 kg/m², CG: +0.07 kg/m²) Significant difference in mean decrease in waist circumference Significant difference in mean percentage body fat change (IG: −0.66%, CG: +0.36%)</td>
</tr>
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(continues)
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<tr>
<th>First Author (Year), Country</th>
<th>Target Behavior</th>
<th>Study Design and Duration</th>
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<th>Principal Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Márquez-Contreras (2004), Spain</td>
<td>HTN</td>
<td>RCT 6 mo</td>
<td>Sample size: N = 104 → 67 (IG: 52 → 34, CG: 52 → 33) Mean age: IG: 56.3 y, CG: 59.4 y Female: IG: 47.1%, CG: 42.4%</td>
<td>IG and CG (at baseline): printed HTN information and prescribed medication IG: weekly SMS for 4 mo CG: standard of care</td>
<td>Primary: patient percentage compliance score, based on medication adherence Secondary: BP and weight Evaluation: baseline and 1, 3, and 6 mo</td>
<td>No significant difference in medication adherence between groups at 6 mo 65% (IG) vs 52% (CG) had controlled BP; however, no significant difference in mean BP decreases between groups Significant mean weight loss decrease in IG Higher medication adherence in IG Overall positive SMS experience, with 80% reporting that the SMS helped them remember to take their medication</td>
</tr>
<tr>
<td>Palileo-Villanueva (reference 22), Philippines</td>
<td>HTN</td>
<td>RCT 3 mo</td>
<td>Sample size: N = 700 → 286 (IG: 350 → 151, CG: 350 → 135) Mean age: IG: 59 y, CG: 59.6 y Female: IG: 66.1%, CG: 64.4%</td>
<td>IG: weekly medication adherence reminders via SMS CG: standard of care</td>
<td>Primary: SBP and DBP Secondary: medication adherence (self-report) and SMS acceptability survey Evaluation: baseline and 3 mo</td>
<td>No significant difference in mean SBP decrease at 3 mo (IG: −13.7 mm Hg, CG: −9.5 mm Hg) Higher medication adherence in IG</td>
</tr>
<tr>
<td>Park (2009), South Korea</td>
<td>HTN, weight loss</td>
<td>Quasi-experimental 2 mo</td>
<td>Sample size: N = 55 → 49 (IG: 30 → 28, CG: 25 → 21) Mean age: IG: 53.2 y, CG: 54.6 y Female: IG: 39.3%, CG: 57.1%</td>
<td>IG: reported BP, weight, and medication information weekly via SMS or Web-based diary + tailored feedback from study staff CG: provided with study information only</td>
<td>Primary: BP, weight, waist circumference, and serum lipids Evaluation: baseline and 2 mo</td>
<td>Significant mean BP decrease in IG only at 2 mo IG showed significant mean weight decrease; however, no significant difference in mean weight loss between groups Significant difference in waist circumference (IG: −2.8 cm, CG: + 2.1 cm) No significant difference in serum lipid level</td>
</tr>
</tbody>
</table>

Abbreviations: BP, blood pressure; BMI, body mass index; CG, control group; DBP, diastolic blood pressure; GP, general provider; HR, heart rate; HTN, hypertension; IG, intervention group; RCT, randomized controlled trial; SBP, systolic blood pressure.

aData available from https://clinicaltrials.gov.
<table>
<thead>
<tr>
<th>First Author (Year)</th>
<th>Content and Topics</th>
<th>Transmission</th>
<th>Frequency</th>
<th>SMS Examples*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrasco (2008)</td>
<td>Self-report measurements and progress: BP, HR, and weight data Feedback and commentary (optional): GP’s HTN management feedback</td>
<td>2 way (SMS feedback from GP was optional)</td>
<td>Weekly, 4 times per week for BP, once a week for HR and weight</td>
<td>None available</td>
</tr>
<tr>
<td>Kiselev (2012)</td>
<td>Medication reminders: BP home monitoring, HTN medication, weight loss and smoking cessation support reminders Self-report measurements and progress: BP, weight, and number of cigarettes smoked data Feedback and commentary: emphasized specific HTN management recommendations based on each participant’s self-reported data Appointment scheduling: prompted by a drastic change in participant’s self-reported BP data</td>
<td>2 way</td>
<td>Daily (medication), weekly (weight, number of cigarettes smoked) Feedback algorithm: daily—initiation of new BP med/missing BP reading/ increase of 20 mm Hg in SBP from last visit; weekly—change in BP med/increase of &lt;20 mm Hg in SBP from last visit; monthly—constant or decrease in SBP from last visit; semiannually—constant or decrease in SBP during the last 6 mo</td>
<td>None available</td>
</tr>
<tr>
<td>Lin (2014)</td>
<td>Self-report measurements and progress: weight loss assigned goal progress data Feedback and commentary: tailored feedback based on each participant’s self-reported goal progress</td>
<td>2 way</td>
<td>Daily (weight loss progress)</td>
<td>Goal progress requests: # Sugary drinks # Cups of fruits and veggies # Packaged or street snacks Had low fat dairy (y/n)? Ate fast-food (y/n)? “Always take your BP pill when you get up in the morning” “Remember that the effect of BP pills wears off after 24 hrs. Some patients have serious problems because they don’t take their pill every day” “Try to take your pills exactly as your doctor advised you. This ensures that your treatment will be useful”</td>
</tr>
<tr>
<td>Márquez-Contreras (2004)</td>
<td>Educational information: HTN information, and good health and diet habits Medication reminders: HTN medication</td>
<td>1 way (study team → participant)</td>
<td>Weekly</td>
<td>None available</td>
</tr>
<tr>
<td>Palileo-Villanueva (reference 22)</td>
<td>Educational information: target BP and benefits of HTN treatment Medication reminders: HTN medication</td>
<td>1 way (study team → participant)</td>
<td>Weekly</td>
<td>None available</td>
</tr>
<tr>
<td>Park (2009)</td>
<td>Self-report measurements and progress: BP, weight, diet, and exercise, and medication information data Feedback and commentary: HTN management feedback that was based on each participant’s self-reported data</td>
<td>2 way</td>
<td>Weekly</td>
<td>“The frequency of the fast food intake was five times last week, please decrease the frequency in two times” “Your exercise duration was 20 minutes last week, you need 10 minutes more”</td>
</tr>
</tbody>
</table>

Abbreviations: BP, blood pressure; GP, general provider; HR, heart rate; HTN, hypertension; SBP, systolic blood pressure.

*Original Short Message Service used did not use abbreviated wording.
secondary outcome. The 6 studies’ evaluation content identified that only 3 studies\textsuperscript{19–21} reported improved BP outcomes in their SMS interventions and expressed overall positive outlooks on SMS use in HTN management care. No significant BP outcome results were reported by the authors of 3 SMS interventions.\textsuperscript{17,18,22} However, the unpublished Palileo-Villanueva study had not yet completed discussion on their outcome results. One study that found no significant results in their SMS intervention evaluated medication adherence as a behavioral outcome.\textsuperscript{18} Per request at various time points, participants brought in their HTN medication(s) and the study team proceeded to discreetly count the individual pills to calculate medication adherence. The use of SMS for medication reminders alone demonstrated no significant improvements in adherence.\textsuperscript{18}

Process evaluations of participants’ responses to SMS and their level of utilization were completed in 5 studies.\textsuperscript{17,19–22} In 2 studies\textsuperscript{19,21} participants were withdrawn if noncompliant in corresponding to SMS after 1 month. Reasons cited for noncompliance included “loss of interest in the intervention” and “technical difficulties with the SMS” in the Kiselev study. Participants’ experiences and receptiveness to using SMS were documented at the end in 2 studies,\textsuperscript{20,22} and both indicated overall favorable responses. One study reported that 95% of participants felt SMS was helpful in achieving their weight loss goals,\textsuperscript{20} whereas 99% of participants from the second study reported that “receiving health information through text is helpful.”\textsuperscript{22} Lastly, 1 study measured the general provider–participants’ SMS utilization by recording the total number of SMS sent to the patient–participant arm.\textsuperscript{17} Fifty percent of the patient–participants failed to receive any SMS, indicating low levels of general provider SMS utilization.\textsuperscript{17}

Quality Ratings

The quality-rating assessments determined 5 studies with high risk of bias and 1 with an unclear risk of bias.\textsuperscript{17} Overall, studies did not provide sufficient information to assess bias in their randomization of study participants. High risk for selection bias was found among all 6 studies. Furthermore, only 2 studies\textsuperscript{20,22} randomly assigned participants, and only 1 of those\textsuperscript{22} also used allocation concealment on study personnel. Figure 2 summarizes our quality-rating findings.

Meta-analysis

Meta-analysis was attempted using the 6 studies. We first addressed the issue of unreported data (ie, standard deviations and mean BP data at baseline and final time point) in 3 study articles\textsuperscript{19–21} that were required to assess the primary outcome. The 3 studies’ corresponding authors were contacted via e-mail to obtain the unreported data, but the author of only 1 study\textsuperscript{19} provided the requested data. More than 1 attempt was made to reach the 2 other studies’ corresponding authors, but we were unable to obtain the unreported data and therefore used the conservative approaches outlined previously.\textsuperscript{16} A comparison for similarities in the participants, interventions, and outcomes indicated moderate clinical heterogeneity. A comparison for similarities in the study design and risk of bias suggested slight heterogeneity. Combined, the heterogeneity was on the border of significance and we thus continued with testing the statistical heterogeneity. Mean difference calculations of systolic BP and diastolic BP resulted in an $I^2$ of 93.5% and 89.9%, respectively, indicating that the statistical heterogeneity was substantial (see Figure 3 for forest plots). Consequently, no further steps were taken to complete the meta-analysis.

Discussion

Our systematic review reveals that 3 studies\textsuperscript{19–21} of the 6 studies had significant improvement in BP outcomes as a result of their SMS component alone or in combination with other components (eg, telephone coach calls). Short Message Service was most effective in those interventions with 2-way communication, individualized patient-tailored content, and a combination of other evidence-based HTN management support effort practices (eg, health education group sessions). Of 3 studies that used medication reminder SMS,\textsuperscript{18,19,22} the Kiselev study allowed for 2-way SMS transmission, which may have contributed considerably to the significant BP outcome exhibited in only the intervention group. Better BP outcomes in the studies with 2-way SMS transmission may have stemmed from the increased communication between the patients and study team. It very well may be that HTN patients are more likely to adhere to medication if their health provider is actively monitoring their treatment progress. Moreover, when patients have to routinely self-monitor and report BP, for example, an inherent automatic reinforcement about their current BP status is achieved and potentially encourages healthier conscious decision making. The finding is consistent with other non-SMS studies of HTN in which active and effective communication between healthcare teams and their patients resulted in improved adherence to HTN treatment.\textsuperscript{23}

A comparison between studies using generic versus individualized SMS demonstrates that patient–participants were more likely to benefit with individualized SMS. Three studies\textsuperscript{17,20,21} used individualized SMS, including study team communication such as feedback to a patient that was based on their most up-to-date self-reported progress, resulting in significantly improved BP levels in 2 of the studies.\textsuperscript{20,21} Findings from this review suggest that patients may benefit more from
SMS communication that tailors its content to be most relevant to each individual’s own HTN management progress. The adherence to BP self-monitoring at home may become less challenging to patients when there is a scheduled cue to initiate and report the information to a health provider who is actively waiting to review it. Evidence supports the utility of an individualized approach (as opposed to generic, nonindividualized) communication aimed toward changing specific health behaviors connected to HTN management. In consideration of these, future SMS intervention should aim to be individualized to the patient’s profile as much as possible.

Frequency of SMS and study duration varied widely, posing a challenge for a close comparison of results across the studies and limited our ability to infer the frequency and length of time optimal for SMS utilization impact. Daily self-report measurement and progress and feedback and commentary SMS was sent in only the Lin study, whereas the Kiselev study sent daily medication reminder SMS and weekly self-report measurement and progress and feedback and commentary SMS. Nevertheless, both studies showed significantly better BP outcomes. Care should be taken to prevent the possibility of overwhelming participants with too many different category SMS on a daily basis, and prioritization of designating the highest frequency to self-report information and progress and individualized feedback and commentary SMS should be applied. Educational information SMS was sent on a weekly basis in 2 studies but did not show a direct contribution to significant clinical and behavioral outcome results. A comparison of the Park, Link, and Kiselev studies shows noticeable differences in study duration (2, 6, and 12 months, respectively), implying that the content and transmission type of the SMS may have had greater influence on BP outcomes than the study duration alone. Future research is warranted to explore adequate frequency and duration of SMS in addressing the needs of individuals with HTN.

FIGURE 2. Methodological quality ratings of included studies.

SMS communication that tailors its content to be most relevant to each individual’s own HTN management progress. The adherence to BP self-monitoring at home may become less challenging to patients when there is a scheduled cue to initiate and report the information to a health provider who is actively waiting to review it. Evidence supports the utility of an individualized approach (as opposed to generic, nonindividualized) communication aimed toward changing specific health behaviors connected to HTN management. In consideration of these, future SMS intervention should aim to be individualized to the patient’s profile as much as possible.

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**FIGURE 3.** Forest plots for the mean difference of changes in blood pressure.
What’s New and Important

- SMS interventions that allowed for 2-way communication were most effective in supporting patients achieve their BP goals.
- Tailoring the content of the SMS message to each patient and combining SMS with evidence-based HTN management practices helped improve BP outcomes.

Overall, SMS utilization in HTN management was limited in terms of effectiveness if either party involved was not fully engaged and accepting of SMS. In the Carrasco study, for example, the general providers exhibited low SMS utilization and infrequently sent feedback and commentary SMS to patients self-reporting BP data. Efforts toward emphasizing the potential benefits and utility of SMS are needed to increase receptiveness among HTN patients and the healthcare system. To effectively use SMS in HTN management, expectations for SMS communication should also be set and clear. The results suggest a need for future research to understand which types of SMS are most helpful or lead to behavioral change in patients.

Maintaining high rigor in methodological qualities remained a challenge for the reviewed studies. For example, only 2 studies used a randomized controlled study design. Limited sample sizes with predominantly white samples were also notable methodological challenges faced by the studies included in this review. Only 3 studies had a statistical power of 80% to address BP outcomes, whereas the remaining 3 studies had inconclusive results because of either no statistical power reported or an unknown sufficient statistical power reference. To further improve understanding on how best capitalize on the benefits of SMS, future research that more rigorously evaluates the effect of SMS on HTN management and outcome in a larger, diverse sample of HTN using a randomized controlled trial is warranted.

There are a number of study limitations. Because of the contrasted nature of studies included in our review, we were unable to complete a meta-analysis. Furthermore, the number of identified studies that met our inclusion criteria was considered too small for any further consideration to separately meta-analyze only a few of the 6 studies. A close direct comparison of the findings was also limited because of the variation in evaluation methods used by studies. Although only 3 studies in this review reported overall positive feedback with respect to using SMS, strict comparison across these studies remained difficult because of their differences in SMS use and its evaluation. These observations reinforce and may partly explain the clear variation of the studies in the forest plots. More studies isolating the effects of SMS on HTN management are needed to provide additional insight into the best SMS practices for HTN management. Because of the nature of the primary studies, certain biases could not be fully avoided, such as blinding of research staff (performance bias). However, special consideration should be given to potentially avoidable biases (eg, ensuring allocation concealment) that can impact the validity of the primary study’s outcome results and degree of statistical heterogeneity when pooling primary studies. To enable completion of a meta-analysis and maximize effect size and precision in future reviews, subsequent studies should do their best to ensure adequate statistical power and sufficiently large sample size. Nonetheless, the studies reviewed herein have provided multiple factors that are key when designing and pursuing HTN management interventions using mHealth, specifically SMS. Future SMS research addressing BP outcomes should consider a comprehensive assessment of the attitudes and experiences of participants with the SMS component's utility. Finally, cost effectiveness was also not mentioned in any of the study interventions reviewed, limiting this review’s understanding of their general feasibility going forward.

In summary, our systematic review provides a more comprehensive appreciation to CVD and its risk factors, specifically HTN management and prevention interventions that are supported by SMS. To our knowledge, this review is the first to focus on SMS-specific mHealth research publications surrounding BP management. Our review provides invaluable insight into how SMS can be applied as a tool to support BP control and play a role in addressing the current HTN burden. Short Messaging Service can provide a pivotal path toward ameliorating the existing disparities surrounding HTN awareness, management, and control experienced by US racial and ethnic communities. These disparities are linked to a number of barriers to healthcare that range from a patient’s lack of insurance coverage and limited financial resources to poor communication with their provider and nonadherence to provider instructions. Integrating SMS into health programming appears to represent a viable method of mitigating the negative impact of the latter factors, enabling patients to better and more regularly communicate with health professionals over time. The positive impact of SMS on mitigating racial/ethnic disparities is further enhanced by widespread mobile phone ownership among African Americans/non-Hispanic blacks and Hispanics/Latinos (93% and 88%, respectively). Overall, the use of SMS in HTN management is supported by the evidence provided within the 6 studies reviewed and can become a practical and influential instrument in HTN management and care efforts.

REFERENCES


