Investigating the effect of an mHealth Intervention on participant health beliefs, adherence, and clinical outcomes of patients with hypertension: A Pilot Study

Karim Zahed [a] (k.zahed@tamu.edu), Carl Markert [a] (carlmarkert@tamu.edu), Patrick Dunn [b] (pat.dunn@heart.org), Farzan Sasangohar [a,c,*] (sasangohar@tamu.edu)

[a] Wm Michael Barnes '64 Department of Industrial & Systems Engineering, Texas A&M University, Emerging Technologies Building, 3131 TAMU, 101 Bizzell Street College Station, TX, USA 77843
[b] American Heart Association Center for Health Technology & Innovation, 7272 Greenville Avenue, Dallas, TX, USA 75231
[c] Center for Outcomes Research, Houston Methodist, 6550 Fannin Street, Houston, TX, USA 77030

*Corresponding Author: Farzan Sasangohar, sasangohar@tamu.edu ; +1-(682)-300-8380; 101 Bizzell St, Mail Stop 3131| College Station, TX 77843-3131.

Keywords: Hypertension, health belief model, technology acceptance model, digital coaching, self-management.

Declarations of interest: none.

Abstract

Introduction: The pilot study has two main objectives. First, we test the effect of a digital health coaching intervention on participants' belief constructs. Second, we assess the relationships between these belief constructs and intentions to utilize the technological intervention, actual adherence metrics, and clinical outcomes related to hypertension.

Methods: Patients with hypertension performed self-measurement of weight and blood pressure for 30 days followed by digital coaching delivered via a mobile application for another period of 30 days. Surveys assessed constructs from the Health Belief Model and Technology Acceptance Model, compared to intention, health belief, blood pressure (BP) self-monitoring adherence, and BP outcomes.

Results: Participant health beliefs significantly improve as a result of coaching. Adherence to BP measurements correlated with perceived health threat and perceived ease of use. Self-efficacy and perceived usefulness were linked with a decrease in diastolic BP.

Discussion: A digital mobile health coaching intervention may be effective at helping patients with hypertension improve their beliefs regarding the self-management of hypertension. Findings show that there is a significant correlation between self-efficacy and Diastolic BP, and higher Perceived Health Threat and Perceived Ease of Use among participants who engaged more with the app.

1. INTRODUCTION

In 2021, more than 100 million adults in the United States suffered from hypertension; a chronic condition characterized by having a systolic blood pressure (SBP) ≥ 130 mmHg or a diastolic blood pressure (DBP) ≥ 80 mmHg [1]. When uncontrolled, hypertension can cause complications such as kidney disease, stroke, and heart disease among others [2]. U.S. Department of Health and Human Services estimated that annual medical costs associated with hypertension care in the United States is approaching $200 billion [2].

Hypertension is associated with unhealthy lifestyle choices, such as poor diet and sedentary lifestyle, and the presence of comorbidities such as diabetes and obesity [3]. Adopting healthy habits is key to effective management of hypertension; however, sustainable behavior change has shown to be a major challenge [4]. Health coaching, which is a patient-centered process that focuses on encouraging health-related behaviors via goal-setting and education, among others [5], has shown promise to improve hypertension and other chronic disease outcomes [6]. We have previously highlighted the need for more research on the efficacy of behavior coaching to improve the self-management of hypertension due to several limitations in the literature such as absence of significant improvements in clinical outcomes [6], or the need for a human coach to provide the coaching [7,8].

Therefore, the emerging mobile health (mHealth) technologies can serve as reliable platforms to deliver automated digital health coaching while facilitating continuous data collection and communication between patients and providers [9–11]. While mHealth interventions have grown in popularity over the past decade, there is limited evidence of their efficacy mainly due to lack of longitudinal methods [12]. In addition, despite the promise shown by these technologies, adoption, adherence, and user satisfaction has been documented as relatively low [13].

Previous research has investigated behavioral constructs and beliefs to understand their predictive utility for adherence to technological interventions [14]. While previous efforts have shown promise in identifying links between the health beliefs and intentions to use mHealth interventions, studies have generally focused on investigating beliefs at a single point in time [10,15]. To our knowledge, Dou et al. [16] is the only study that investigated the health beliefs as predictors of intention to use a Self-Measured Blood Pressure (SMBP) monitoring intervention that included a blood pressure (BP) cuff device and an associated mHealth tool for daily self-measurements and then compared the intentions to actual usage. While Dou et al.'s study provides evidence for the efficacy of using health belief constructs in predicting intentions to use a technological intervention for hypertension, more work is warranted to validate these findings and better understand the relationship between beliefs and actual behaviors performed.

To address this gap, this article reports on a pilot study that focuses on documenting a longitudinal study investigating two main objectives. First, we test the effect of a digital health coaching intervention on participants' belief constructs. Second, we assess the relationships between these belief constructs and intentions to utilize the technological intervention, actual adherence metrics, and clinical outcomes related to hypertension. The intervention used was an

SMBP plus weight kit that included a weight scale and a BP cuff device as well as mHealth coaching.

To quantify the relationship between behavioral constructs and intention or actual use, we utilized several constructs from the Health Belief Model (HBM). HBM has been commonly used to investigate how health beliefs affect one's intention to perform health-related behavior [17]. In addition, the widely-used Technology Acceptance Model (TAM) [18] was utilized to assess use-related constructs such as *perceived ease of use* and *perceived usefulness*. Finally, in line with Dou et al. (2017) the *resistance to change* construct which assessed the willingness to try new interventions and perform new behaviors was added. These constructs were used to define several hypotheses and are detailed below.

1.1 Hypotheses

The HBM posits that behavioral intention is influenced by several constructs. In this study, intention is operationalized as the intention to complete the tasks assigned to improve one's hypertension self-management while the actual behavior or adherence was measured as the number of assigned tasks completed.

First, *perceived health threat* (PHT) from HBM assesses the extent to which an individual perceives their condition as threatening to their health [17], which has been found to influence intention to manage hypertension [16]. Therefore, we hypothesize that *higher PHT from hypertension positively affects intention to use the intervention* (H1a). Accordingly, it is hypothesized that participants with *higher PHT adhere more to the required tasks* (H1b). Additionally, previous research has shown that education about the risks of unhealthy behavior increases perceived health threat [19]. Therefore, we hypothesize that *educating participants about hypertension increases their PHT* (H1c).

Self-Efficacy (SE) refers to how confident the individual is in their ability to manage their condition. Dou et al. (2017) found that *SE* was a significant predictor of intention to adhere to an SMBP regimen. Therefore, we hypothesize that *high SE positively impacts intention to use a hypertension coaching intervention* (H2a). In addition, given the evidence of low *self-efficacy* among patients with hypertension [20], we hypothesize that *health coaching increases SE* (H2b), since patients will have access to educational resources and may be more motivated to adopt a healthy lifestyle. Finally, in previous research, patients with hypertension who had high self-efficacy showed higher adherence to self-management routine [21], so we hypothesize that *participants with high SE will experience higher adherence to required tasks* (H2c) *and more significant improvement in their clinical outcomes* (H2d).

Perceived barriers (PB), defined as the perception of the potential negative aspects of performing a certain health behavior [17], has been shown to negatively influence intentions to perform such behaviors [22]. Therefore, we hypothesize that *high PB negatively affect the intention to use the intervention* (H3a) and *adherence to the required tasks* (H3b). Also, it is expected that the *PB* to manage hypertension will decrease through the course of the intervention since participants are provided with the motivation and devices needed to better self-manage

their condition. Therefore, we hypothesize that *the hypertension coaching intervention lowers participants' PB* (H3c).

Cues to Action (CTA) reflects individuals' internal ability to remember to perform certain tasks or behaviors. It has been shown that stronger *CTA* results in intention to perform behaviors [17]. Therefore, we hypothesize that *higher CTA increase the intention to manage hypertension* (H4a). Similarly, it is expected that our digital coaching intervention which includes goal setting and reminders would support such prospective memory to perform the required tasks regularly (e.g., BP measurements) [23]. Therefore, we hypothesize that *higher CTA would positively influence participants' adherence to performing required tasks* (H4b), and that *CTA would increase significantly with the intervention* (H4c).

One of the constructs in TAM is *Attitude* (ATT) that refers to the degree of favorable or unfavorable evaluation of the behavior [18]. *Attitude* has been found to positively influence intention to use technology [24]. Therefore, we hypothesize that *positive ATT towards managing hypertension positively impacts the intention to do so* (H5a) *and will result in higher user adherence to performing required tasks* (H5b). In addition, since our intervention includes coaching content from a credible source such as the AHA, then we hypothesize that *participants will have a significant improvement in their ATT towards hypertension self-management* (H5c) [25].

Next, *perceived usefulness* (PU), a core construct of TAM, has been shown to positively influence the use of technology [18]. *PU* indicates how useful and beneficial a system is perceived by an individual to help achieve a specific purpose. Therefore, we hypothesize that *PU positively impacts participants' intention* (H6a) and *adherence to the hypertension self-management tasks required* (H6b). We also anticipate that *participants' PU of the hypertension coaching tool will increase after exposure to the intervention* (H6c).

Additionally, *perceived ease of use* (PEOU) from TAM has been used to show that technologies that are easier to use positively influence intentions to use them [26], therefore, we hypothesize that *stronger PEOU positively impacts intention* (H7a) and *user adherence* (H7b). We also anticipate that given the user-centered design approach used to design and evaluate the intervention, our participants will have an increase in the *PEOU* after exposure to the hypertension digital coaching intervention. Therefore, we hypothesize that *PEOU will significantly increase after exposure to the intervention* (H7c).

Resistance to change (RTC), originally from the Dual Factor Model [27], is based on the claim that there are inhibiting beliefs that prevent individuals from trying new behaviors that could help them with their condition. *RTC* has been found to negatively influence intention in various studies [16,28]. Therefore, we hypothesize that *RTC negatively impacts intention* (H8a) and *user adherence* (H8b). Finally, interventions that successfully change behavior or improve outcomes influence a person's may mitigate RTC as per the Dual Factor Model [27]. Therefore, we hypothesize that the *hypertension coaching intervention will lower the participants' RTC* (H8c)

2. MATERIALS AND METHODS

2.1 Study Design

A longitudinal home study was conducted which required participants to use a custom-designed mHealth app called *HyperCoach* along with Bluetooth-enabled BP cuff and weight scale devices for 60 days. The first 30-days were considered a health awareness phase during which participants were asked to do daily self-measurement of BP and weight but did not receive any health coaching. The second 30-days involved completing daily health coaching tasks in addition to self-measurements following an American Heart Association (AHA) approved 30-day plan. The tasks mainly consisted of educational material provided through videos and pdfs, as well as weekly quizzes and assessments of progress. Participants would be able to see their progress and review automated feedback regarding their progress. However, participants didn't receive tailored feedback from the researchers regarding their results and were only contacted in case of missing measurements. A more detailed description of the health coaching tasks, the *HyperCoach* mHealth app, and the impact on the hypertension outcomes are discussed in Markert et al. [29].

2.2 Participants

Thirty-five participants were recruited through a bulk mail sent out to a large university community in the southern United States. Patients were included in the study on a rolling basis between January and May 2021. The inclusion criteria only allowed participants who were at least 18 years of age or older, spoke English, and whose primary diagnosis was hypertension. Additionally, participants had to take medication to control their hypertension and use an iOS smartphone with continuous internet access. Participants were excluded if they had resistant hypertension or more than two comorbidities based on the Charlson Index [30]. The study was approved by the Institutional Review Board of Texas A&M University (IRB2019-1070) and informed consent was obtained from all participants.

2.3 Study Procedure

Behavioral constructs mentioned earlier were elicited via a questionnaire taken at the beginning, middle (when participants switched to the coaching phase), and end of the study (Figure 1). Ten constructs were measured with at least 2 questions for each construct (Table 1) to assess reliability. The questions for each construct were rated on a 1-7 Likert scale ranging from Strongly disagree to Strongly Agree. Measures of clinical outcomes, namely systolic blood pressure (SBP), diastolic blood pressure (DBP), weight, and quality of life (SF-36) [31], in addition to hypertension health literacy (a 10-question test developed in collaboration with the AHA), were captured during both the awareness and coaching phase. Adherence metrics were also assessed including total time spent on educational material, total educational content completed, blood pressure (BP) and weight readings taken, and assessments and quizzes completed.

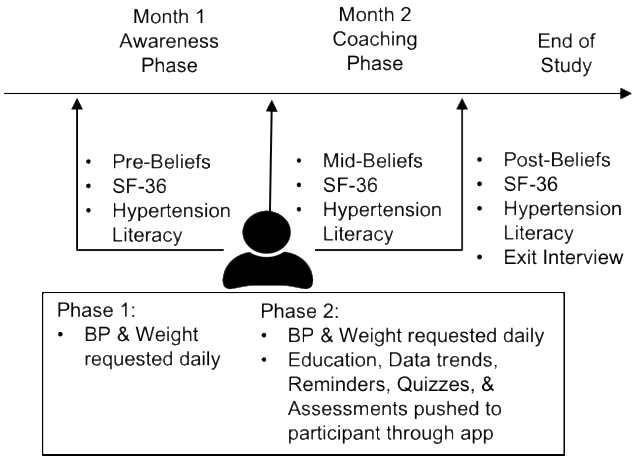

Figure 1 – Study Timeline

Table 1 – Questions and constructs used in the study as well as the reliability measures

Constructs	Questions	Reliability
Attitude (TAM)	This intervention will motivate me to regularly manage my hypertension	α = .93
	I don't believe that I will be motivated to manage my hypertension through this intervention	
	I think this intervention will help me manage my hypertension	
	I don't think this intervention helps in managing hypertension	
Intention	I would really like to manage my hypertension better	α = .74
	I don't really want to manage my hypertension	
	I would like to engage with the app regularly	
	I don't want to regularly engage with the app	
Perc. Health Threat (HBM)	I am concerned about the risks of hypertension on my health	α= .87
	I am not concerned about the risk of hypertension on my life	
	I feel hypertension is dangerous to my health	
	I don't think hypertension is dangerous to my health	
Self-Efficacy (HBM)	I am confident that I know how to manage my symptoms	rs = -.76
	I don't feel confident to manage my symptoms	
Perc. Barriers (HBM)	There are barriers to managing my symptoms	rs = -.74
	I do not feel there are barriers to manage my condition	
Resist. to Change	I do not want this intervention to change the way I deal with hypertension	rs = -.5
	I would like this intervention to change how I deal with hypertension	
Perc. Usefulness (TAM)	I am able to use this intervention without much time and energy	rs = -.45
	I don't feel this intervention is worth my time and energy	
Perc. Ease of Use (TAM)	Using the app was very easy for me	rs = -.68
	I do not think the app is easy to use	
	I regularly remember to follow the recommendations to manage hypertension	rs = -.65

Cues to Action (HBM)	I tend to forget what I need to do to manage hypertension	

2.4 Analysis

Constructs that included more than 2 questions were tested using a Cronbach's alpha for reliability while questions that only included 2 questions were assessed via a Spearman's correlation to assess reliability. To test for significant changes in the behavioral constructs over time, a Kruskal-Wallis test was performed since the questionnaire data was non-parametric. A Partial Least Square (PLS) regression analysis was conducted to assess the magnitude and significance of the causal relationships between a dependent variable (DV) and the independent variables that may influence it. *Intention* (DV) was compared to other behavioral constructs, clinical outcomes, and adherence metrics to detect any causal relationships. *RStudio* was utilized for all analyses.

3. RESULTS

Out of 35 participants recruited, 34 participants completed the study. One participant dropped out of the study due to personal obligations and other health issues. Participants had a mean age of 44.8 years (SD = 14.1; Range 19-79). Out of the 34 participants completed, 25 identified as females and 9 as males. Participants had a mean baseline SBP of 136.3 mmHg (SD = 18.4), a mean baseline DBP of 84.2 mmHg (SD = 11.4), and mean baseline BMI of 32.0 (*SD* = 6.9).

3.1 Reliability

The first three constructs had more than 2 questions so a Cronbach's alpha test was performed. Results for *ATT* ($\alpha = .93$), *INT* ($\alpha = .74$), and *PHT* ($\alpha = .87$) indicate high reliability. The Spearman's correlation analysis showed adequate reliability for the other variables ($p < .001$ for all variables) (Table 1).

3.2 Changes in Beliefs

The means of belief constructs and Kruskal-Wallis analysis for change in respective beliefs can be found in the Table 2. Only one construct, namely *PEOU* significantly increased ($H(1) = 17.87$, $p < .001$) in the health awareness phase from (*Mdn* = 4) to (*Mdn* = 6) just before coaching began and then to (*Mdn* = 7) after coaching was complete. Therefore, H7c was supported. However, by the end of the study, six additional constructs had improved due to coaching. *SE* increased as well ($H(1) = 15.12$, $p < .001$) from (*Mdn* = 4.75) to (*Mdn* = 6.5), therefore, H2b was supported. *CTA* increased ($H(1) = 5.33$, $p < .05$) from (*Mdn* = 5.25) to (*Mdn* = 6), so H4c was supported. *ATT* increased ($H(1) = 10.35$, $p < 0.01$) from (*Mdn* = 5.95) to (*Mdn* = 6.5), therefore hypothesis H5c was supported. *PU* increased ($H(1) = 15.02$, $p < .001$) from (*Mdn* = 6) to (*Mdn* = 6.5), therefore, H6c was supported. *RTC* decreased significantly ($H(1) = 4.05$, $p < .05$) from (*Mdn* = 2) to (*Mdn* = 1.25), so H8c was supported. *PHT* decreased from pre-study to post-study, however, this change was not statistically significant. Therefore, H1c was not supported. Similarly, while *PB* decreased over time, this change was not significant. Therefore, H3c was not

supported. A full list of hypotheses and whether they were supported or not is included in Table 3.

Table 2-Belief means and significant changes over the length of the study

Construct	M[a] (Pre)	M (mid)	M (Post)	KW[b] (Pre-Mid)	KW (Mid-Post)	KW (Pre-Post)
Attitude (ATT)	5.68	5.82	6.2*	.44	**.02***	**.002***
Intention (INT)	6.1	6.14	6.38	.92	.10	.09
Perc. Health Threat (PHT)	6.53	6.56	6.54	.98	.79	.82
Self-Efficacy (SE)	4.57	4.63	5.98*	.96	**<.001***	**<.001***
Perc. Barriers (PB)	4.1	4.25	3.41	.83	.06	.12
Resistance to Change (RTC)	1.97	2.23	1.81*	.68	**.03***	**.04***
Perc. Usefulness (PU)	5.65	5.98	6.47*	.09	.07	**<.001***
Perc. Ease of Use (PEOU)	4.69	6.0*	6.59*	**<.001***	**.014***	**<.001***
Cues to Action (CTA)	5.04	5.01	5.91*	.81	**.011***	**.02***

[a] M is the mean rating for each construct
[b] KW is the Kruskal-Wallis significance for a construct between two time periods
* Denotes significance

Table 3 – Hypotheses Status

Hypotheses	Status	Significance
(H1a) Higher PHT from hypertension positively affects intention to use the intervention	Supported	$\beta = .32$ $p < .05$
(H1b) Participants with higher PHT adhere more to the required tasks	Supported	$\beta = .033$ $p < .01$
(H1c) Educating participants about hypertension increases their PHT	Not Supported	$p = .82$
(H2a) High SE positively impacts intention to use a hypertension coaching intervention	Not Supported	$p = .12$
(H2b) Health coaching increases SE	Supported	$p < .001$
(H2c) Participants with high SE will experience higher adherence to required tasks	Not Supported	$\beta = -.014$ $p < .05$
(H2d) Participants with high SE will experience more improvement in their clinical outcomes	Supported	$\beta = -2.92$ $p < .05$
(H3a) High PB negatively affect the intention to use the intervention	Not Supported	$\beta = .12$ $p < .05$
(H3b) High PB negatively affect adherence to the required tasks	Not Supported	$p = .61$
(H3c) A hypertension coaching intervention lowers participants' PB	Not Supported	$p = .12$
(H4a) Higher CTA increase the intention to manage hypertension	Not Supported	$p = .64$
(H4b) Higher CTA would positively influence participants' adherence to performing required tasks	Supported	$\beta = .019$ $p < .01$
(H4c) CTA would increase significantly with the intervention	Supported	$p < 0.05$
(H5a) Positive ATT towards managing hypertension positively impacts the intention to do so	Supported	$\beta = .29$ $p < .01$
(H5b) Positive ATT towards managing hypertension will result in a higher user adherence to perform required tasks	Not Supported	$p = .08$

(H5c) Participants will have a significant improvement in their ATT towards hypertension self-management	Supported	$p < .01$
(H6a) PU positively impacts participants' intention	Not Supported	$p = .44$
(H6b) PU positively impacts participants' adherence to the hypertension self-management tasks required	Not Supported	$p = .86$
(H6c) PU of the hypertension coaching tool will increase after exposure to the intervention	Supported	$p < .001$
(H7a) Stronger PEOU positively impacts intention	Not supported	$p = .52$
(H7b) Stronger PEOU positively impacts adherence	Supported	$\beta = .0277$ $p < .001$
(H7c) PEOU will significantly increase after exposure to the intervention	Supported	$p < .001$
(H8a) RTC negatively impacts intention	Supported	$\beta = -.18$ $p < .01$
(H8b) RTC negatively impacts adherence	Supported	$\beta = -.014$ $p < .01$
(H8c) The hypertension coaching intervention will lower the participants' RTC	Supported	$p < .05$

3.3 Constructs Influencing Intention

At the beginning of the coaching phase, *INT* was significantly predicted ($R^2 = .79$, $F(10,23) = 8.49$, $p < .001$) by four constructs as represented in Figure 2. *PHT* had a significant positive effect ($\beta = .32$, $p < .05$). *PB* had a mild effect ($\beta = .12$, $p < .05$). *ATT* had a significant positive impact ($\beta = .29$, $p < .01$) and *RTC* had a negative effect on INT ($\beta = -.18$, $p < .01$). Therefore, H1a, H5a, and H8a were all supported. Higher *PB* had a mild positive effect on *INT* contrary to the original hypothesis so H3a was not supported. The other behavioral constructs did not have an impact on intention, so H2a, H4a, H6a, and H7a were also not supported.

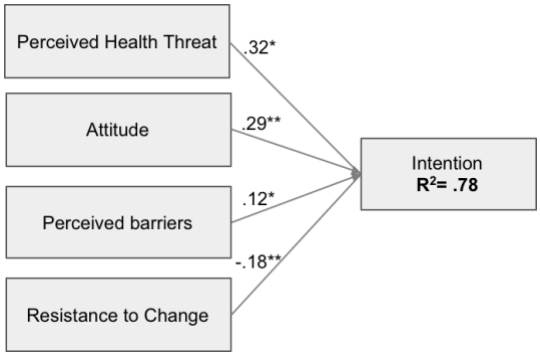

*Figure 2 - Significant constructs impacting intention (*** = p < .001, ** = p < .01, * = p < .05)*

3.4 Constructs Influencing Adherence Metrics

A t-test for patient adherence with completing BP and weight measurements was performed and indicated a significant increase in measurements taken (t (44.63) = -2.66, $p < .05$) during the second phase of the study which included coaching. The adherence of patients to performing their measurements increased from a proportion completed of ($M = .884$, $SD = .149$) before

coaching to a higher proportion of measurements completed (*M* = .958, *SD* = .064) during coaching.

A PLS regression analysis was conducted to understand the effects of behavioral constructs on self-measurement of BP adherence. No relationships were found between adherence to BP measurements and beliefs during the awareness phase. As for the coaching phase (Figure 3), adherence to measurements was influenced by several behavioral constructs (R^2 = .79, F(11,22) = 7.78, p < .001) including *PHT* (β = 0.033, p < .01), *INT* (β = -.060, p < .01), *SE* (β = -.014, p < .05), *CTA* (β =.019, p < .01), RTC (β = -.014, p < .01) , and *PEOU* (β =.0277, p < .001). Therefore, H1b, H4b, H7b, and H8b were all supported. *SE* had a contrary effect on BP measurements compared to the hypothesis so H2c was not supported. No other variable had a significant impact on BP measurement adherence, therefore, H3b, H5b, and H6b were not supported. No other significant relationship was found between any of the belief constructs and either the weight measurements performed, assessments completed, or educational material completed.

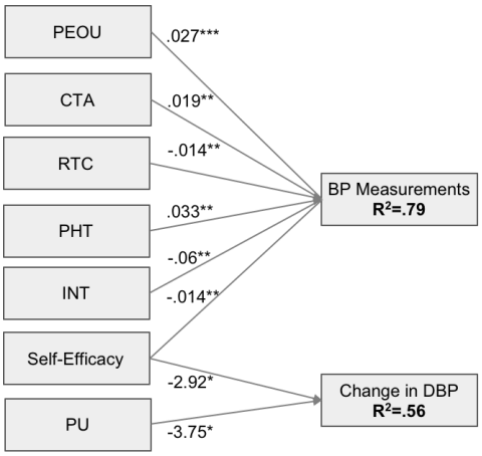

*Figure 3 - Relation between constructs and BP Measurements and DBP (*** = p < .001, ** = p < .01, * = p < .05)*

3.5 Constructs influencing Clinical Outcomes

The impact of the intervention on clinical outcomes is out of the scope of this paper and is reported in more detail elsewhere [29]. In brief, during the health coaching phase participants' mean SBP significantly decreased from 136.3 (*SD* = 15.6) to 130.8 (*SD* = 13.5), as well as mean DBP which significantly decreased from 85.1 (*SD* = 9.5) to 81.2 (*SD* = 9.5). Quality of life and health literacy all improved significantly during the health-coaching phase as well. However, weight slightly decreased but didn't change significantly due to the short length of the study.

An assessment of the relationship between change in health outcomes and behavioral constructs during coaching revealed that only change in DBP (R^2 = .56, F(11,22) = 2.53, p < .001) had a significant relationship with *SE* (β = -2.92, p < .05) and *PU* (β = -3.75, p < .05). Therefore, H2c was supported. No significant relationships were found between the belief constructs and either SBP, weight change, quality of life, or health literacy during coaching (see Figure 3 above).

4. DISCUSSION AND CONCLUSION

4.1 Discussion

This study showed that several constructs related to health beliefs have improved because of a technological intervention to improve hypertension outcomes. In addition, we found interesting relationships between some of these constructs and intentions, adherence, and clinical outcomes.

4.1.1 Changes in Beliefs

Although we did not expect a change in beliefs during the awareness phase, our findings showed that *Perceived ease of use* improved significantly. This is in line with the post-study interviews where participants reported that the app was easy to use. However, limited functionality was operational during this phase which could explain the lack of significant improvement in the *perceived usefulness* of the app or any other beliefs. When the coaching features were introduced, several beliefs significantly improved. First, *perceived usefulness*, *attitude,* and *resistance to change* significantly improved indicating the participants benefitted from the app features. We believe this is mostly due to improvements in health outcomes which have positively affected the perception of the intervention. Second, *self-efficacy* improved significantly during the coaching phase. Setting goals for the intervention, empowering participants to achieve those goals, and a positive trend in health outcomes might have helped participants feel more confident in their routine as suggested by Direito et al. [25]. Third, daily reminders to perform measurements may have helped participants form a habit of recalling to perform behaviors related to hypertension self-management. In turn this led participants to perceive a significant increase in their *cues to action*. Finally, *perceived health threat* is believed to be impacted by training and education [32]. In fact, our previous study evaluating an educational intervention to mitigate drowsy driving among nurses showed a similar impact of education on *perceived health threat* [19]. However, we did not witness any improvement in *perceived health threat* in this study. A possible explanation for this finding might be the scope of the educational and coaching content that focused more on mitigation methods and healthy behaviors compared to making the consequences of hypertension tangible.

4.1.2 Beliefs and Adherence

As expected, during the awareness phase, no significant relationships between adherence measures and beliefs were detected. Similarly, as hypothesized, during the coaching phase, we found a positive correlation between *perceived ease of use* of the app, *perceived health threat*, reduced *resistance to change* and stronger *cues to action* and adherence to BP measurements. However, in contrast to previous research [e.g., 21], a negative relationship between adherence and two health beliefs, namely *self-efficacy* and *intention* was found. This counterintuitive relationship can be explained by the intention-behavior gap [33] which posits that even with strong intentions, inaction may happen due to forgetfulness, willpower, or complacency. Such complacency might have been the case in our study due to significant positive progress and may describe the counterintuitive findings related to self-efficacy. Indeed, in our study those with higher *self-efficacy* had a stronger decrease in their DBP which might have led to complacency. It is notable that patients with hypertension have generally been found to have lower *self-efficacy*

than patients of other chronic conditions [20] which necessitates interventions to improve patients' perception of their abilities to self-manage their condition. However, our results may suggest that the benefits of increased self-efficacy may diminish if not managed properly. Similar effects have been widely documented in the literature where upon accomplishing personal goals, individuals become complacent which results in a worse subsequent performance [e.g., 34].

4.1.3 Beliefs and Clinical outcomes

In addition to significant improvement in SBP and DBP reported in Markert et al. [29], we attempted to test the relationship between beliefs and changes in clinical outcomes. We found a linear relationship between *self-efficacy* and *perceived usefulness* and DBP. In other words, the more confident the participants felt in managing their condition and the more useful they perceived the intervention to be, the more improvements they have seen in terms of lower DBP. This finding reaffirms the strong relationship between *SE* and patient progress in managing hypertension seen in the literature [35].

However, no linear relationship was found between any beliefs and the decrease in SBP even though (as reported in [29]) mean SBP and DBP both significantly decreased after the coaching phase. The probable reason for this could be that SBP has been reported to have a greater variation coefficient than DBP [36], making a linear relationship between SBP and beliefs more difficult to detect.

4.1.4 Limitations

This study had several limitations that may impact the generalizability of findings. First, the sample size is relatively small, and the population used were from a large university community in Texas. Indeed, this is reflected in our sample's demographics which shows homogeneity when it comes to education levels. Demographic factors have been previously reported to impact patients' understanding of hypertension which may affect beliefs [37]. More work is warranted to validate our findings with smaller and more stratified samples across education, geographical location, age, and other variables. Third, despite our promising results, it is not clear if the benefits and beliefs changes observed are sustainable. Work is in progress in collaboration with the AHA to address these gaps in a follow up study that evaluates the efficacy of a 90-day hypertension coaching plan in well-served and underserved areas. Finally, given the naturalistic nature of such an at-home study we did not have control over some confounding variables that may have influenced the participants' change in beliefs, behaviors, or clinical outcomes.

4.2 Conclusion

There is a general gap in understanding the utility of using patients' beliefs to predict behaviors and clinical outcomes when exposed to technological interventions. The results from this study showed that some health beliefs such as *attitude*, *resistance to change*, and *perceived health threat* were key predictors of *intention* to use an mHealth coaching plan for self-management of hypertension. We also found that utilizing this intervention was effective at helping patients with

hypertension improve beliefs such as *self-efficacy*, internal *cues to action*, *attitude*, and *perceived usefulness* regarding the self-management of hypertension. Consequently, this may have led to improvements in their adherence to daily measurements and a significant decrease in BP. More work is warranted to monitor these changes over a longer study period and across a more diverse population.

4.3 Practice Implications

Findings from the study show the efficacy of using health beliefs and technology acceptance constructs to predict intentions and actual behavior when exposed to mHealth coaching interventions. Given the non-intrusive and cost-efficient nature of these methods, even modest predictive utility may provide valuable input during front-end analyses. The findings also show that mHealth digital coaching interventions may provide patients with hypertension the training, resources, and motivation needed to improve their attitudes and beliefs toward managing their condition, may increase their adherence to a new self-management regimen which may improve clinical outcomes, lower risk of cardio vascular disease, and increase life expectancy [38]. Moreover, since intention alone may not be sufficient in predicting action [16], accounting for belief constructs such as *perceived health threats*, *cues to action, and perceived ease of use* may help in capturing more of the variance of the actual behavior as seen in this study. Given the evidence presented in this paper, interventions focused on these three variables may potentially prove effective in positive changes in behavior. For example, coaching content can educate the patients about the long-term effects of unhealthy behaviors and habits to increase the *perceived health threats* or integrated targeted reminders may increase participants' *cues to action* and support the prospective memory to perform a particular behavior. Future work should consider incorporating behavior change techniques explicitly aimed at targeting specific constructs based on the impact they have on specific beliefs [25].

Funding: This work was sponsored by the National Science Foundation Engineering Research Center: Precise Advanced Technologies and Health Systems focused on Underserved Communities (PATHS-UP).

Acknowledgments: The study was developed in conjunction with the American Heart Association Center for Health Technology & Innovation and utilizing coaching material developed as part of the American Heart Association's 12-week hypertension CarePlan. The authors would also like to thank Jacob M. Kolman, MA, ISMPP CMPP, of Houston Methodist and Texas A&M University, for his critical review, editing, and formatting assistance.

Abbreviations

AHA: American Heart Association
ATT: Attitude
BP: Blood Pressure
CTA: Cues to Action
DBP: Diastolic Blood Pressure
HBM: Health Belief Model
INT: Intention

PB: Perceived Barriers
PEOU: Perceived Ease of Use
PHT: Perceived Health Threat
PU: Perceived Usefulness
RTC: Resistance to Change
SBP: Systolic Blood Pressure
SE: Self-Efficacy
SMBP: Self-Measured Blood Pressure
TAM: Technology Acceptance Model

REFERENCES

[1] R.M. Carey, P.K. Whelton, Prevention, detection, evaluation, and management of high blood pressure in adults: synopsis of the 2017 American College of Cardiology/American Heart Association Hypertension Guideline, Ann. Intern. Med. 168 (2018) 351–358.

[2] Centers for Disease Control and Prevention, The Surgeon General's Call to Action to Control Hypertension, Cent. Dis. Control Prev. (2020). https://www.cdc.gov/bloodpressure/CTA.htm (accessed February 10, 2022).

[3] Centers for Disease Control and Prevention, High Blood Pressure Symptoms, Causes, and Problems, Cent. Dis. Control Prev. (2021). https://www.cdc.gov/bloodpressure/about.htm (accessed September 20, 2021).

[4] P. Lally, C.H.M. van Jaarsveld, H.W.W. Potts, J. Wardle, How are habits formed: Modelling habit formation in the real world, Eur. J. Soc. Psychol. 40 (2010) 998–1009. https://doi.org/10.1002/ejsp.674.

[5] J.S. Oliveira, C. Sherrington, A.B. Amorim, A.B. Dario, A. Tiedemann, What is the effect of health coaching on physical activity participation in people aged 60 years and over? A systematic review of randomised controlled trials, Br. J. Sports Med. 51 (2017) 1425–1432. https://doi.org/10.1136/bjsports-2016-096943.

[6] H. Weerahandi, S. Paul, L.M. Quintiliani, S. Chokshi, D.M. Mann, A mobile health coaching intervention for controlling hypertension: Single-arm pilot pre-post study, JMIR Form. Res. 4 (2020) e13989. https://doi.org/10.2196/13989.

[7] X. Lu, H. Yang, X. Xia, X. Lu, J. Lin, F. Liu, D. Gu, Interactive mobile health intervention and blood pressure management in adults, Hypertension. 74 (2019) 697–704. https://doi.org/10.1161/HYPERTENSIONAHA.119.13273.

[8] L.F. Obro, K. Heiselberg, P.G. Krogh, C. Handberg, J. Ammentorp, G.T. Pihl, P.J.S. Osther, Combining mHealth and health-coaching for improving self-management in chronic care. A scoping review, Patient Educ. Couns. 104 (2021) 680–688. https://doi.org/10.1016/j.pec.2020.10.026.

[9] J.E. Owen, B.K. Jaworski, E. Kuhn, K.N. Makin-Byrd, K.M. Ramsey, J.E. Hoffman, mHealth in the wild: Using novel data to examine the reach, use, and impact of PTSD Coach, JMIR Ment. Health. 2 (2015) e7. https://doi.org/10.2196/mental.3935.

[10] X. Zhang, X. Han, Y. Dang, F. Meng, X. Guo, J. Lin, User acceptance of mobile health services from users' perspectives: The role of self-efficacy and response-efficacy in technology acceptance., Inform. Health Soc. Care. 42 (2017) 194–206. https://doi.org/10.1080/17538157.2016.1200053.

[11] C. Markert, F. Sasangohar, B.J. Mortazavi, S. Fields, The Use of Telehealth Technology to Support Health Coaching for Older Adults: Literature Review, JMIR Hum. Factors. 8 (2021) e23796. https://doi.org/10.2196/23796.
[12] M.S. Marcolino, J.A.Q. Oliveira, M. D'Agostino, A.L. Ribeiro, M.B.M. Alkmim, D. Novillo-Ortiz, The Impact of mHealth Interventions: Systematic Review of Systematic Reviews, JMIR MHealth UHealth. 6 (2018) e23. https://doi.org/10.2196/mhealth.8873.
[13] M.L. Tanenbaum, S.J. Hanes, K.M. Miller, D. Naranjo, R. Bensen, K.K. Hood, Diabetes Device Use in Adults With Type 1 Diabetes: Barriers to Uptake and Potential Intervention Targets, Diabetes Care. 40 (2017) 181–187. https://doi.org/10.2337/dc16-1536.
[14] H.A. Forquer, J.L. Christensen, A.S.L. Tan, Predicting continuance—findings from a longitudinal study of older adults using an eHealth newsletter, Health Commun. 29 (2014) 937–946. https://doi.org/10.1080/10410236.2013.833580.
[15] A. Alaiad, M. Alsharo, Y. Alnsour, The determinants of mHealth adoption in developing countries: An empirical investigation., Appl. Clin. Inform. 10 (2019) 820–840. https://doi.org/10.1055/s-0039-1697906.
[16] K. Dou, P. Yu, N. Deng, F. Liu, Y. Guan, Z. Li, Y. Ji, N. Du, X. Lu, H. Duan, Patients' Acceptance of Smartphone Health Technology for Chronic Disease Management: A Theoretical Model and Empirical Test, JMIR MHealth UHealth. 5 (2017) e177. https://doi.org/10.2196/mhealth.7886.
[17] N.K. Janz, M.H. Becker, The health belief model: A decade later, Health Educ. Q. 11 (1984) 1–47.
[18] F.D. Davis, Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology, MIS Q. 13 (1989) 319. https://doi.org/10.2307/249008.
[19] K. Zahed, A. Smith, A.D. McDonald, F. Sasangohar, The Effects of Drowsiness Detection Technology and Education on Nurses' Beliefs and Attitudes Towards Drowsy Driving, IISE Trans. Occup. Ergon. Hum. Factors. (2022).
[20] M.J. Lee, S. Romero, H. Jia, C.A. Velozo, A.L. Gruber-Baldini, L.M. Shulman, Self-efficacy for managing hypertension and comorbid conditions, World J. Hypertens. 9 (2019) 30–41. https://doi.org/10.5494/wjh.v9.i3.30.
[21] F.C.J.H. Tan, P. Oka, H. Dambha-Miller, N.C. Tan, The association between self-efficacy and self-care in essential hypertension: a systematic review, BMC Fam. Pract. 22 (2021) 44. https://doi.org/10.1186/s12875-021-01391-2.
[22] T.M. Williamson, C.R. Rouleau, S.G. Aggarwal, R. Arena, T.S. Campbell, Bridging the intention-behavior gap for cardiac rehabilitation participation: the role of perceived barriers, Disabil. Rehabil. 42 (2018) 1284–1291. https://doi.org/10.1080/09638288.2018.1524519.
[23] S. Liu, J.F. Willoughby, Do Fitness Apps Need Text Reminders? An Experiment Testing Goal-Setting Text Message Reminders to Promote Self-Monitoring, J. Health Commun. 23 (2018) 379–386. https://doi.org/10.1080/10810730.2018.1455768.
[24] V. Venkatesh, Determinants of Perceived Ease of Use: Integrating Control, Intrinsic Motivation, and Emotion into the Technology Acceptance Model, Inf. Syst. Res. 11 (2000) 342–365. https://doi.org/10.1287/isre.11.4.342.11872.
[25] A. Direito, D. Walsh, M. Hinbarji, R. Albatal, M. Tooley, R. Whittaker, R. Maddison, Using the Intervention Mapping and Behavioral Intervention Technology Frameworks: Development of an mHealth Intervention for Physical Activity and Sedentary Behavior Change, Health Educ. Behav. Off. Publ. Soc. Public Health Educ. 45 (2018) 331–348. https://doi.org/10.1177/1090198117742438.

[26] M.J. Rho, I.Y. Choi, J. Lee, Predictive factors of telemedicine service acceptance and behavioral intention of physicians., Int. J. Med. Inf. 83 (2014) 559–571. https://doi.org/10.1016/j.ijmedinf.2014.05.005.
[27] R.T. Cenfetelli, Inhibitors and Enablers as Dual Factor Concepts in Technology Usage, J. Assoc. Inf. Syst. 5 (2004) 16. https://doi.org/10.17705/1jais.00059.
[28] O. Nov, C. Ye, Users' personality and perceived ease of use of digital libraries: The case for resistance to change, J. Am. Soc. Inf. Sci. Technol. 59 (2008) 845–851. https://doi.org/10.1002/asi.20800.
[29] Markert C, Zahed K, Sasangohar F, Dunn P. Using mHealth to Support Health Coaching for Patients with Hypertension: A Pilot Pre-Post Study [Internet]. ACELab; 2022. Available from: https://acelab.tamu.edu/wp-content/uploads/sites/23/2022/07/Using-mHealth-to-Support-Health-Coaching-for-Patients-with-Hypertension_A-Case-Control-Study_Human-Factors-.pdf
[30] M.E. Charlson, P. Pompei, K.L. Ales, C.R. MacKenzie, A new method of classifying prognostic comorbidity in longitudinal studies: Development and validation, J. Chronic Dis. 40 (1987) 373–383. https://doi.org/10.1016/0021-9681(87)90171-8.
[31] R.D. Hays, C.D. Sherbourne, R.M. Mazel, The rand 36-item health survey 1.0, Health Econ. 2 (1993) 217–227. https://doi.org/10.1002/hec.4730020305.
[32] S. Hajian, K. Vakilian, K.M. Najabadi, J. Hosseini, H.R. Mirzaei, Effects of education based on the health belief model on screening behavior in high risk women for breast cancer, Tehran, Iran, Asian Pac. J. Cancer Prev. APJCP. 12 (2011) 49–54.
[33] P. Sheeran, T.L. Webb, The Intention-Behavior Gap: The Intention-Behavior Gap, Soc. Personal. Psychol. Compass. 10 (2016) 503–518. https://doi.org/10.1111/spc3.12265.
[34] J.B. Vancouver, C.M. Thompson, A.A. Williams, The changing signs in the relationships among self-efficacy, personal goals, and performance, J. Appl. Psychol. 86 (2001) 605–620. https://doi.org/10.1037/0021-9010.86.4.605.
[35] S.J. Yu, M.S. Song, Y.J. Lee, The Effects of Self-efficacy Promotion and Education Program on Self-efficacy, Self-Care Behavior, and Blood Pressure for Elderly Hypertensives, Korean J. Adult Nurs. 13 (2001) 108–122.
[36] V.M. Musini, J.M. Wright, Factors Affecting Blood Pressure Variability: Lessons Learned from Two Systematic Reviews of Randomized Controlled Trials, PLoS ONE. 4 (2009) e5673. https://doi.org/10.1371/journal.pone.0005673.
[37] I. Grotto, M. Huerta, Y. Sharabi, Hypertension and socioeconomic status, Curr. Opin. Cardiol. 23 (2008) 335–339. https://doi.org/10.1097/HCO.0b013e3283021c70.
[38] P.M. Kris-Etherton, K.S. Petersen, J.-P. Després, C.A.M. Anderson, P. Deedwania, K.L. Furie, S. Lear, A.H. Lichtenstein, F. Lobelo, P.B. Morris, F.M. Sacks, J. Ma, on behalf of the American Heart Association Council on Lifestyle and Cardiometabolic Health; Council on Cardiovascular and Stroke Nursing; Stroke Council; Council on Clinical Cardiology; Council on Arteriosclerosis, Thrombosis and Vascular Biology; and Council on Hypertension, Strategies for Promotion of a Healthy Lifestyle in Clinical Settings: Pillars of Ideal Cardiovascular Health: A Science Advisory From the American Heart Association, Circulation. 144 (2021). https://doi.org/10.1161/CIR.0000000000001018.