Using mHealth to Support Health Coaching for Patients with Hypertension: A Case-Control Study

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Abstract

Objective: The purpose of this study was to determine if patients with hypertension could better self-manage their disease by using automated mHealth to support health coaching.

Background: Hypertension is a chronic disease that affects millions of people worldwide. A mobile health (mHealth) coaching app called HyperCoach was developed to assist patients with self-management of their hypertension.

Method: Participants with hypertension were provided a blood pressure monitor and weight scale that communicated an mHealth app via Bluetooth to deliver health coaching for hypertension. The first 30 days of the study involved a health awareness phase that informed the participants of the daily status of their hypertension. The second 30-day phase initiated an automated health coaching plan developed in collaboration with the American Heart Association. Blood pressure, heart rate, weight, health-related quality of life and health literacy were measured.

Results: Thirty-four participants completed the study. Results showed no significant improvements in outcomes during the health awareness phase; however, during the health coaching phase significant improvements were noted in systolic and diastolic blood pressure, quality of life and hypertension health literacy.

Conclusion: Our study found that improved awareness of blood pressure values may not be enough for a change in health-related behaviors except for those people in the most severe condition – stage 2 hypertension. However, providing health coaching information in conjunction with daily blood pressure values may encourage a person to change their health-related behaviors.

Application: mHealth apps may assist patients with hypertension in self-managing their disease.

Keywords: mobile applications, self-management, telemedicine

Précis: A mobile health coaching app called HyperCoach was developed with materials from the American Heart Association to assist patients with self-management of their hypertension. Health coaching functionality led to improved systolic and diastolic blood pressure, quality of life and hypertension health literacy compared to an awareness-only phase of app functionality.

INTRODUCTION

Hypertension is a chronic disease affecting more than 100 million adults in the United States (Carey & Whelton, 2018). Uncontrolled hypertension can lead to the development of other chronic health conditions including heart disease, stroke, kidney disease, pregnancy complications and cognitive decline later in life (U.S. Department of Health and Human Services, 2020). Total annual medical costs associated with hypertension in the U.S. have been projected to exceed $220 billion annually by 2035 (U.S. Department of Health and Human Services, 2020). In addition, healthcare services were estimated to cost approximately $2,500 more per year for people with hypertension compared to those without hypertension (U.S. Department of Health and Human Services, 2020).

Hypertension can be attributed partly to unhealthy lifestyle choices, such as a poor diet and sedentary lifestyle, and health conditions such as diabetes and obesity (Centers for Disease Control and Prevention, 2021). Health coaching has been increasingly utilized in the past decade for adopting healthy lifestyles, mostly related to nutrition and weight loss. Health coaching is a patient-centered process that focuses on changing health-related behaviors and includes goal-setting, education, encouragement, and feedback (Oliveira et al., 2017). Health coaching is traditionally conducted by a trained health coach through periodic interaction with a patient (Jonk et al., 2015); however, recent years has seen an increasing trend in digital health coaching for hypertension using mobile devices (Xu & Long, 2020). Applications of mobile computing and communication technologies in healthcare, commonly referred to as mobile health (mHealth), can facilitate data collection and enable self-management of chronic conditions (Owen et al., 2015).

A systematic review of mHealth apps for hypertension self-management found that patient education or health recommendations were only included in three studies, highlighting the need for further research on behavior coaching for hypertension self-management (Xu & Long, 2020). However, few studies utilized mHealth interventions for hypertension combined with health coaching, albeit with promising results. One recent pilot study of an mHealth intervention utilized a smartphone app and Bluetooth-enabled devices to track blood pressure (BP), heart rate (HR), weight, and physical activity, alongside a diet log for tracking food intake, remote monitoring, and health coaching provided by a human coach (Weerahandi et al., 2020). Findings from this study indicated that an mHealth app for promoting healthy behaviors was feasible and engaged participants; however, the study did not find a significant improvement in physiological outcomes (SBP, DBP, HR and weight; Weerahandi et al., 2020). Another recent study of an mHealth intervention for hypertension in an underserved community utilized a Bluetooth-enabled BP device and a smartphone app for monitoring and tracking BP and weekly follow-up with the patient by a healthcare provider (Zha et al., 2020). Findings showed a significant improvement in SBP in the intervention group and an increased motivation for a patient to self-monitor their BP and to engage with the mHealth technology (Zha et al., 2020). Despite these promising studies, most involved health coaching by a human coach, while the application of automated digital health coaching to hypertension care seems largely absent. A systematic review of 11 randomized controlled trials evaluating the use of mHealth for the self-management of hypertension found that all included some form of human interaction and intervention (Lu et al., 2019). Similarly, a scoping review of nine studies combining mHealth and health coaching for self-managing chronic diseases found that all included intervention by a human coach (Obro et al., 2021).

This study aimed to determine if patients with hypertension could better self-manage their disease by using mHealth combined with digital health coaching, designed in collaboration with the American Heart Association (AHA).

METHODS

Study Design

A longitudinal home study was conducted from December 2020 to May 2021 to evaluate the feasibility and early outcomes evaluation for HyperCoach, an iOS mHealth app designed to deliver health coaching for hypertension. We used a case-control design that consisted of two 30-day phases comprising a health awareness phase and a health coaching phase. The first phase of the study involved a self-measured blood pressure (SMBP) program. The goal of this phase was to make patients more aware of their hypertension health status through the daily monitoring and feedback of their BP, HR, weight and daily step values in numerical and trend chart formats. The second phase involved digital health coaching in addition to the daily monitoring. The health coaching provided by this intervention was fully automated with no direct interaction by a human health coach. The study was approved by the Institutional Review Board of Texas A&M University (IRB2019-1070); participants gave written informed consent.

Participants

Thirty-five patients were recruited from a large university community in Texas. Recruitment material was sent through the university bulk email system using a snowballing technique to increase the sample size. Participants were eligible if they were at least 18 years of age, English-speaking, had a primary diagnosis of hypertension, were taking medication to control their hypertension, and owned an iOS smartphone with a data plan. Participants with resistant hypertension or more than two comorbidities determined by the Charlson Index (Charlson et al., 1987) were excluded.

Intervention – mHealth Coaching

The intervention for this study consisted of the mobile application (HyperCoach) that delivered an AHA-approved 30-day hypertension coaching plan and two devices: an Indie Health Bluetooth-enabled weight scale and an Indie Health Bluetooth-enabled blood pressure cuff. Figure 1 provides an overview of the mHealth intervention for the two different phases of the study.

Coaching Plan

We partnered with the AHA to design a novel 30-day health coaching plan based on the AHA 12-week hypertension CarePlan (Dunn & Walker, 2019). The HyperCoach plan included daily physiological monitoring (BP, HR and weight) and pushed daily coaching content using the HyperCoach app. The health coaching content included daily reminders to perform BP and weight measurements; the establishment of goals; AHA educational content comprising short videos and one-to-two-page brochures on BP, BP monitoring, hypertension, ways to self-manage hypertension, and healthy lifestyle changes for improving and maintaining a healthy BP; weekly multiple-choice quizzes on the educational material; and weekly progress reports. There was no specific communication between the patient and their healthcare team as part of this study; patients interacted with their physicians independently of the study protocol.

HyperCoach

The main features of the HyperCoach app were a calendar of activities, list of daily tasks, and overview widgets for daily BP, HR, weight, and step values, averages, and trends (Figures 2 - 4). Participants had access to a “My Plan Calendar” widget (Figure 2a) through which they could review tasks for a given day such as BP and weight measurements as well as coaching tasks. A green checkmark next to the activity in the *Tasks* section indicated completion for that day (Figure 2b). Educational content such as articles or videos were interactive (e.g., ability to zoom in/out) and optimized for mobile displays. Participants could also interact with the widgets to view a "Dashboard" display (Figure 2b) showing their daily values of BP, HR, weight, and step count. We utilized a user-centered design process for HyperCoach that included two formative usability testing studies.

The "Blood Pressure" widget (Figure 3a) showed the range of BP readings over the previous 90 days; trend of BP readings for the last seven days color-coded as normal (green), elevated (yellow), and stage I (orange) or stage II hypertension (red); the AHA-recommended BP goal of 120/80 (represented as green horizontal lines); the latest BP value; and the weekly average BP value. Similar widgets were provided for HR (Figure 3b), weight (Figure 4a) and daily steps (Figure 4b).

Data Management

The HyperCoach app was connected to a cloud storage server (Amazon Web Services). Measurement data (SBP, DBP, HR and weight) were uploaded in real-time; the current cumulative daily step count was uploaded each time the app uploaded new data. In addition, time spent interacting with the coaching material (time spent on each task and task completion) was recorded and uploaded to the cloud storage. Quality monitoring of the data was accomplished through daily checks by team members with participant follow-up if warranted (i.e., missing data for a given period).

Study Procedure

Due to the COVID-19 pandemic, this study was conducted virtually, requiring shipment of the devices to participants and four separate virtual researcher-participant interactions. These interactions included: (1) the onboarding session where informed consent was obtained and inclusion/exclusion criteria verified; (2) the installation of a limited version of the HyperCoach app on their mobile device, a walkthrough of the measurement devices and the app, verification that the app was synced to the cloud, and a review of study requirements to monitor their BP and weight daily; (3) the transition from the health awareness phase to the health coaching phase with a walkthrough of the various coaching features enabled on the HyperCoach app; and (4) an exit interview to obtain feedback on the study and the HyperCoach app.

During the health awareness phase, participants were instructed to measure their BP and weight daily under similar physiological conditions. It was suggested that they measure these values after awakening and using the restroom and before eating or engaging in physical activities for the day. Participants received feedback via HyperCoach in numerical and trend chart formats for their BP, HR, weight, and step count readings. No other forms of health coaching were provided during this phase.

During the health coaching phase, participants were provided the full coaching content of the HyperCoach app for the self-management of hypertension. In addition to the daily BP and weight measurements tasks, participants were assigned a daily coaching task to either watch an educational video, read an information brochure, take a multiple-choice quiz on that week's educational material, review weekly progress, respond to an assessment regarding their progress, or set goals for the upcoming week. The daily coaching task(s) could be performed anytime during the day, and the educational material was available on demand for future reviews.

Outcome Variables

Clinical outcomes, health-related quality of life, health literacy, compliance, engagement and usability were assessed.

Clinical Outcomes

SBP, DBP, HR and weight (to calculate body mass index [BMI]) were measured daily to assess changes during each phase of the study. Measurements from both devices (BP Cuff and weight scale) were uploaded automatically to HyperCoach.

Health-related quality of life (HRQOL) is a state of mind regarding how someone perceives their health status and not merely the absence of diseases (Moriarty et al., 2003). HRQOL was measured at the beginning of the study, after the health awareness phase and after the health coaching phase using the 36-Item Short Form Health Survey (SF-36; Hays et al., 1993). HRQOL scores can range from 0 to 100 with higher scores representing better quality of life.

Health Literacy

Hypertension health literacy was assessed at the beginning of the study, after the health awareness phase and after the health coaching phase using a 10-question multiple choice quiz developed in consultation with the AHA. Hypertension health literacy was calculated based on the percentage of correct responses to the quizzes. General health literacy was assessed after the health awareness phase and after the health coaching phase using the Short Assessment Of Health Literacy-English (SAHL-E) test (Lee et al., 2010).

Compliance and Engagement

Participant compliance with daily measurements was assessed during both study phases by calculating the percentage of days they performed the BP and weight measurements. Participant engagement with the coaching material was assessed during the coaching phase as the time spent reviewing coaching material and percentage of total coaching tasks completed.

Usability Assessment

Interviews were conducted with the participants upon study completion to obtain feedback on the study and the HyperCoach app. Usability of the HyperCoach app was assessed using the System Usability Scale (SUS; Lewis & Sauro, 2009). Participants rated the app by responding to 10 questions depicted in Figure 5 on a 5-point alternate response Likert continuum (from strongly disagree to neutral to strongly agree). Responses were converted to a score from 0 to 100. Higher scores were associated with better usability.

Analysis Methods

Pre-post changes in outcomes were determined after each phases of the study (mean values, standard deviations and paired t-tests for significance) compared to initial baseline measurements. A one-way analysis of variance (ANOVA) was performed to determine the individual effect of demographic variables on the changes in the mean values of SBP, DBP, BMI, HRQOL and hypertension health literacy. In addition, user feedback on the overall study and the HyperCoach app was obtained at the end of the study.

RESULTS

One female participant dropped out of the study at the midpoint leaving a total of 34 participants (25 females and 9 males) who completed both phases of the 60-day study with a mean age of 44.8 years (SD = 14.1; Range: 19-79), mean baseline SBP of 136.3 (SD = 18.4), mean baseline DBP of 84.2 (SD = 11.4) and mean baseline BMI of 32.0 (SD = 6.9). Additional demographics for the participants in this study are listed in Table 2.

Outcomes

Table 3 provides a summary of the means and paired sample t-test results for the changes in SBP, DBP, BMI, HRQOL, hypertension health literacy, and general health literacy at the different stages of the study.

Clinical outcomes

The mean values of SBP, DBP and BMI for the participants at baseline, mid-study and post-study were compared. Figure 6 shows the mean SBP values for the participants at the beginning of the study, after the health awareness phase and after the health coaching phase of the study. Participants' mean SBP value did not change during the health awareness phase but showed a statistically significant decrease from 136.3 (*SD* = 15.6) to 130.8 (*SD* = 13.5) during the health coaching phase ($t(33) = 2.840$, $p = .008$) with a medium effect size ($d = 0.49$ 95% CI [.13-.84]). Figure 7 shows the mean DBP values for the participants at the beginning of the study, after the health awareness phase and after the health coaching phase of the study. Mean DBP increased slightly from 84.2 (*SD* = 11.4) to 85.1 (*SD* = 9.5) during the health awareness phase but showed a significant decrease from 85.1 (*SD* = 9.5) to 81.2 (*SD* = 9.5) during the health coaching phase ($t(33) = 2.916$, $p = .006$) with a medium effect size ($d = 0.50$ 95% CI [.14-.85]). The participants' mean BMI value did not change during the health awareness phase but showed a non-significant decrease from 32.0 (*SD* = 7.0) to 31.8 (*SD* = 6.9) during the health coaching phase.

Health-related Quality of Life

Figure 8 shows the mean HRQOL scores for the participants at baseline, after the health awareness phase and after the health coaching phase of the study. Participants' mean HRQOL score showed a non-significant increase from 67.7 (*SD* = 16.9) to 68.4 (*SD* = 16.3) during the health awareness phase but a statistically significant increase from 68.4 (*SD* = 16.3) to 74.6 (*SD*

= 15.7) during the health coaching phase ($t(33) = -5.040$, $p < .001$) with a large effect size (d = -.86 95% CI [(-1.26)-(-.46)]).

Health Literacy

Figure 9 shows the mean hypertension health literacy scores for the participants at baseline, after the health awareness phase and after the health coaching phase of the study. Participants' mean score for knowledge of hypertension showed a non-significant increase from 70.8% (SD = 11.1) to 74.7% (SD = 11.3) during the health awareness phase but showed a statistically-significant increase from 74.7% (SD = 11.3) to 85.2% (SD = 9.3) during the health coaching phase ($t(33) = -5.037$, $p < .001$) with a large effect size (d = -.86 95% CI [(-1.25)-(-.46)]). The participants' general health literacy was assessed mid-study and post-study. The participants' mean score for general health literacy showed a non-significant increase from 95.8% (SD = 5.5) to 97.5% (SD = 3.4) during the health coaching phase. All participants scored high (above 14/18) on the SAHL-E test, so no additional analysis of this metric was performed.

Analysis of Variance

One-way ANOVA was performed to determine the individual effect of demographic variables listed in Table 2 on the changes in the mean values of SBP, DBP, BMI, HRQOL and hypertension health literacy. Table 4 summarizes the variables with significant effects.

Tukey HSD post hoc analysis resulted in four instances where a significant difference was found between education and gender groups. Table 5 lists the results of the post hoc analyses with significant results.

Initial Blood Pressure Category. During the health awareness phase, participants' initial blood pressure category was a significant predictor of both the change in mean SBP value ($F(1,32) = 6.02$, $p = .02$) and the change in mean DBP value ($F(1,32) = 9.83$, $p = .02$).

Conversely, during the health coaching phase, participants' initial blood pressure category only predicted the change in mean SBP value ($F(1,32) = 4.15$, $p = .05$). A review of the participants' mean SBP and DBP values showed that only participants in hypertension stage 2 showed a decrease in mean SBP and DBP value during the health awareness phase. However, during the health coaching phase, the mean SBP and DBP values showed a decrease for participants in the elevated, hypertension stage 1 and hypertension stage 2 categories.

Education Level. During the health awareness phase, the main effect of participants' education level on the change in mean SBP value was significant ($F(1,32) = 7.12$, $p = .012$). Post hoc analysis indicated that the change in SBP was significantly better for participants with a graduate degree ($M = -6.5$, $SD = 14.7$) than for participants without a bachelor's degree ($M = 9.9$, $SD = 15.5$). During the health awareness phase, the main effect of a participant's education level on the change in mean DBP value was significant ($F(1,32) = 6.02$, $p = .020$). Post hoc analysis showed that the change in DBP was significantly better for participants with a bachelor's degree ($M = -3.8$, $SD = 9.0$) or a graduate degree ($M = -1.0$, $SD = 6.1$) than for participants without a bachelor's degree ($M = 6.9$, $SD = 6.6$). The results showed that during the health awareness phase, the mean DBP and SBP decreased only for participants with either a bachelor's or graduate degrees. However, during the health coaching phase, these values decreased regardless of education level.

Gender. During the health awareness phase, the effect of a participant's gender on the change in DBP was significant, $F(1,32) = 4.46$, $p = .043$. Post hoc analysis showed that the change in DBP was significantly better for males ($M = -4.0$, $SD = 7.0$) than for female participants ($M = 2.6$, $SD = 8.4$). Only male participants showed a decrease in mean SBP and

DBP values during the health awareness phase. However, during the health coaching phase both males and female groups showed a decrease in mean SBP and DBP values.

BMI. During the health awareness phase, the main effect of participants' BMI on the change in hypertension health literacy was significant ($F(1,32) = 4.72$, $p = .037$). However, post hoc analysis did not find any significant differences in the change in hypertension health literacy between the participant groups based on their BMI category.

Compliance and Engagement

Average participants' compliance with daily BP and weight measurements increased from 96.2% during the health awareness phase to 96.3% during the health coaching phase. Average engagement with coaching material averaged 100% during the health coaching phase.

Usability Assessment

The mean SUS rating for the HyperCoach app was 93 ($SD = 7$) with a range of 67.5 to 100 (27 of 34 participants rated 90 or greater). A study of nearly 1000 SUS surveys correlated SUS scores with adjective ratings from "worst imaginable" for a SUS mean score of 12.5 to "best imaginable" for a SUS mean score of 90.9 (with a SUS mean score of 85.5 correlated with an adjective rating of "excellent"; Bangor et al., 2009). Thus, the SUS rating of the HyperCoach app was between "excellent" and "best imaginable" by the participants in our study.

DISCUSSION

Our findings suggest that mHealth-enabled coaching shows promise in improving self-management of hypertension including positive trends in SBP, DBP, HRQOL and patients' hypertension literacy. Furthermore, a majority of participants felt the intervention helped them manage their hypertension, improved their awareness and knowledge of their hypertension and made them more self-accountable for monitoring and/or managing their hypertension. Our results showed that during the awareness phase which resembled a typical SMBP program, significant improvements to BP values were observed only for patients with the most severe condition (Stage II). On the other hand, during the coaching phase, BP values improved significantly regardless of severity or education levels. These results align with recent reviews of mHealth interventions for self-management of hypertension (Li et al., 2020; Lu et al., 2019; Xu & Long, 2020) which support the efficacy of utilizing mHealth interventions for self-management of hypertension. However, to our knowledge, this is the first study evaluating the effects of digital coaching with no human coach involvement on hypertension outcomes and engagement. Given the promising results documented here, more work is warranted to explore the longitudinal impact of mHealth coaching on hypertension self-care.

While we believe the coaching content in addition to health awareness contributed to changes in lifestyle choices including nutritional intake, our study did not show a significant change in BMI over the course of the study. This may be partly attributed to the short duration of the coaching phase of the study (30-days). This is consistent with a recent systematic literature review of the effect of mHealth on weight loss which reported an insignificant decrease in BMI at three months but a significant decrease in BMI at six months (Park et al., 2019). In addition, the AHA-based coaching material was targeted towards changes in lifestyle associated with hypertension control and not specifically for weight loss (Dunn & Walker, 2019).

One of the contributions of this research is to assess the role of education and health literacy in investigating the efficacy of mHealth coaching to improve hypertension outcomes. Health literacy has been identified as a significant barrier limiting the patients' ability to self-manage their healthcare (T. T. Lin & Bautista, 2017). A recent systematic review of the effects of mHealth-based interventions on health literacy concluded that mHealth inventions were effective in improving health literacy, particularly when patients are willing to receive mHealth-based interventions and are proficient with the operation of mHealth devices (Y.-H. Lin & Lou, 2021). However, our results showed that improving awareness of patients' health metrics through mHealth may only impact health literacy for those with higher levels of education (i.e., graduate degrees). On the other hand, improved awareness combined with mHealth coaching improved hypertension health literacy significantly regardless of education levels. These findings concur with recent literature (e.g., Bonet et al., 2022) which suggests that the design of health information such as graphs and visualizations should account for the users' literacy levels if not accompanied by coaching.

Similarly, while self-reported measures of patient HRQOL are often used in clinical trials to monitor patient response to an intervention (Lapin, 2020), this important holistic health measure has been rarely used in studies evaluating mHealth interventions. A recent study of mHealth interventions on the HRQOL for cancer patients showed positive improvements in quality of life (Buneviciene et al., 2021); however, we are not aware of any studies assessing HRQOL for hypertension mHealth interventions. More work is needed to verify if such changes on quality of life is sustainable over a longer period.

Sustainable effects of an mHealth intervention requires an emphasis on designing for usability and engagement. A study that evaluated patients' engagement with mHealth technology for hypertension found that higher patient engagement with the intervention resulted in a significant reduction in BP (Kaplan et al., 2017). A separate systematic literature review of mHealth interventions for cardiovascular disease using smartphone apps (Spaulding et al., 2021) found statistically significant weight reduction with higher user engagement with the app. We believe the surprisingly high engagement with our intervention was partly due to our user-centered and heuristic-based design and evaluation efforts that resulted in easy-to-perform measurements using Bluetooth-enabled devices, intuitive and immediate presentation of results and health status in numerical and trend chart formats, as well as short (mostly 2-3 minute) but informative educational content. A recent systematic literature review of design features for improving user engagement with mHealth interventions identified personalization, reinforcement and communication as the most commonly cited app design features to improve user engagement (Wei et al., 2020). Personalization was achieved in the HyperCoach app by personalized greetings, allowing users to set goals, and providing personalized user feedback as well as weekly progress reports. Reinforcement was achieved in the HyperCoach app via daily reminders, weekly quizzes that reinforce the educational material and congratulatory messages in the weekly progress report. While the app communicated tasks and health values, communication with healthcare professionals or peers was not included as part of the HyperCoach app as it was designed to be fully automated with no human intervention.

This was a complex study that was completed entirely virtual. This study serves as an example of how to adapt an in-person study to pandemic conditions precluding direct face-to-face interaction. The lessons learned from this adaptation make it a productive contribution to the literature on adapting human research studies to pandemic conditions (Gaba & Bhatt, 2020; Indraratna et al., 2021; Orkin et al., 2021; Perlis et al., 2021).

Limitations

This study has several limitations that may affect generalizability of findings. First, this study was conducted using a relatively small sample size. Second, recruitment was mainly focused on a university population which may not represent the overall population. This is evidenced by the literacy assessment indicating that most participants had a high general health literacy based on the SAHL-E score, likely since many participants were college students or faculty at the university. More work is needed to validate these findings using a larger and more diverse sample. Third, given the case-control design used in this study, some of the effects observed during the coaching phase might have been due to the build-up of confidence, increased trust, and observed benefits. In addition, given the difficulties of conducting a longitudinal home study, the design did not use a real control group (i.e., a group with no intervention). Other designs such as between-subjects experiments can verify differences between the awareness and coaching.

CONCLUSION

This study demonstrated that using mHealth to support health coaching can improve the self-management of hypertension. In addition, our study demonstrated that a carefully designed mHealth app grounded in user-centered design and human factors engineering principles can improve health literacy and engagement. Future planned work includes replication of this hypertension mHealth study with a larger sample size; longer duration; and inclusion of participants from low socioeconomic status communities. In addition, participants' BP and BMI will be monitored for up to 90 days after the end of the coaching to check for compliance with daily measurements and sustainment of the effects of coaching. Additional future planned work includes incorporation of the mHealth coaching attributes of this hypertension study into similar mHealth interventions for hypoglycemia self-management, stress self-management and mental health self-management.

KEY POINTS

- Using mHealth to support health coaching can assist in the self-management of hypertension. Our findings suggest that mHealth-enabled coaching shows promise in improving self-management of hypertension including positive trends in SBP, DBP, HRQOL and patients' hypertension literacy.

- Improved awareness of blood pressure values alone may not be enough for a change in health-related behaviors except for those people in the most severe condition – stage 2 hypertension. However, providing health coaching information in conjunction with daily blood pressure values may encourage a person to change their health-related behaviors.
- Improving awareness of patients' health metrics through mHealth may only impact health literacy for those with higher levels of education (i.e., graduate degrees). On the other hand, improved awareness combined with mHealth coaching improved hypertension health literacy significantly regardless of education levels.
- We believe the surprisingly high engagement with our intervention was partly due to our user-centered and heuristic-based design and evaluation efforts that resulted in easy-to-perform measurements using Bluetooth-enabled devices, intuitive and immediate presentation of results and health status in numerical and trend chart formats, and short but informative educational content.

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Figure legends

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Tables

Table 1. Hypertension health literacy multiple choice quiz

1. What range of blood pressure is classified as hypertension?
    a. Less than 120/80
    b. More than 120/80
2. High blood pressure means that the pressure in your arteries is higher than it should be.
    a. True
    b. False
3. Choose three risk factors for hypertension.
    a. Consuming high levels of caffeine
    b. Eating high sodium diets
    c. Exercising regularly
    d. Eating high potassium diets
    e. Managing stress levels
    f. Using tobacco products
4. Choose three methods to avoid hypertension.
    a. Consuming high levels of caffeine
    b. Eating high sodium diets
    c. Exercising regularly
    d. Eating high potassium diets
    e. Managing stress levels
    f. Using tobacco products
5. You shouldn’t exercise if you have hypertension.
    a. True
    b. False
6. You get hypertension from stress.
    a. True

b. False

7. You can feel when your blood pressure goes up.

a. True

b. False

8. Hypertension causes kidney disease.

a. True

b. False

9. Which one provides more sodium?

a. Table salt

b. Fast food and packaged food

10. What is the recommended ideal limit of sodium a day?

a. 800 mg

b. 1,500 mg

c. 2,300 mg

d. 3,400 mg

Table 2. Participants' demographic information

Characteristics		**Mean (SD)**
Age (years)		44.8 (14.1)
Years Living with Hypertension		8.6 (9.5)
		Counts (percentage)
Blood Pressure Category	*Normal*	5 (14.1%)
	Elevated	8 (23.5%)
	Hypertension – Stage 1	9 (26.5%)
	Hypertension – Stage 2	12 (35.3%)
Body Mass Index (BMI) Category	*Normal: 18.5 < BMI < 24.9*	6 (17.6 %)
	Overweight: 25 < BMI < 29.9	6 (17.6 %)
	Obese: BMI > 30	22 (64.7%)
Gender	*Male*	9 (26.5%)
	Female	25 (73.5%)
Ethnicity		
	White	24 (70.6%)
	Non-White or Other	10 (29.4%)
Education Level		
	High school or some college	12 (35.3%)
	Bachelor's degree	11 (32.4%)

	Graduate degree	11 (32.4%)
Marital Status	*Married (or domestic partnership)*	19 (55.9%)
	Single (never married)	8 (23.5%)
	Divorced/Separated	7 (20.6%)
Household Income Level	*Less than $40,000*	9 (26.5%)
	$40,000 to $100,000	12 (35.3%)
	Above $100,000	13 (38.2%)

Table 3. Summary of outcomes for clinical measures, quality of life and health literacy

Outcome	**Pre**	**Mid**	**Post**	**ΔHA**	**t-test p-value**	**ΔHC**	**t-test p-value**
Systolic blood pressure mean (*SD*)	136.3 (18.4)	136.3 (15.6)	130.8 (13.5)	0	1.000	-5.5	**0.008**
Diastolic blood pressure mean (*SD*)	84.2 (11.4)	85.1 (9.5)	81.2 (9.5)	0.9	0.549	-3.9	**0.006**
Body mass index mean (*SD*)	32.0 (6.9)	32.0 (7.0)	31.8 (6.9)	0	0.888	-0.2	0.075
Health-related quality of life mean (*SD*)	67.7 (16.9)	68.4 (16.3)	74.6 (15.7)	0.7	0.695	6.2	**<.001**
Hypertension health literacy mean (*SD*)	70.8 (11.1)	74.7 (11.3)	85.2 (9.3)	3.9	0.103	10.5	**<.001**
General health literacy mean (*SD*)	N/A	95.8 (5.5)	97.5 (3.4)	N/A	N/A	1.7	0.078

Abbreviations: *SD*: standard deviation; Pre: Pre-study value; Mid: Mid-study value; Post: Post-study value; ΔHA: change during health awareness phase (Mid compared to Pre); ΔHC: change during health coaching phase (Post compared to Mid)

Table 4. Overview of the effects of demographic variables on outcomes

Comparison – Health Awareness Phase	**F Statistic**	**p-value**
Initial blood pressure category → change in systolic blood pressure	$F(1,32) = 6.02$	**.020**
Initial blood pressure category → change in diastolic blood pressure	$F(1,32) = 9.83$	**.004**
Education level → change in in systolic blood pressure	$F(1,32) = 7.12$	**.012**
Education level → change in in diastolic blood pressure	$F(1,32) = 6.02$	**.020**
Gender → change in in diastolic blood pressure	$F(1,32) = 4.46$	**.043**
Body mass index → change in hypertension health literacy	$F(1,32) = 4.72$	**.037**
Comparison – Health Coaching Phase	**F Statistic**	**p-value**
Initial blood pressure category → change in systolic blood pressure	$F(1,32) = 6.02$	**.050**

Table 5. Summary of the post hoc analysis

Comparison – Health Awareness Phase	**Group 1**	**Group 2**	**Mean Difference**	**p-value**
Education level → change in in systolic blood pressure	*High school or some college*	*Graduate Degree*	-16.46	**.033**
Education level → change in in diastolic blood pressure	*High school or some college*	*Bachelor's Degree*	-10.73	**.004**
Education level → change in in diastolic blood pressure	*High school or some college*	*Graduate Degree*	-7.92	**.038**
Gender → change in in diastolic blood pressure	*Female*	*Male*	-6.64	**.043**

Figures

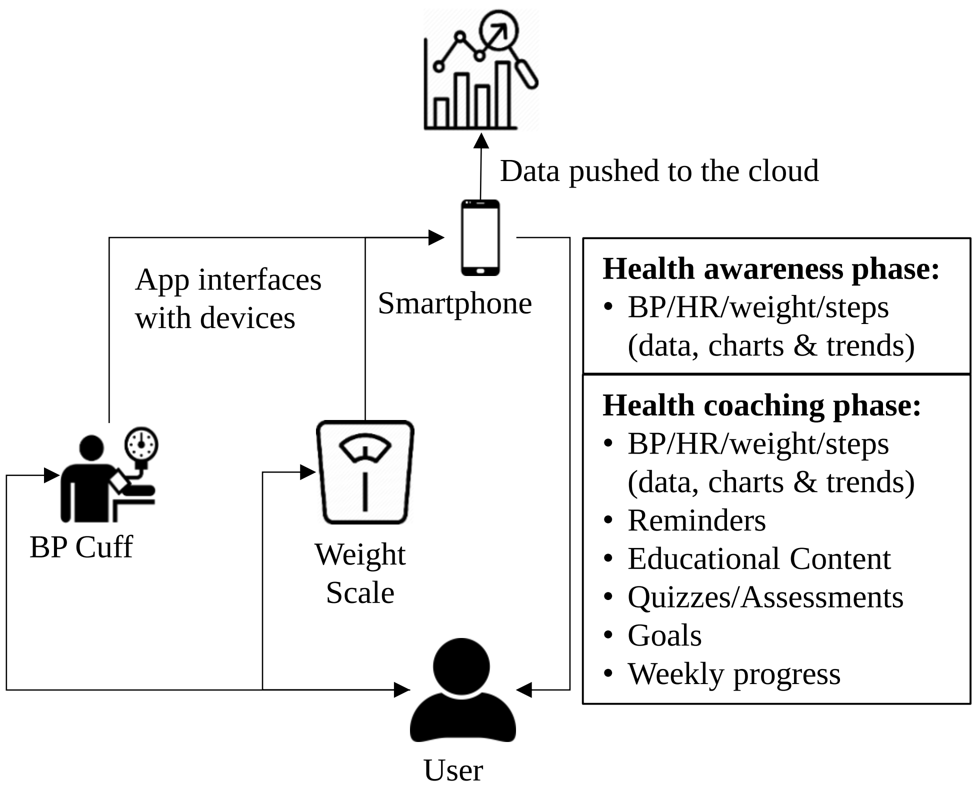
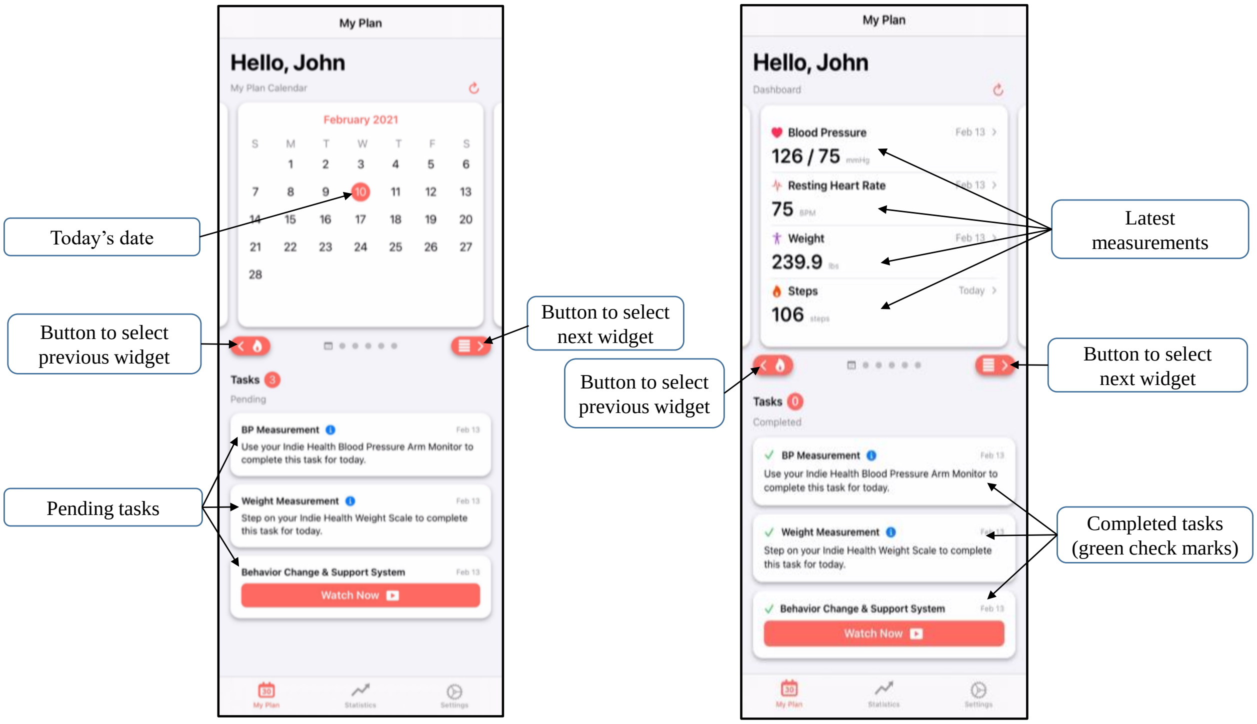
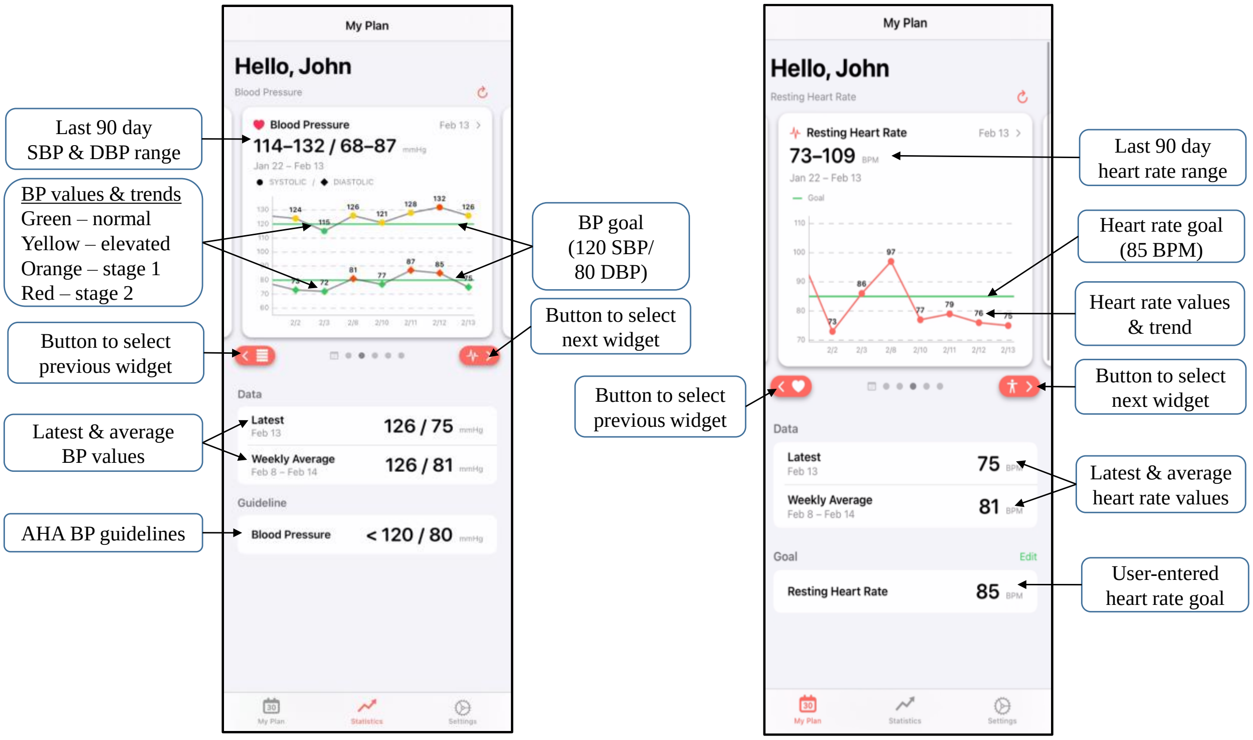


Figure 1. Overview of HyperCoach mHealth intervention



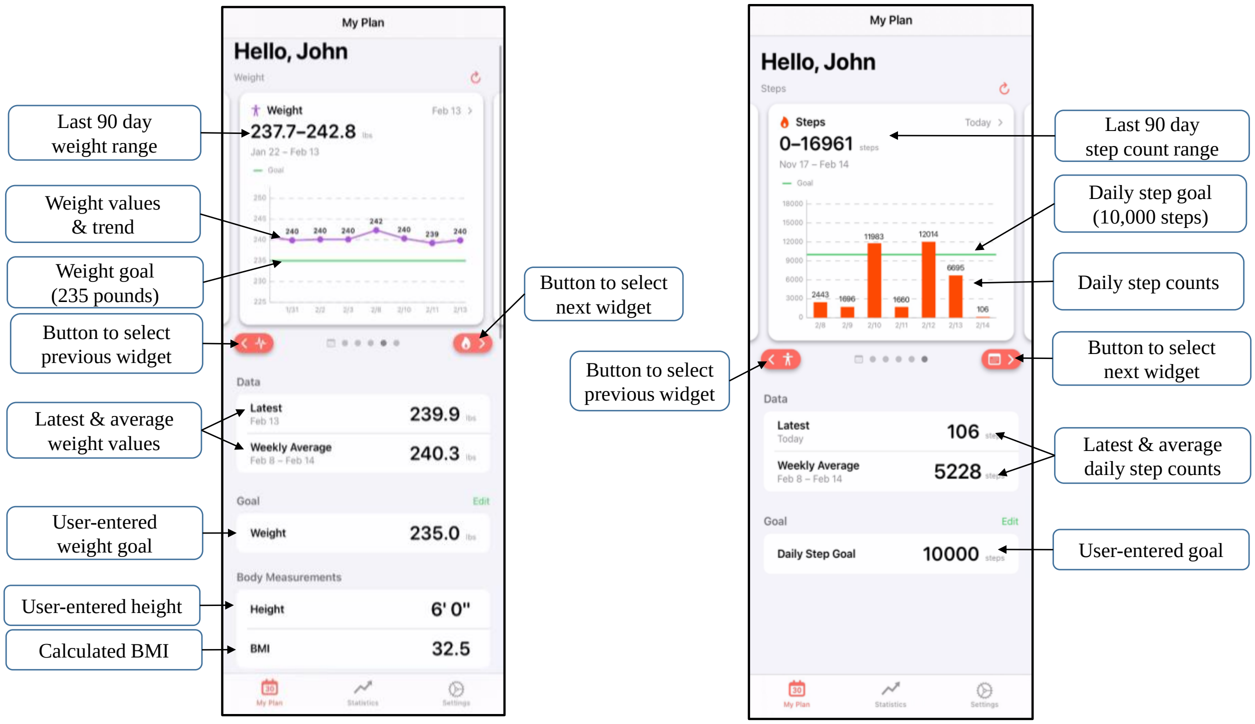
(a) My Plan Calendar (b) Dashboard

Figure 2. HyperCoach app “My Plan Calendar” and “Dashboard” widgets



(a) Blood Pressure **(b) Heart Rate**

Figure 3. HyperCoach app “Blood Pressure” and “Heart Rate” widgets



(a) Weight **(b) Steps**

Figure 4. HyperCoach app “Weight” and “Steps” widgets

	The System Usability Scale Standard Version	**Strongly disagree** 1	2	**Neutral** 3	4	**Strongly agree** 5
1	I think that I would like to use this system.	O	O	O	O	O
2	I found the system unnecessarily complex.	O	O	O	O	O
3	I thought the system was easy to use.	O	O	O	O	O
4	I think that I would need the support of a technical person to be able to use the system.	O	O	O	O	O
5	I found the various functions in the system were well integrated.	O	O	O	O	O
6	I thought there was too much inconsistency in this system.	O	O	O	O	O
7	I would imagine that most people would learn to use this system very quickly.	O	O	O	O	O
8	I found the system very cumbersome to use.	O	O	O	O	O
9	I felt very confident using the system.	O	O	O	O	O
10	I needed to learn a lot of things before I could get going with this system.	O	O	O	O	O

Figure 5. System usability scale

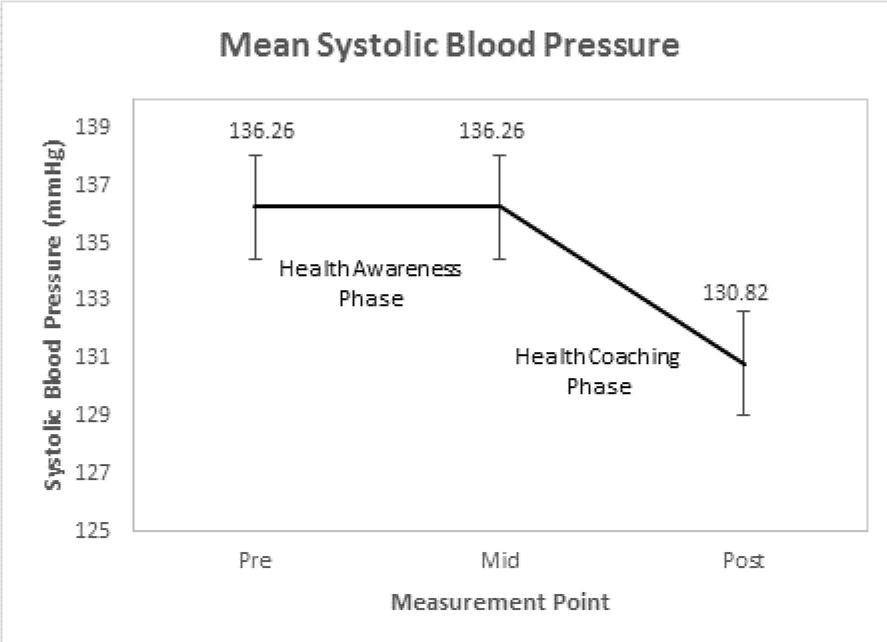


Figure 6. Systolic blood pressure results

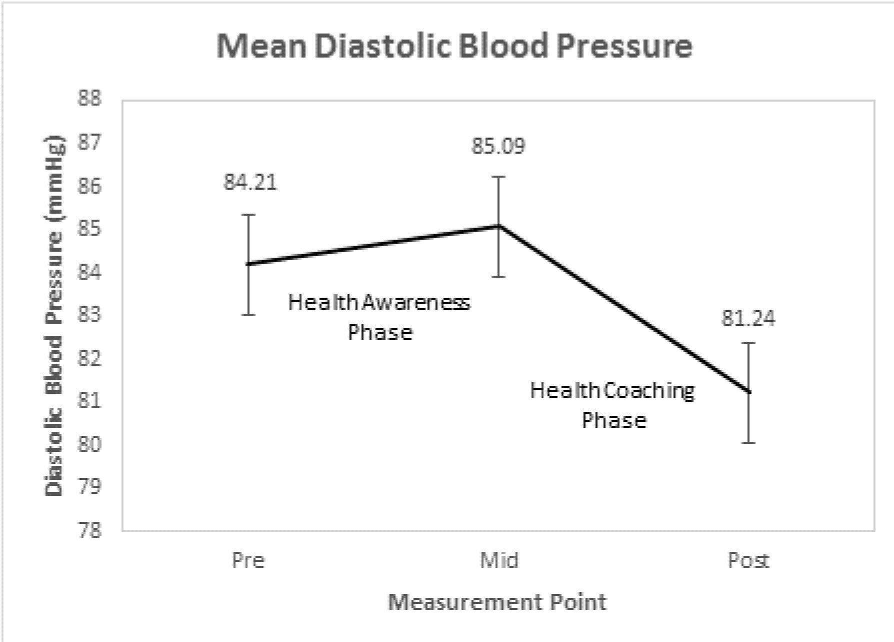


Figure 7. Diastolic blood pressure results

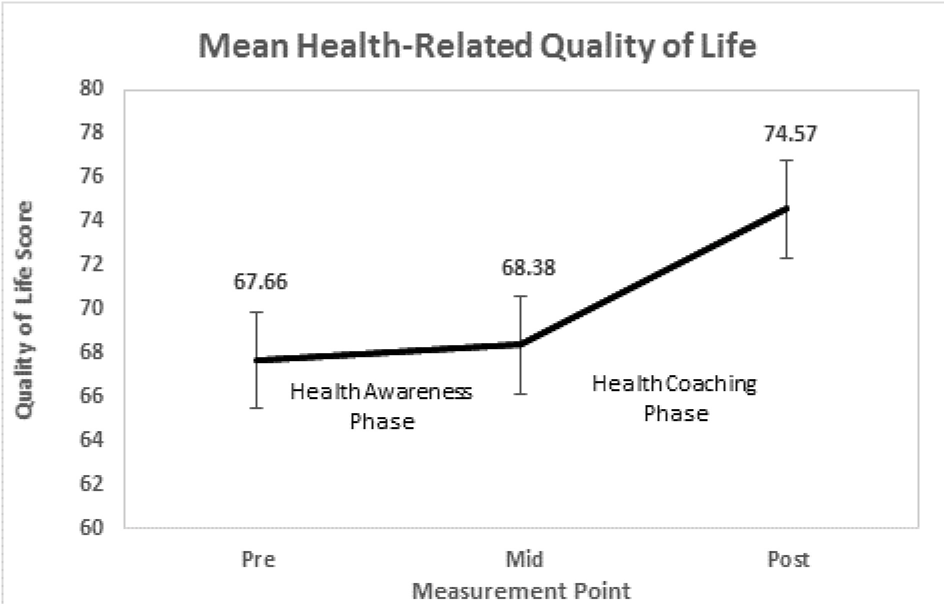


Figure 8. Health-related quality of life results

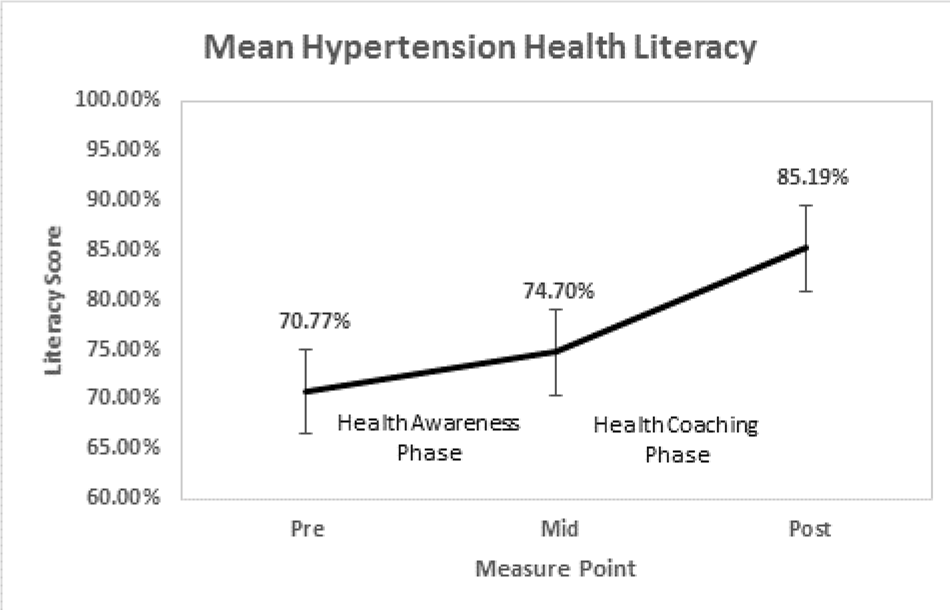


Figure 9. Hypertension health literacy results