Understanding Patient-related Factors that Impact Telemonitoring of Hypertension: A Mixed-methods Approach

by

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Dedication

This dissertation is dedicated to God Almighty.

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Abstract

About half of the adults in the United States have hypertension, and uncontrolled hypertension leads to significant illness and death. Telemonitoring of blood pressure (BP), where patients with hypertension take their BP at home and remotely communicate with their healthcare providers through technologies from the comfort of their homes and receive feedback, improves BP control. However, many patients are not using BP telemonitoring due to personal, technological and health system barriers. Specifically, individuals are required to have electronic health literacy (e-HL), defined as knowledge and skills to use technology services such as BP telemonitoring effectively. Yet, patients' e-HL in using BP telemonitoring is not known.

To fully understand the factors impacting telemonitoring of BP, we did three studies of BP telemonitoring and BP-related technology behaviors using a mixed-methods approach. The studies included, 1. Prediction of smartphone and tablet use in achieving health goals and communicating with healthcare providers via SMS text messaging among people with hypertension using patient-reported data from 3045 patients with hypertension within the Health Information National Trends Survey (HINTS), 2. Facilitators and barriers to telemonitoring of BP using the e-HL framework (comprised of 7 domains) among 21 patients receiving care at Michigan Medicine, 3. Predictors of participation in BP telemonitoring using an online national survey of 507 people with hypertension sampled based on age and education a priori quotas.

In the first study, we found that electronic communication with the doctor or doctor's office through email or internet and having a wellness app were significant predictors of using

SMS text message communication with a healthcare professional, adjusting for other demographic and technology-related variables. The odds of achieving health-related goals with the help of a tablet or smartphone declined significantly with older age and ownership of basic cellphones. However, they increased significantly with being a woman or with being married having a wellness app using devices other than smartphones or tablets to monitor health, making health treatment decisions, and discussing with a with the help of a tablet or smartphone. The second study identified five main themes including knowledge, motivation, skills, systems, and behaviors along with 28 subthemes comprising facilitators or barriers of BP telemonitoring. The mixed-methods results showed concordance between the participants' e-HL status and their experiences in the ability to actively engage with BP monitoring and managing digital services (domain 3) of the e-HL framework. The third study showed that about 12 percent of people with hypertension use BP telemonitoring. Participation in BP telemonitoring was positively predicted by awareness of BP telemonitoring, sharing health information electronically with a healthcare provider, and having digital services that suit individual needs (domain 7).

Collectively, the results show that considering patient characteristics such as age and education and prior technology use will likely increase BP telemonitoring. As well, awareness of BP telemonitoring programs and recommendation to participate from healthcare providers are likely to increase BP telemonitoring. Participants' e-HL status was related to their ability to actively engage in BP monitoring and management through digital services. Future research is needed to incorporate these concepts into media and programs to increase the uptake of BP telemonitoring.

Chapter 1 Introduction

1.1 Hypertension: Prevalence, Complications and Treatment

Globally, about 1.28 billion adults within 30-79 years of age have hypertension.(1) Almost half of adults with hypertension are unaware of their condition and only about 21% have their hypertension under control worldwide.(1) In the United States, 122.4 million adults aged 20 years or older have hypertension (50.4% males; 43.0% females).(2) Among those with hypertension, 62.0% are aware, 52.6% are receiving treatment, and about a quarter (25.7%) have their hypertension under control.(2) Hypertension is a significant risk factor for other cardiovascular diseases. Uncontrolled hypertension can lead to stroke (3), systemic embolism and bleeding (4), congestive heart failure (5), myocardial infarction (6), renal damage, dementia, aortic aneurysm, angina pectoris, metabolic syndrome, diabetes, blindness and death.(7,8) Hypertension is a major cause of death worldwide.(1) From 2010 to 2020, the number of deaths ascribable to hypertension in the United States rose by 90.1%.(2) The average annual cost of hypertension in the United States for 2018 to 2019 has been estimated at $52.2 billion.(2)

Treatment of hypertension involves both pharmacological and non-pharmacological strategies. The World Health Organization guideline on pharmacological treatment of hypertension in adults recommends the use of thiazide or thiazide-like diuretics, angiotensin converting enzyme inhibitors or angiotensin-II receptor blockers, and long acting dihydropyridine calcium-channel blockers as first line treatment either alone or in combination.(9) The non-pharmacological treatment recommendations include: salt-intake reduction, increase in fruits and vegetables diet, being physically active, avoiding tobacco usage, alcohol consumption reduction, limiting the intake of food with saturated and trans-fat.(9) The latest guideline for the management of hypertension in adults reported by the eighth Joint National Committee (JNC 8) recommends setting blood pressure (BP) goals and pharmacological treatment based on individual's age, comorbidities, and race in addition to the non-pharmacological treatments.(10)

Despite effective lifestyle and pharmaceutical treatments, the 2023 Heart Disease and Stroke Statistics reported that only about a quarter of adult patients with hypertension have their BP controlled in the United States using the age-adjusted nationally representative data from the 2017-2020 National Health and Nutrition Examination Survey (NHANES).(2) For the purpose of this prevalence, they defined hypertension as systolic BP (SBP) ≥ 130 mmHg, diastolic BP (DBP) ≥ 80 mmHg, or positive answer to taking antihypertensive medication. Hypertension was considered controlled with SBP < 130 mmHg or DBP < 80 mmHg.(2) The systolic blood pressure intervention trial (SPRINT) of 9361 participants with SBP ≥ 130 mmHg and increased cardiovascular risk but no diabetes or stroke showed that managing the BP to a goal of SBP < 120 mmHg (intensive treatment group) led to a significant reduction in cardiovascular events and death when compared with SBP < 140 mmHg (standard treatment) goal group.(11) These participants were followed for about 3.3 years of the intervention study. However, about 4.5 years after the study ended, the SBP increased to 140 mmHg in the intensive treatment group and the cardiovascular events and mortality benefits were lost.(12) This suggests that consistent control of BP is important.

There is a need to harness every arsenal possible to mitigate the challenge of uncontrolled BP. To improve hypertension control, Jones et al., had suggested incentivizing the health system to prioritize preventive care by inculcating study intervention strategies into routine clinic care; use of telehealth strategies; healthier food policies; aggressive early lifestyle modification for individuals with family history of hypertension; early use of antihypertensive medication in teenagers and young adults; and use of lifetime cardiovascular risk instead of 10-year risk for BP management decisions.(13)

One critical strategy is involving patients in their disease management through technology application. The innovations in information and communication technology provide great opportunity for improvements in hypertension control. For example, there are portable digital BP measuring devices available for home use, wearable devices that keep count of body movements, and mobile smartphones with health applications. There has been a steady increase in the number of internet users and mobile cellular subscribers since the year 2000. According to Pew Research Center 2022 report, 93% of Americans use internet, and the increase in internet use is seen across all age groups.(14) Also, 97% of Americans own a cellphone and 85% now use smartphones.(15) There are different technology devices and strategies that could be applied in hypertension management. The next paragraph will introduce the available technology that could help patients with hypertension management.

1.2 Technology to the Rescue

Health technology is any practice, knowledge, substance, or tool that is applied to improve health.(16) The last few years have witnessed a surge in technological approaches to tackle several health challenges and hypertension is not exempt. Several technologies have been applied at system's, physician's, and patient's levels of hypertension management. For instance, there are telehealth enabling policies to be made at the system level, clinical decision support technologies at the physician level, and portable electronic devices to help patients connect with the physicians and the health system.(17)

For this project, we focused on those technologies that patients can relate with, for example electronic health records, pill bottles, flash cards, quick response (QR) coded videos, phone calls, short message service (SMS) alerts, email, alarms, wearable wireless devices, and health applications. Single or combination use of these technologies have been applied in hypertension medication adherence, self-monitoring, and telemonitoring of BP.

1.2.1 Technology use in Hypertension Medication Adherence

With hypertension being a chronic disease, the importance of medication adherence in hypertension management can never be overemphasized. However, only about one half of patients who started an anti-hypertensive medication remain on it after 12 months.(18) The consequences of non-adherence to hypertension treatment regimens include treatment failure, increased incidence of other cardiovascular diseases, increased healthcare cost and mortality.(19–23) Examples of different approaches to improve medication adherence among people with hypertension include medication simplification, patient counseling and education, financial incentives, patient-centered medical home and health technology tools.(24,25) In this section, we will discuss the health technology tools that have been applied to improve patients' adherence to their hypertension medication.

The impact of these technologies was determined by a literature review. The databases searched were PubMed® and Google Scholar®. Search terms included were ("hypertension" OR "high blood pressure*") AND ("medication adherence" OR "medication compliance" OR "drug compliance") OR ("hypertension medication adherence") AND ("technolog*" OR "device*" OR "digital*" OR "electronic pill bottles" OR "smartphone app*" OR "SMS text messages" OR "phone call" OR “flash cards” OR “QR codes” OR “electronic health record” OR “EHR” OR “self-monitoring of blood pressure”), randomized controlled trials, reviews, systematic reviews and meta-analysis articles from year 2013 to 2023. Over 70 articles published in English were identified. The purpose of this section is not to provide a systematic review of literature but to show how technology has influenced hypertension management in the last ten years. Therefore, we present here some examples of the randomized controlled trials, systematic reviews, and meta-analysis studies where available.

Electronic pill bottles of different designs and forms have been applied in medication adherence improvement strategies. In a longitudinal nonblinded randomized study of 134 low health literacy patients with hypertension, the intervention group received a summary of the counseling message recorded in a Talking Pill Bottle while the control group received the usual counseling without the Talking Pill Bottle.(26) Both groups were followed up at 30, 60 and 90 days. At the end of 90 days, the intervention group had significantly decreased mean systolic (-4.09 mmHg, P = 0.036) and diastolic (-2.42 mmHg, P = 0.027) BP compared to baseline. No significant change in BP readings over time was seen in the control group. A three-arm randomized controlled trial of 149 patients with hypertension compared the use electronic pill bottle or bidirectional text messaging to improve adherence to usual care.(27) Patients in the electronic pill bottle arm received their pill in a wireless electronic pill bottle that monitors bottle opening and sends electronic alert to a software platform used in the study. Those in the bidirectional text message arm received text message asking them to reply Yes or No to having taken their medication. Both arms received daily feedback text messages and were followed-up for 4 months. At the end of the study, though medication adherence was high in both pill bottle (77.2%) and bidirectional text messaging (79.4%) arms, there was no difference in self-reported baseline and follow-up medication adherence surveys. Also, no significant differences were observed in the BP control among the pill bottle, text messaging and usual care groups.(27) A pre-and post-intervention study of the effect of a monthly electronic medication organizer with inbuilt alarm clock on medication adherence and BP control of 32 elderly patients with hypertension, showed that 78.1% who were less adherent at the beginning became more adherent post intervention, P < 0.001.(28) The alarm was programmed to go off at the specified patient medication taking time and the intervention time was 6 months. The mean differences in systolic and diastolic BP pre-and post-intervention were -21.6 mmHg, P < 0.001 and -4.7 mmHg, P < 0.001, respectively.(28)

A systematic review of electronic medication packages (EMP) employed to improve adherence in different disease settings including hypertension showed a positive result in favor of EMP compared to traditional pill bottles.(29) Thirty-seven studies (9 on patients with hypertension) constituting 4,326 patients were reviewed. Ten of the 37 studies were on EMP with patient-interface only, while 29 were on EMP with patient-interface coupled with healthcare provider intervention. The EMP types included simple recorders (22 studies), recorders with audio and/or visual reminders (6), recorders with digital display (5), recorders with audiovisual reminders and display (5), and a device using real time wireless monitoring.(29) The overall effect estimates of EMP on the mean medication adherence ranged from -2.9 to 34.0%, and that of proportion of adherent patients ranged from -8.0 to 49.5%.

Flash cards are cards containing summarized information about any subject. It is used to aid recall of the full subject. Quick response (QR) codes are machine-readable codes made up of black and white squares. QR code can be used to store written information, pictures, or videos. The flashcards are useful reminders and videos are particularly helpful, especially in patients with lower health literacy. In a prospective matched quasi-experimental study of 68 adult patients prescribed targeted oral heart failure, hypertension and type 2 diabetes medications, disease- and medication-specific flash cards and QR coded online videos resulted to higher proportion of days covered (PDC) in patients in intervention group than the control (71% vs. 44%; $P < 0.0069$) after 180 days.(30) The low health literacy (based on first grade reading level or below) flashcards educated patients on medication indications, administration counseling, disease state counseling and common side effects. Each flashcard had a corresponding pharmacist's counseling video linked to a QR code and attached to patient's medication bottles.

Phone calls, SMS alerts, and smartphone application (app) reminders are common and effective strategies in improving medication adherence. Mobile health apps have helped patients in setting alarms and reminders to take their hypertension medications.(31) An individually tailored telephone call intervention aimed at reminding patients to adhere to their medications, DASH diet, weight loss, reduced salt intake, exercise and moderate alcohol intake, among 558 patients with hypertension under Medicaid coverage recorded improvement in medication possession ratio from 55% at 9-12 months before the intervention to 77%, 9-12 months after.(32) The study was a quality improvement program in three community-based provider networks. The care manager called patients up to 10 times at about 3-week intervals over a 6-month period. A one-time phone call intervention to identify barriers to medication adherence among 186 patients with hypertension and diabetes who were on an angiotensin converting enzyme inhibitor (ACEI) or angiotensin receptor blocker (ARB) showed that that the call was a significant predictor of increased adherence among the intervention groups ($\beta = 0.3182$, 95% CI 0.19-0.38, $P < 0.001$).(33) In a similar study to improve medication adherence, 734 patients with hypertension and diabetes on ACEI/ARB were randomized to intervention and control groups.

The intervention group received motivational interviewing via phone call once a month for 6 months. Patients who completed the initial phone call and at least 2 follow-up calls were more likely to be adherent ($\beta = 0.0604$, $P < 0.001$) and less likely to discontinue their medication (OR = 0.29, 95% CI 0.15-0.54, $P < 0.001$) compared to control.(34)

In a randomized controlled trial (RCT) involving 314 patients with hypertension, SMS text messaging increased medication adherence from 49% to 62.3%, P = 0.01 in the SMS group and decreased from 59.3% to 51.4% in the non-SMS after 6 months follow-up.(35) The text messages included information on healthy diet, medication schedule, and importance of medication adherence. The messages were sent every 12-14 days during the 6-month period. In a two arm unblinded RCT, 123 African Americans with uncontrolled hypertension were randomized to an automated text messaging intervention to improve medication adherence (BPMED).(36) The BPMED intervention included daily medication taking reminder text messages, and twice weekly hypertension management educational text messages. Patients were followed-up for one month. Medication adherence was measured with the eight-item Morisky Medication Adherence Scale-8 (MMAS-8) at baseline and one month. The BPMED group had greater but non-significant mean improvement on their medication adherence compared to usual care (mean change 0.9, SD 2.0 vs mean change 0.5, SD 1.5, P = 0.26). Also, non-significant but greater mean improvement in systolic BP (mean change -12.6mmHg, SD 24.0 vs mean change -11.3 mmHg, SD 25.5, P = 0.78) and diastolic BP (mean change -4.9 mmHg, SD 13.1 vs mean change -3.3 mmHg, SD 14.3, P = 0.54) were observed in the BPMED group versus the usual care group.(36) A meta-analysis of 16 RCTs involving 2742 patients with chronic diseases showed that text messaging significantly improved medication adherence (odds ratio 2.1; 95% CI 1.52 – 2.93; $P < 0.001$).(37) Fifteen out of the 16 studies sent messages at a preset time while one study only sent at real time if the patient failed to open the medication dispenser. The messaging form ranged from a personalized format to a two-way communication. The frequency of messaging was daily in 8 studies, weekly in 3, and variable in others. The message content was mainly medication reminders, though some included health education and non-medical general topics.(37) A more recent systematic review of 12 RCTs on the effectiveness of text messaging reported that text messaging interventions significantly reduced systolic BP (standard mean difference 0.13, P = 0.01) but not diastolic BP (standard mean difference 0.06, P = 0.56).(38) The frequency of the text messaging varied from daily to biweekly, and were mostly unidirectional. The meta-analysis of seven (those lasting 6 months or less) out of the 12 studies showed that once a week or less messaging frequency resulted in systolic BP (effect size 0.35, P < 0.01) and diastolic BP (effect size 0.28, P = 0.01) reductions. The authors did not provide analysis on medication adherence due to high heterogeneity in medication adherence assessment methods in the studies.(38)

In an RCT on 411 adult patients with uncontrolled hypertension, the use of a smartphone app increased medication adherence in the intervention group compared to the control (between-group difference, 0.4; 95% CI, 0.1-0.7; P = 0.1) at 12 weeks.(39) The intervention group were instructed to download the app which provided medication taking reminders, adherence reports and optional peer support. The medication adherence was measured using the MMAS-8. Ng et al, conducted a systematic review of the impact of mobile applications on medication adherence including 11 RCTs and 10 non-RCTs.(40) The studies targeted various chronic diseases, nine of which were cardiovascular diseases including hypertension. The app features included reminders, education, medication e-diary, and communication with a healthcare professional. They reported improvement in adherence in all 11 RCTs with statistically significance improvement in 7. The non-RCTs showed statistically significant improvement in adherence in two studies. The heterogeneity of the studies in terms of design, app features, and adherence measures made it hard to a draw conclusion on the mobile app impact. However, the studies showed that medication adherence may be improved by using mobile apps.(40)

A more recent study on the technology-based interventions to improve medication adherence in hypertension management reviewed 12 RCTs.(41) Five out of the 12 studies showed significant improvement in adherence compared to the control. The improvements were seen with studies that applied electronic-medication bottle caps with audio-visual reminder, educational SMS alerts, sending self-measured BP to a telephone-linked computer system, and incentivized video submission of drug taking.(41)

All indications point to the advantages of these technologies in improving adherence and hence BP control. More studies are however needed to fully understand the extent of their impact. In addition to medication adherence, the actual measuring of the BP and regular monitoring of the numbers by the patient is an important part of maintaining BP control.(42) There are many commercial portable BP machines that patients can get for their home use. The Center for Disease Control (CDC) and the American Heart Association have guidelines on to how to choose the appropriate BP cuff sizes and measure BP for patients.(43,44) The next section discusses self-monitoring of BP and evidence of its effectiveness in literature.

1.2.2 Self-monitoring of Blood Pressure

Self-monitoring of blood pressure (SMBP) is an important aspect of self-management of hypertension.(45) Self-monitoring entails the patients taking their BP measurements outside of their health providers’ office, usually at home. Self-monitoring provides BP data for detection of uncontrolled high BP or white coat effect thereby ensuring appropriate clinical treatment decisions. SMBP can help to improve medication adherence as well as BP control, as discussed in this section.

Fletcher et al, conducted a systemic review and meta-analysis of 28 RCTs involving 7,021 participants to show the effect of SMBP on medication adherence and BP control.(46) The participants were adults with hypertension receiving care in ambulatory settings and prescribed hypertension medications. The protocol for SMBP varied from twice daily to monthly BP measurements. Participants follow-up ranged from 2 weeks to 12 months. Out of the 28 studies, 13 and 11 studies qualified for meta-analysis of the effect of SMBP on medication adherence and BP control respectively. The analysis showed an overall significant improvement in medication adherence among the SMBP group compared to control with the standardized mean difference (SMD) of 0.21 (95% CI 0.08-0.34).(46) An overall significant reduction in mean diastolic BP at 6 months was observed (-2.02 mmHg, 95% CI -2.93, -1.11) in favor of SMBP while no difference was seen for systolic BP.(46)

Another review of 52 prospective comparative studies on the effectiveness of SMBP with or without additional support in adults with hypertension demonstrated a clinically important improvements in systolic and diastolic BP compared to control.(47) When comparing SMBP alone versus usual care, significant differences in systolic and diastolic BP were seen at 6 month (weighted mean difference, -3.9 mmHg and -2.4 mmHg, respectively) in favor of the SMBP group but not at 12 month (weighted mean difference, -1.5 mmHg and -0.8 mmHg, respectively). When SMBP was supported with additional interventions such as telemonitoring, patient education, counselling and behavior management, high-strength evidence resulted in an overall reduction in mean systolic BP (range, -2.1 to -8.3 mmHg) and diastolic BP (range, 0.0 to -4.4 mmHg) occurred at 12 months in the intervention group compared to usual care group.(47)

Similar BP outcomes were mostly found when SMBP alone was compared with SMBP plus additional support but low-strength evidence. The effectiveness of SMBP was further demonstrated by Sheppard et. al., in their systematic review and individual patient data meta-analysis of 16 RCTs involving 6,522 patients with hypertension-related comorbidities.(48) The patients had hypertension plus other morbidities including coronary heart disease, stroke, obesity, diabetes, and chronic kidney disease (CKD). Despite the heterogeneity across the studies, self-monitoring was associated with mean reductions in systolic and diastolic BP of -3.12 mmHg (95% CI -4.78, -1.46) and -1.44 mmHg (95% CI -2.13, -0.74) respectively in all patients. Increasing the number of co-morbidities resulted in no difference in self-monitoring effectiveness with systolic and diastolic BP p-values of 0.260 and 0.079 respectively. Those involved in self-monitoring had reduced odds of having uncontrolled BP at 12-month follow-up (odds ratio (OR) 0.71, 95% CI 0.58, 0.87) regardless of the number of comorbidities.(48) Another interesting finding from the Sheppard et al., study was the significant interaction found between self-monitoring and intensity of co-intervention. The co-intervention was either low-intensity or high-intensity. Low-intensity intervention was defined as self-monitoring with minimal additional contact and automated feedback or support. High-intensity intervention was defined as self-monitoring plus active and significant tailored support that included electronic feedback, education as well as healthcare provider monitoring. Patients with stroke, diabetes, CKD, and obesity receiving high-intensity intervention were less likely to have uncontrolled BP at 6-month follow-up.(48) Another meta-analysis 7,138 of individual patient data from 25 reviewed articles found that BP self-monitoring led to reduced overall reduction in clinic systolic blood (-3.2 mmHg, 95% CI -4.9, -1.6) compared with usual care at 12 months.(49) However, self-monitoring combined with co-intervention such as medication titration or lifestyle counseling led to a greater reduction in systolic blood (-6.1 mmHg, 95%CI -9.0, -3.2).(49)

These findings suggest that though SMBP is effective in BP reduction and control, SMBP combined with additional interventions such as telemonitoring may result in greater BP control. The next section discusses BP telemonitoring.

1.2.3 Telemonitoring of Blood Pressure

In his call to action to control hypertension published October 2020, the US surgeon general recognized that multifaceted approaches are required to control BP including consolidated use of health technology, empowering and equipping patients to use self-measured BP monitoring, medication adherence strategies, and maintenance of the patient-healthcare provider communications.(50) Advancements in technology such as electronic communication tools and monitoring devices as well as the experiences with the global COVID-19 pandemic have made telehealth a viable option in management of various diseases including hypertension.(51–53) Telehealth is defined as “the delivery and facilitation of health and health-related services including medical care, provider and patient education, health information services, and self-care via telecommunications and digital communication technologies”.(54) The four major forms of technologies used in telehealth include mobile health apps, store and forward electronic transmission, video conferencing and remote patient monitoring.(54)

Remote patient monitoring (RPM), also known as telemonitoring is simply monitoring of patients from a distance.(55,56) It comprises the use of electronic communication devices such as mobile monitoring devices, wearables, smartphone apps, internet-enabled computer, usually from a patient’s home to collect and transmit patient’s health data to a healthcare provider for evaluation and appropriate intervention.(54,57,58) The health data transmission could be automated or manually entered by the patient. Telemonitoring could be accompanied by structured telephone support (human or machine delivered phone calls)(59) or text messages(60,61) that provide reminders and self-care health education to the patient.(58) According to the Telehealth.HHS.gov website, conditions such as diabetes, heart conditions, chronic obstructive pulmonary disease, sleep apnea and asthma, and symptoms like high BP, weight loss or gain can be telemonitored.(62)

Over the years, telemonitoring has evolved in both the components and processes of administration. Several systematic reviews published from 2003 to 2022 about telemonitoring in varying diseases exist, and the results are mixed. A systematic review of 272 publications on telemonitoring from 2000 to 2018 showed that it is effective in improving patient outcomes in 209 (76.8%) of the papers.(56) Most of the papers reviewed were on telemonitoring of cardiovascular (47.8%) and endocrinologic (18.0%) diseases. De Farias et al, also noted a significant increase in the number of publications on telemonitoring between 2015 and 2018 demonstrating the growing interest in its use in patient health improvement.

Another systematic review of randomized controlled studies on telemonitoring using non-invasive wearable devices(63) showed some positive results. They demonstrated that remote monitoring could reduce chronic obstructive pulmonary disease (COPD)-related hospitalization and costs; improve BP control in select patients; reduce pain and improve function in low back pain patients; and improve mobility in Parkinson’s disease and systemic sclerosis or rheumatoid arthritis. However, the meta-analysis of the 15 randomized controlled studies - six on weight, five on systolic BP, and four on diastolic BP - showed no statistically significant differences in patient outcomes between the telemonitored and control groups, mainly due to heterogeneity and few high-quality studies.(63)

Similarly, a systematic review of 91 different telemonitoring studies utilizing invasive and non-invasive devices, and manual data entry into tablets, smartphones or websites demonstrated effectiveness in reducing hospital admission, length of stay and emergency visits in 49% (n = 44/90), 49% (n = 23/47), and 41% (n = 13/32) of the studies where measured, respectively.(64) The disease conditions in this review were cardiovascular 59% (n = 54), COPD 20% (n = 18) or cardiovascular and COPD comorbidity 4% (n = 4) with schizophrenia, inflammatory bowel disease, peritoneal dialysis, nursing home residents and people on home ventilation also included 17% (n = 15).(63) The outcome measures monitored were heart rate 57% (n = 52), BP 54% (n = 49), weight 48% (n = 44), and oxygen saturation 43% (n = 39).

Omboni et al., meta-analyzed 23 RCTs comprising 7037 patients with hypertension randomized to home BP telemonitoring (HBPT) and usual care. They found that the patients in HBPT group had a significant reduction in the systolic BP (-4.71 mmHg, 95%CI -6.18, -3.24, P < 0.001) and diastolic BP (-2.45 mmHg, 95% CI -3.33, -1.57, P < 0.001) compared to usual care.(65) Though health cost was higher in the HBPT group, participating in telemonitoring improved their quality of life significantly (SF-12 or SF-36 questionnaire: +2.78 [+1.15, +4.41] P < 0.001).(65) Finally, a meta-analysis of 32 randomized controlled studies done in patients with hypertension living in urban areas demonstrated higher BP control rates among the remote BP monitoring group (relative ratio 1.226, P < 0.001) compared to the usual care group.(66)

Though heterogeneity in BP telemonitoring studies has led to identification of lack of difference in positive patient outcomes between telemonitored and non-telemonitored groups in some studies, the bulk the of meta-analysis studies demonstrated greater improvement in BP control among those in the telemonitoring group. BP telemonitoring is thus considered a viable digital management strategy for hypertension and so there is need to increase its adoption among patients that would most benefit from it.

1.2.4 Blood Pressure Telemonitoring Challenges

Despite mixed evidence of effectiveness in improving patient outcomes, support for telemonitoring is still growing.(67) The focus is now on how to overcome the challenges of telemonitoring, especially related to patient experiences. A review of the literature in this area was done by searching Google Scholar® and PubMed® for studies on BP telemonitoring adoption challenges from 2013 to 2023. From this review, 19 studies were identified including ten systematic reviews, seven qualitative studies, and two quantitative studies that provided insights on BP telemonitoring challenges experienced by patients as discussed in the paragraphs below.

Thomas et al, noted that patient-centered RPM which ensures patients have appropriate knowledge, skills, and behaviors combined with frequent communication with healthcare providers is successful in reducing acute care use.(68) Among patients with various chronic diseases, remote monitoring was facilitated by the disease-specific knowledge gained, early identification of disease decline triggers, improved self-management skills, and shared decision-making with providers.(69) Nonetheless, there is still fear of losing in-person contact and apathy towards technology caused by a lack of trust and skill.(69) A weighted analysis of the health information national trends survey (HINTS), showed that among adults with hypertension, previous electronic communication with healthcare providers through email or the internet and access to health Apps were important predictors of interacting with healthcare providers through SMS text messages.(70) Furthermore, a randomized controlled study of patients with hypertension in telemonitoring and non-telemonitoring groups showed that BP telemonitoring was facilitated by the acceptability of the intervention, data safety, and timely communication with the healthcare provider. The barriers were concerns for data safety, lack of motivation, and technology skills.(71)

A scoping review of 36 studies on digital health technology (including telemonitoring) adoption for hypertension management reported technology usability and support, better patient-provider communication, improved self-management, and fewer clinic visits as patient-related facilitators.(72) Barriers to digital health technology adoption for patients were cost, data privacy and security concerns, anxiety, loss of the patient-provider relationship, and lack of technology trust, skills and support.(72) Another systematic review of the adoption of telemedicine for the management of hypertension reported similar facilitators and barriers, in addition to the availability of access to care, improved patient knowledge, and involvement.(73)

Furthermore, other challenges limiting the widespread adoption of BP telemonitoring including the lack of skill required to operate the technology, acceptability, beliefs, long-term adherence, lack of healthcare provider feedback, accessibility, and complexity of the technology have also been reported in literature.(58,74–85) In summary, factors related to the individual, technology in question, and the health system could impact whether a particular technology is used by a patient or not. As BP telemonitoring is currently the most ready implementable solution among the various digital health strategies(76), it is important that these challenges especially regarding the skills required to operate the technologies are addressed.

1.2.5 Theoretical Applications to Blood Pressure Telemonitoring

Most studies on the adoption of BP telemonitoring were not based on any theoretical or behavioral model or framework. The few studies that applied a framework used the technology acceptance model (TAM).(86) According to TAM, a person's intention to use technology depends on the perception of the usefulness and ease of use of the particular technology. TAM has been used to explain patients' acceptance of technology in management of chronic diseases like hypertension.(77,87,88) There is also a series of modifications from TAM to TAM2, TAM3, and the unified theory of acceptance and use of technology (UTAUT).(89) With these modifications, however, it is important to note that electronic health literacy (e-HL) could be at the foundation of any perception a patient using technology might have as literacy usually influences perception.(90–92) There is therefore need to explore the concept of e-HL among patients as it relates to RPM. This next section discusses different theories and scales of e-HL and its importance in telemonitoring of blood pressure.

1.3 Electronic Health Literacy (e-HL)

eHealth was one of the terms that arose with the spread of internet usage. Eysenbach(93) provided the first comprehensive definition of eHealth in the academic setting as follows "eHealth is an emerging field in the intersection of medical informatics, public health, and business, referring to health services and information delivered or enhanced through the internet and related technologies. In a broader sense, the term characterizes not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology." Several other definitions of eHealth have been postulated depending on the context and the defining body.(94) The most common denominator has always been the use of technology to support health and healthcare. The World Health Organization (WHO) currently defines eHealth as "the cost-effective and secure use of information and communication technologies in support of health and health-related fields, including health-care services, health surveillance, health literature, and health education, knowledge and research".(95) However, individuals can only enjoy the benefits of eHealth if they are able to access and use them.

To account for the skills and knowledge needed to use eHealth, Norman and Skinner coined the concept of eHealth literacy (e-HL). They defined e-HL as "the ability to seek, find, understand, and appraise health information from electronic sources and apply the knowledge gained to addressing or solving a health problem".(96) Later definitions of e-HL captured the required skills within the context of social, individual, and technology interactions not represented in the original definition.(97–99) Norman and Skinner put forward the first e-HL model called the "Lily Model" over a decade ago.(96) They also developed the eHealth Literacy Scale (eHEALS) to measure e-HL.(100) Several other e-HL models and measuring scale have been proposed over the years including the e-HL Framework (e-HLF) and e-HL Questionnaire (e-HLQ).(101,102)

1.3.1 Literature Review of Electronic Health Literacy Theories and Scales

This section provides a review of the available e-HL theories and measures beginning with the pioneer general measure developed in 2006(100), its extended version, other general measures of e-HL up to the latest diabetic-specific measure of e-HL.(103)

The Lily model of e-HL comprises six different literacies grouped into analytical and context-specific skills.(96) The analytical skills are broadly applicable, and they include traditional literacy and numeracy (ability to understand text and numbers), media literacy (ability to process media content and quality), and information literacy (ability to find, use and organize knowledge). The context-specific skills include computer literacy (ability to solve problems using a computer), health literacy (ability to understand and apply health information to healthcare), and scientific literacy (ability to understand basic scientific texts). Norman and Skinner utilized the Lily model and social cognitive theory (self-efficacy) to develop a measuring scale for e-HL called eHEALS.(100) The eHEALS is an 8-item scale with questions on individual's ability on what, where, how to find and use health information on the internet. The questions responses are on 5-point Likert scale ranging from strongly agree to strongly disagree. The eHEALS has high coefficient alpha 0.88, item-scale correlation range of 0.51 to 0.76 and modest test-retest reliability. Being the pioneer e-HL measure, the eHEALS has been validated in different languages and populations.(104–111) However, the scale was developed among a healthy youth population which may not represent the larger population of unhealthy individuals needing to use eHealth. The authors also noted that developing eHEALS as part of a larger study may have affected the test-retest reliability suggesting consideration for context of use. Still on the context of use, it should be noted that it was developed in the era of Web 1.0 before the widespread of social media, mobile health and other electronic devices.(112) Consequently, it applies mostly to Health 1.0 (information only) applications and not Health 2.0 (interactive applications).(113) The 8-item measure offers a simple and quick way of testing individual's e-HL but may not capture all the complexities therein. Its psychometric quality and unidimensionality have also been questioned.(104,114) Norman agrees that a revision of eHEALS is warranted.(112)

Petric et al., developed an extended version of eHEALS (eHEALS-E) for users of online health communities.(115) eHEALS-E comprises 20-item measure on 5-point Likert scale presented in six dimensions including awareness of information sources, recognizing quality and meaning , understanding information, perceived efficiency, validating information, and being smart on the Net. These six dimensions capture the accessing, understanding, appraising, and applying health information relevant to health definition components of e-HL.(96) Though the eHEALS-E incorporates additional items to understand people's e-HL status, it seems to be limited to the online health community test population used in the development and requires more studies in other populations and settings to confirm its psychometric qualities. It is also limited to the same e-HL definition in eHEALS which does not capture the current social environment of health technology.

Based on the concept of health literacy, trust, action, and behavior, Seckin et al., developed another e-HL measuring tool known as electronic health literacy scale (e-HLS).(116) They captured the individual-health professional's interaction as well as the individual's ability to not just find information but to also be able to assess the quality of information found. The e-HLS is a 19-item scale measured in three dimensions including behavior, communication, and attitude. The responses are rated on a 5-point Likert scale ranging from never or strongly disagree (1) to always or strongly agree (5). They reported a Cronbach's alpha coefficient of 0.93. Apart from the development study, e-HLS has only been used in e-HL evaluation of Chinese patients with stroke with a similar Cronbach's alpha coefficient of 0.91.(117) It therefore needs more widespread usage to confirm its psychometric properties.

Van der Vaart et al., measured e-HL in 31 patients with rheumatic diseases by observing them perform specific online tasks.(118) They assigned 15 patients to Health 1.0 task and 16 patients to Health 2.0 task. All tasks were related to their disease condition. The Health 1.0 assignment was information retrieval only while Health 2.0 assignment included retrieval of information, interpretation, creating and contributing their own content to online platforms. Patients were asked to think aloud as they perform their tasks. The study found that rheumatology patients lack the skills to properly apply Health 1.0 and 2.0 to their advantage. The problems identified were operating the computer and internet browser, Web navigation and orientation, search engine utilization, information relevance and reliability assessment, personal content addition, and protecting privacy.(118) The outcome of this study prompted the development of the Digital Health Literacy Instrument (DHLI) to capture Health 1.0 and 2.0 skills needed to navigate eHealth environment.(119) DHLI implemented the problems discovered in the previous study to arrive at 7 skill categories for e-HL including operational skills (for computer and internet browser use), navigation skills (for Web navigation and orientation), information searching skill (for correct search strategies), evaluating reliability of information in general, determining relevance of information to oneself, adding self-generated content to Web-based apps, and protecting and respecting privacy while using the internet. Three items were developed under each skill including a performance-based item. The result was a 21-item instrument measured on 4-point scale ranging from "very easy" to "very difficult" and from "never" to "often".(119) DHLI was validated among adults ≥ 18 years old who had internet access and were mostly highly educated. It is available in Dutch and English versions. Though DHLI was found to have overall satisfactory psychometrics, it is however, limited by the population used for validation, non-inclusion of mobile health skills, and low internal consistency of the performance-based items. DHLI has been adapted mostly to measuring digital health literacy in the COVID-19 pandemic with validations in difference languages and settings.(120–128)

Paige et al., developed the Transactional eHealth Literacy Instrument (TeHLI)(129) based on the Transactional Model of eHealth Literacy (TMeHL).(130) The TMeHL was designed from the concepts of the Transactional Model of Communication, interpersonal computer-mediated communication, and noise-inducing factors that affect communication. TMeHL views e-HL as being transactional in that the interaction between the user- and task-related factors influences the intrapersonal skillset of e-HL. The user-related factors include personal, relational, knowledgeable, and technological factors. The task-related factors refer to message type, source, channel, and language. The interactions determine how an individual responds to eHealth to achieve desired health outcomes. TMeHL captures the intrapersonal, interpersonal, and eHealth contexts in relation to e-HL. The TeHLI is a 18-item instrument with 4 dimensions including functional (4 items), communicative (5 items), critical (5 items), and translational (4 items). It is rated on a 5-point Likert scale ranging from 1 “strongly disagree” to 5 “strongly agree”. The instrument was validated among patients ≥ 40 years old at risk or having obstructive lung diseases. It was reported to have satisfactory psychometrics. The TeHLI is limited by the development population and cannot generalized across all ages. It also does not reflect actual eHealth tasks performance capabilities. The TeHLI has been validated among cancer caregivers with a proposal of clinical eHealth literacy as the fifth dimension.(131) More studies of the instrument in other disease conditions and population are needed to confirm the psychometrics.

The e-health literacy framework (e-HLF) is another model of e-HL put forward by Norgaard et al.(101) It was developed by systematic inductive methods involving inputs from patients with chronic health conditions, information technology (IT) experts, health professionals, and e-health professionals to capture all the elements that may impact individuals’ decision to use eHealth for their health management. The e-HLF posits e-HL as a function of external observable and internalized traits of individuals and the e-health systems, and the interactions between them. They thus proposed seven dimensions of e-HL including 1. Ability to process information, 2. Engagement in own health, 3. Ability to actively engage with digital services, 4. Feel safe and in control, 5. Motivated to engage with digital services, 6. Access to digital services that work and 7. Digital services that suit individual needs.(Figure 1.1) The first two domains (1 and 2) dependent on the individual's capability, the last two (6 and 7) are dependent on the e-health system, while the three domains in the middle (3,4, and 5) show interaction between the individual and the e-health system. The e-health literacy questionnaire (eHLQ)(132) was designed from the e-HLF. eHLQ is a 35-item questionnaire with seven domains. Each item is rated on a 4-point Likert scale (strongly disagree, disagree, agree, strongly agree). The eHLQ was validated using both classical test theory and item response theory psychometrics, and the domains items were found to have strong composite scale reliability (CSR). The e-health literacy domains variables include 1. Using technology to process health information (5 items, CSR: 0.84), 2. Understanding health concepts and language (5 items, CSR: 0.75), 3. Ability to actively engage with digital services (5items, CSR: 0.86), 4. Feel safe and in control (5 items, CSR: 0.87), 5. Motivated to engage with digital services (5 items, CSR: 0.84), 6. Access to digital service that works (6 items, CSR: 0.77), 7. Digital services that suit individual need (4 items, CSR: 0.85). Each domain score is the average of the individual item scores in the domain. The eHLQ validity evidence in terms of relations to other variables like age, education, and information communication technology use has been studied and found to be satisfactory.(133) It has also been validated in patients with chronic diseases in other languages(134,135) and used to study e-HL in different populations and settings.(136–142) The eHLQ is not disease-specific and does not recall time for the scale items.

There are other models(97,99) of e-HL and measuring instruments available including e-health literacy assessment toolkit (eHLA)(143), revised German version of eHEALS (GR-eHEALS)(144), e-health literacy Web 3.0 (eHLS-Web 3.0)(145), and the diabetes-specific e-HL instrument.(103) Systematic reviews by Lee et al.,(102) and Tavousi et al.,(146) provide overview of the psychometrics of different e-HL measuring scales available as at the year 2021. No tool is perfect and there is no goal standard yet for e-HL measurement now. The e-HLQ was selected for this project because it was developed with inputs from various stakeholders including patients with chronic diseases, IT experts, e-health, and health professionals. The tool items portray individual and systems functionalities, observable and unobservable traits, access to systems, the interactions between the individual and the e-health systems. The robustness of this framework makes it a viable tool to understand why patients with hypertension may or may not be engaging in technologies proven to improve BP control.

1.3.2 Electronic Health Literacy (e-HL) and Blood Pressure Telemonitoring (BPT)

Considering the ever advancing technology types and processes involved in telemonitoring of BP, e-HL is paramount for any patient to benefit from its advantages.(58,147) However, most studies on BPT are focused on its effectiveness in hypertension management. Concurrent exploration of patient's e-HL status as a predictor or mediator in relation to engagement in BPT is limited. Google Scholar® and PubMed® search of any type of article published on BPT and e-HL in any year using the search terms ("blood pressure telemonitoring") AND ("electronic health literacy" OR "ehealth literacy" OR "e-health literacy" OR "digital health literacy" OR "digital literacy") yielded 10 studies focused on BPT.(78,148–156) Out of these 10 articles, only three accounted for the patients' e-HL status.(78,153,156) Hence, the need for this project to fill this important gap in literature.

Having established the importance of studying BPT in the context of e-HL, another unique dimension to our study is the application of mixed-methods approach to fully understand the patient-related factors impacting BPT. The following section provides an explanation of mixed-methods research, different mixed-methods research integration strategies, and the advantages and disadvantages.

1.4 Mixed-methods Research Advantage

Mixed-methods research (MMR) is defined as “an approach to research when both quantitative and qualitative data are collected, analyzed and integrated, and the researcher can therefore draw interpretation based on the combined strengths of both sets of data”.(157) MMR also includes coordinating the research procedures within designs that are based a particular theory or philosophy.(158) The main difference between MMR and combinations of qualitative and quantitative researches lies in the data integration. Integration of data in MMR can occur at various levels of the research including design, methods, and interpretation and reporting.(159)

Generally, the integration strategy to apply in MMR stems from the study purpose and design.(158) When the intention is to explore, expand, diffract, or construct a case, then the integration strategy should be to explain, enhance, initiate, or transfer findings respectively. The accompanying design is usually sequential. If the study’s intent is to construct a case or compare or match the quantitative and qualitative data, the integration strategy could be merging or corroborating (triangulation). This is common with convergent design. However, when any of the aforementioned study intentions are placed within a larger framework, embedding becomes the integration strategy of choice. Pluye et al.,(160) described three types of MMR integration including connection of phases, comparison of results, and assimilation of data based on the principles of complementarity, dialectic tension, and unification respectively. Pluye’s integration types are similar to the types described by Fetters et al.,(159) The next section will briefly describe the integration strategies as reported by Fetters et al.(159)

1.4.1 Integration by design

At the design level, integration can be achieved by designing the study using the basic designs (exploratory-sequential, explanatory-sequential, and convergent) or advanced frameworks (multistage, intervention, case, and participatory studies). Exploratory-sequential design involves the initial collection and analysis of the qualitative data and using the results to decide quantitative data collection. Explanatory-sequential design is basically the opposite of exploratory-sequential design in that the quantitative data is collected and analyzed first. The result is then used to determine the qualitative data collection and analysis. In convergent design, however, both qualitative and quantitative data are collected and analyzed at similar period. This is also called concurrent design and could follow interactive or parallel approach. In convergent-interactive design, repetitive data collection and analysis guides the data collection processes. In convergent-parallel design, the quantitative and qualitative data collection occurs side-by-side and integration is done in the analysis or both data are analyzed separately and then consolidated.

The multistage framework involves using three or more stages of the sequential (exploratory- or explanatory-sequential) designs or two or more stages of the convergent design. The intervention framework is about performing an intervention. Qualitative data are collected to help in the design of the intervention, understand intervention context and explain the outcomes. In case study framework, the focus is on using both quantitative and qualitative data to explain a particular case. The participatory framework as the name suggests, allows the active participation of the target population studied to determine the research process.

1.4.2 Integration by methods

Qualitative and quantitative data integration can happen by methods in four ways namely connecting, building, merging, and embedding.(159) Integration by connecting happens through the sampling frame. For instance, the participants for the qualitative part are drawn from those who participated in the quantitative part of the study. Connecting can happen irrespective of the mixed-methods design applied. Integration by building occurs when the findings from the quantitative data collection determines how the qualitative data will be collected and vice versa. Integration through building usually occur with the sequential design because lessons from one procedure are built into the next procedure. Integration by merging occurs when the quantitative and qualitative data are brought together for analysis and comparison. For a successful merging to occur, both data should have similar items for comparison. Merging can be applied in both sequential and convergent designs. Integration by embedding happens when the quantitative and qualitative data collection and analysis are linked at various points. Embedding could be a mixture of connecting, building, and merging all in one study. Embedding mostly happens with intervention studies.

1.4.3 Integration at interpretation and reporting level

At the interpretation and reporting level, qualitative and quantitative data integration can happen in three ways, namely narrative, data transformation, and joint display.(159) In the narrative integration, the researcher presents the qualitative and quantitative results as one or more descriptions or stories. The narration could follow the weaving, contiguous or staged approach. The weaving approach involves writing both results in a theme-by-theme or concept-by-concept manner. The contiguous approach, the qualitative and quantitative results are presented separately in different parts of one write-up. In staged approach, the data are reported in stages as they become available. This is common in multistage intervention mixed-methods studies. The data transformation integration occurs when the qualitative data is converted to a quantitative form and the transformed qualitative data is then integrated with the untransformed quantitative data and vice versa. In integration by joint display, the researchers use visualization to link the qualitative and quantitative data together and draw a meta-inference from both results. It could be a figurative, tabular, graphical, or matrix representation of both data that provides a better understanding of the mixed-methods results.

1.4.4 Joint Display

Fetters defined a joint display as “a table or figure that can be used for organizing mixed data collection and analysis in a table , matrix, or figure that a) can be used to represent juxtaposed data collection or findings of qualitative and quantitative strands of a project; b) includes or implies specific linkages or areas of commonalities across the qualitative and quantitative strands that can be expressed as constructs or domains, and c) contains an interpretation, often called metainferences, about the meaning of the two types of results when considered together”.(161) This broad definition captures joint display as a tool to depict MMR data integration at the design, method, analysis and interpretation levels. In addition to use of tables and figures, Guetterman et al.,(162) have proposed the extension of the joint display visuals to include graphs, charts, maps, diagrams, visual models, or any other graphical representations. They argued that these additional visuals aid the integration, understanding, and interpretation of MMR.

Creation of joint display starts from the project planning stage (to ensure that similar linkable constructs are being addressed in qualitative and quantitative sections); through data collection stage (to ensure adequate linkable data collection); to the analysis and interpretation stage (identifies linkages in both data and findings and provides a metainference).(161) Different types of joint display have been reported in literature.(163–165) The six major types of joint display include side-by-side, statistics-by-themes or themes-by-statistics, interview questions, participant selection, and instrument developments joint displays.(162) A recent study by Younas and Durante(166) provides a comprehensive guide on how to choose the joint display type best suited for one's project based on the MMR design, purpose and integration methods.

1.4.5 Advantages and disadvantages of using MMR

The quantitative and quantitative research methods can each be used to understand or solve research problems. Each method has its strengths and weaknesses. However, sometimes one method is not enough to provide detailed understanding of the challenge at hand. Hence, MMR becomes necessary. MMR provides opportunity to build on the strengths of both qualitative and quantitative research methods while minimizing their weaknesses. MMR is necessary when there is need to explore an idea before measuring it; provide an explanation for a measured concept; build on an experimental project; describe, compare, or validate results from qualitative and quantitative methods.(158,167,168)

With the advantages of MMR come some challenges of its use. MMR is more time consuming and requires more resources to complete than if only qualitative or quantitative method is used. It also requires that the researcher acquire the necessary skills to conduct an adequate MMR.(158,169,170) Not having the skills and understanding of how and what MMR entails could lead to the three common errors seen in MMR publications including non-specific MMR design followed, lack of systematic integration of data, and lack of rigor.(169,171,172) Rao and Shiyanbola highlighted these challenges, proffered solutions to them and suggested best practices for conducting MMR including choosing a specific MMR design, appropriate integration method and ensuring credibility and validity of the MMR.(171) There is also the challenge of educating other researchers and the public on the value of using MMR.(158)

1.5 Study Objectives

Our *long-term* goal is to improve BP control in hypertensive patients. Our *overall objectiv*e is to understand the factors that impact technology use in remote monitoring of BP. We were poised to conduct this mixed methods study because we have experience using publicly available, nationally representative databases and we have access to patients where the use of technology in telemonitoring of BP has been lower than desired. This was, therefore, a unique opportunity to apply the e-HL framework to this crucial self-management behavior. To attain the overall objective, we propose the following *specific aims*:

1. **Quantify predictors of smartphone and tablet use in achieving health goals among hypertensive respondents using Health Information National Trend Survey (HINTS).** Our research question is "what are the relationships of patients' characteristics with the use of smartphones or tablets to achieve health goals among a nationally representative sample with hypertension".
2. **Determine the facilitators and barriers of technology use experienced by patients in telemonitoring of BP**. Our research question is "what are the facilitators and barriers that affect the use of technology in remote monitoring of BP".
3. **Assess the association of e-health literacy and patients' characteristics with engagement in BP telemonitoring**. Our research question is "what are the relationships between e-HL and patients' characteristics with engagement in remote monitoring of BP".

Our mixed methods analysis will then integrate the findings in aim 2 and across the three aims to elucidate the factors that impact technology use in telemonitoring of BP from patients' perspective.

1.5.1 Rationale for using MMR in this project

In this study, MMR was used because we think that quantitative or qualitative research alone would not be sufficient to explore and explain the nuances involved in patients' experiences with technology and BP telemonitoring. The quantitative survey alone may not truly reflect all the patients' everyday lives experiences with technology. Using the survey and interviewing the patients provides a broader understanding of the research questions. The integration of both methods provides the opportunity to describe, compare and corroborate results from both quantitative and qualitative methods.

A multistage mixed-methods design was used. We first conducted a quantitative survey to describe the relationship patients' characteristics with the use of smartphone or tablet to achieve goals. The results from this first quantitative section were linked to a convergent parallel mixed-methods design seeking to explore and explain facilitators and barriers to remote BP monitoring through "connecting". With the convergent parallel mixed-methods design, data integration occurred at the design, interpretation and reporting levels using side-by-side joint display (merging and comparing) and the results "built" into the third quantitative section. The third quantitative section sought to assess the relationships of e-HL and patient's characteristics with engagement in remote BP monitoring. We then summarized the findings from every section to give our final interpretation on the factors that impact remote monitoring of BP in patients with hypertension from the patients' perspective.

In the following chapters, we present the first quantitative study as already published in the Journal of Medical Internet Research.(70) This is followed by the convergent mixed-methods study as published in Digital Health journal.(173) Then, a manuscript of the third quantitative section. The last chapter provides the discussion and interpretation of all the sections to show what we learnt about patients' experiences in BP telemonitoring and the implications for our health systems and future studies.

1.6 References

1. (WHO) WHO. Hypertension. World Heal Organ [Internet]. 2021;(August). Available from: https://www.who.int/news-room/fact-sheets/detail/hypertension
2. Tsao CW, Aday AW, Almarzooq ZI, Anderson CAM, Arora P, Avery CL, et al. Heart Disease and Stroke Statistics—2023 Update: A Report From the American Heart Association. Circulation. 2023;147(8):e93–621.
3. Guzik A, Bushnell C. Stroke Epidemiology and Risk Factor Management. Contin Lifelong Learn Neurol. 2017;23(1):15–39.
4. Ishii M, Ogawa H, Abe M, Iguchi M, Masunaga N, Unoki T, et al. Relationship of Hypertension and Systolic Blood Pressure With the Risk of Stroke or Bleeding in Patients With Atrial Fibrillation: The Fushimi AF Registry. Am J Hypertens [Internet]. 2017 May 30;30(11):1073–82. Available from: https://dx.doi.org/10.1093/ajh/hpx094
5. Kannan A, Janardhanan R. Hypertension as a Risk Factor for Heart Failure. Curr Hypertens Rep [Internet]. 2014;16(7):447. Available from: https://doi.org/10.1007/s11906-014-0447-7
6. Yandrapalli, Srikanth Nabors C, Goyal A, Aronow WS, Frishman WH. Modifiable Risk Factors in Young Adults With First Myocardial Infarction. J Am Coll Cardiol [Internet]. 2019;73(5):573–84. Available from: https://doi.org/10.1016/j.jacc.2018.10.084
7. Aronow WS. Treatment of systemic hypertension. Am J Cardiovasc Dis [Internet]. 2012;2(3):160–70. Available from: http://www.ncbi.nlm.nih.gov/pubmed/22937486%5Cnhttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC3427981
8. Billups SJ, Saseen JJ, Vande Griend JP, Schilling LM. Blood pressure control rates

measured in specialty vs primary care practices within a large integrated health system. J Clin Hypertens. 2018;20(9):1253–9.

9. Guideline for the pharmacological treatment of hypertension in adults. Geneva: World Health Organization [Internet]. 2021. Available from: https://apps.who.int/iris/bitstream/handle/10665/344424/9789240033986-eng.pdf

10. James PA, Oparil S, Carter BL, Cushman WC, Dennison-Himmelfarb C, Handler J, et al. 2014 Evidence-Based Guideline for the Management of High Blood Pressure in Adults: Report From the Panel Members Appointed to the Eighth Joint National Committee (JNC 8)2014 Guideline for Management of High Blood Pressure2014 Guideline for Management of H. JAMA [Internet]. 2014 Feb 5;311(5):507–20. Available from: https://dx.doi.org/10.1001/jama.2013.284427

11. Lewis CE, Fine LJ, Beddhu S, Chueng AK, Cushman WC, Cutler JA, et al. Final Report of a Trial of Intensive versus Standard Blood-Pressure Control. N Engl J Med. 2021;384(20):1921–30.

12. Jaeger BC, Bress AP, Bundy JD, Cheung AK, Cushman WC, Drawz PE, et al. Longer-Term All-Cause and Cardiovascular Mortality With Intensive Blood Pressure Control: A Secondary Analysis of a Randomized Clinical Trial. JAMA Cardiol [Internet]. 2022;27154:1–9. Available from: http://www.ncbi.nlm.nih.gov/pubmed/36223105

13. Daniel W. Jones, MD; Donald Clark III, MD; Michael E. Hall M. Blood Pressure Control After SPRINT—Back to Reality. JAMA Cardiol. 2022;

14. Pew Research Center. Internet Use Over Time. Pew Res Cent [Internet]. 2021;1–8. Available from: https://www.pewresearch.org/internet/fact-sheet/internet-broadband/

15. Pew Research Center. Mobile Fact Sheet. Paw Res Cent [Internet]. 2021;1–11. Available

from: https://www.pewresearch.org/internet/fact-sheet/mobile/

16. Franklin NC, Lavie CJ, Arena RA. Personal health technology: A new era in cardiovascular disease prevention. Postgrad Med. 2015;127(2):150–8.

17. Schreiweis B, Pobiruchin M, Strotbaum V, Suleder J, Wiesner M, Bergh B. Barriers and facilitators to the implementation of eHealth services: Systematic literature analysis. J Med Internet Res. 2019;21(11):1–12.

18. Vrijens B, Antoniou S, Burnier M, de la Sierra A, Volpe M. Current Situation of Medication Adherence in Hypertension. Front Pharmacol. 2017;8(100):1–8.

19. Hameed MA, Dasgupta I. Medication adherence and treatment-resistant hypertension: a review. Drugs Context. 2019;8(212560):1–11.

20. Yang Q, Chang A, Ritchey MD, Loustalot F. Antihypertensive Medication Adherence and Risk of Cardiovascular Disease Among Older Adults: A Population-Based Cohort Study. J Am Heart Assoc. 2017;6(6).

21. Xu T, Yu X, Ou S, Liu X, Yuan J, Tan X, et al. Adherence to Antihypertensive Medications and Stroke Risk: A Dose-Response Meta-Analysis. J Am Heart Assoc. 2017;6(7).

22. Corrao G, Zambon A, Parodi A, Merlino L, Mancia G. Incidence of Cardiovascular Events in Italian Patients With Early Discontinuations of Antihypertensive, Lipid-Lowering, and Antidiabetic treatments. Am J Hypertens [Internet]. 2012 May 1;25(5):549–55. Available from: https://dx.doi.org/10.1038/ajh.2011.261

23. Degli Esposti L, Saragoni S, Benemei S, Batacchi P, Geppetti P, di Bari M, et al. Adherence to antihypertensive medications and health outcomes among newly treated hypertensive patients. Clin Outcomes Res. 2011;3(1):47–54.

24. Izeogu C, Kalinowski J, Schoenthaler A. Strategies to Improve Adherence to Anti-Hypertensive Medications: a Narrative Review. Curr Hypertens Rep. 2020;22(12).

25. Choudhry NK, Kronish IM, Vongpatanasin W, Ferdinand KC, Pavlik VN, Egan BM, et al. Medication adherence and blood pressure control: A scientific statement from the american heart association. Hypertension. 2022;79(1):E1–14.

26. Lam AY, Nguyen JK, Parks JJ, Morisky DE, Berry DL, Wolpin SE. Addressing low health literacy with "Talking Pill Bottles": A pilot study in a community pharmacy setting. J Am Pharm Assoc [Internet]. 2017;57(1):20-29.e3. Available from: http://dx.doi.org/10.1016/j.japh.2016.07.003

27. Mehta SJ, Volpp KG, Troxel AB, Day SC, Lim R, Marcus N, et al. Electronic Pill Bottles or Bidirectional Text Messaging to Improve Hypertension Medication Adherence (Way 2 Text): a Randomized Clinical Trial. J Gen Intern Med. 2019;34(11):2397–404.

28. Vieira LB, Reis AMM, Ramos C de Á, Reis TM Dos, Cassiani SH de B. The use of an electronic medication organizer device with alarm to improve medication adherence of older adults with hypertension. Einstein (Sao Paulo). 2021;19:eAO6011.

29. Checchi KD, Huybrechts KF, Avorn J, Kesselheim AS. Electronic medication packaging devices and medication adherence: A systematic review. JAMA - J Am Med Assoc. 2014;312(12):1237–47.

30. Yeung DL, Alvarez KS, Quinones ME, Clark CA, Oliver GH, Alvarez CA, et al. Low–health literacy flashcards & mobile video reinforcement to improve medication adherence in patients on oral diabetes, heart failure, and hypertension medications. J Am Pharm Assoc [Internet]. 2017;57(1):30–7. Available from: http://dx.doi.org/10.1016/j.japh.2016.08.012

31. Thangada ND, Garg N, Pandey A, Kumar N. The Emerging Role of Mobile-Health Applications in the Management of Hypertension. Curr Cardiol Rep [Internet]. 2018;20(9):78. Available from: https://doi.org/10.1007/s11886-018-1022-7

32. Bosworth HB, DuBard CA, Ruppenkamp J, Trygstad T, Hewson DL, Jackson GL. Evaluation of a self-management implementation intervention to improve hypertension control among patients in Medicaid. Transl Behav Med. 2011;1(1):191–9.

33. Abughosh SM, Wang X, Serna O, Henges C, Masilamani S, Essien EJ, et al. A pharmacist telephone intervention to identify adherence barriers and improve adherence among nonadherent patients with comorbid hypertension and diabetes in a medicare advantage plan. J Manag Care Spec Pharm. 2016;22(1):63–72.

34. Abughosh S, Wang X, Serna O, Esse T, Mann A, Masilamani S, et al. A motivational interviewing intervention by pharmacy students to improve medication adherence. J Manag Care Spec Pharm. 2017;23(5):549–60.

35. Varleta P, Acevedo M, Akel C, Salinas C, Navarrete C, García A, et al. Mobile phone text messaging improves antihypertensive drug adherence in the community. J Clin Hypertens [Internet]. 2017 Dec 1;19(12):1276–84. Available from: https://doi.org/10.1111/jch.13098

36. Buis L, Hirzel L, Dawood RM, Dawood KL, Nichols LP, Artinian NT, et al. Text Messaging to Improve Hypertension Medication Adherence in African Americans From Primary Care and Emergency Department Settings: Results From Two Randomized Feasibility Studies. JMIR mHealth uHealth [Internet]. 2017 Feb 1;5(2):e9–e9. Available from: https://pubmed.ncbi.nlm.nih.gov/28148474

37. Thakkar J, Kurup R, Laba TL, Santo K, Thiagalingam A, Rodgers A, et al. Mobile telephone text messaging for medication adherence in chronic disease a meta-analysis.

JAMA Intern Med. 2016;176(3):340–9.

38. Tam HL, Wong EML, Cheung K, Chung SF. Effectiveness of text messaging interventions on blood pressure control among patients with hypertension: Systematic review of randomized controlled trials. JMIR mHealth uHealth. 2021;9(9).

39. Morawski K, Ghazinouri R, Krumme A, Lauffenburger JC, Lu Z, Durfee E, et al. Association of a Smartphone Application With Medication Adherence and Blood Pressure Control: The MedISAFE-BP Randomized Clinical TrialSmartphone App and Blood Pressure Medication AdherenceSmartphone App and Blood Pressure Medication Adherence. JAMA Intern Med [Internet]. 2018 Jun 1;178(6):802–9. Available from: https://doi.org/10.1001/jamainternmed.2018.0447

40. Ng R, Carter SR, El-Den S. The impact of mobile applications on medication adherence: A systematic review. Transl Behav Med. 2020;10(6):1419–35.

41. Chun-Yun Kang G. Technology-based interventions to improve adherence to antihypertensive medications – An evidence-based review. Digit Heal. 2022;8:1–16.

42. Shimbo D, Artinian NT, Basile JN, Krakoff LR, Margolis KL, Rakotz MK, et al. Self-measured blood pressure monitoring at home: A joint policy statement from the american heart association and american medical association. Circulation. 2020;142(4):E42–63.

43. Muntner P, Shimbo D, Carey RM, Charleston JB, Gaillard T, Misra S, et al. Measurement of blood pressure in humans: A scientific statement from the american heart association. Hypertension. 2019;73(5):E35–66.

44. Center for Disease Control (CDC). Measure Your Blood Pressure: How can I measure my blood pressure at home? 2021;1–6. Available from: https://www.cdc.gov/bloodpressure/measure.htm

45. Sheppard JP, Schwartz CL, Tucker KL, McManus RJ. Modern Management and Diagnosis of Hypertension in the United Kingdom: Home Care and Self-care. Ann Glob Heal [Internet]. 2016;82(2):274–87. Available from: http://dx.doi.org/10.1016/j.aogh.2016.02.005

46. Fletcher BR, Hartmann-Boyce J, Hinton L, McManus RJ. The Effect of Self-Monitoring of Blood Pressure on Medication Adherence and Lifestyle Factors: A Systematic Review and Meta-Analysis. Am J Hypertens [Internet]. 2015 Feb 26;28(10):1209–21. Available from: https://dx.doi.org/10.1093/ajh/hpv008

47. Uhlig K, Patel K, Ip S, Kitsios GD, Balk EM. Self-Measured Blood Pressure Monitoring in the Management of Hypertension: A Systematic Review and Meta-analysis. Ann Intern Med [Internet]. 2013 Aug 6;159(3):185–94. Available from: https://dx.doi.org/10.7326/0003-4819-159-3-201308060-00008

48. Sheppard JP, Tucker KL, Davison WJ, Stevens R, Aekplakorn W, Bosworth HB, et al. Self-monitoring of blood pressure in patients with hypertension related multi-morbidity: Systematic review and individual patient data meta-analysis. Am J Hypertens [Internet]. 2019;1–9. Available from: http://www.ncbi.nlm.nih.gov/pubmed/31730171

49. Tucker KL, Sheppard JP, Stevens R, Bosworth HB, Bove A, Bray EP, et al. Self-monitoring of blood pressure in hypertension: A systematic review and individual patient data meta-analysis. PLoS Med. 2017;14(9):1–29.

50. U.S. Department of Health and Human Services. The Surgeon General’s Call to Action to Control Hypertension. Washington, DC: U.S. Department of Health and Human Services, Office of the Surgeon General; 2020. 2020;

51. Telehealth is here to stay. Nat Med [Internet]. 2021;27(7):1121. Available from:

https://doi.org/10.1038/s41591-021-01447-x

52. Blandford A, Wesson J, Amalberti R, AlHazme R, Allwihan R. Opportunities and challenges for telehealth within, and beyond, a pandemic. Lancet Glob Heal. 2020;8(11):e1364–5.

53. Omboni S, McManus RJ, Bosworth HB, Chappell LC, Green BB, Kario K, et al. Evidence and recommendations on the use of telemedicine for the management of arterial hypertension: An international expert position paper. Hypertension. 2020;76(5):1368–83.

54. What is Telehealth ? NEJM Catal Innov Care Deliv [Internet]. 2018;8. Available from: https://catalyst.nejm.org/doi/full/10.1056/CAT.18.0268

55. Meystre S. The Current State of Telemonitoring: A Comment on the Literature. Telemed e-Health [Internet]. 2005 Feb 1;11(1):63–9. Available from: https://doi.org/10.1089/tmj.2005.11.63

56. De Farias FACD, Dagostini CM, Bicca YDA, Falavigna VF, Falavigna A. Remote patient monitoring: A systematic review. Telemed e-Health. 2020;26(5):576–83.

57. Paré G, Jaana M, Sicotte C. Systematic Review of Home Telemonitoring for Chronic Diseases: The Evidence Base. J Am Med Informatics Assoc. 2007;14(3):269–77.

58. Parati G, Dolan E, McManus RJ, Omboni S. Home blood pressure telemonitoring in the 21st century. J Clin Hypertens. 2018;20(7):1128–32.

59. Pandor A, Thokala P, Gomersall T, Baalbaki H, Stevens JW, Wang J, et al. Home telemonitoring or structured telephone support programmes after recent discharge in patients with heart failure: systematic review and economic evaluation. Health Technol Assess. 2013;17(32).

60. Logan AG, Jane Irvine M, McIsaac WJ, Tisler A, Rossos PG, Easty A, et al. Effect of

home blood pressure telemonitoring with self-care support on uncontrolled systolic hypertension in diabetics. Hypertension. 2012;60(1):51–7.

61. Wang JB, Cadmus-Bertram LA, Natarajan L, White MM, Madanat H, Nichols JF, et al. Wearable Sensor/Device (Fitbit One) and SMS Text-Messaging Prompts to Increase Physical Activity in Overweight and Obese Adults: A Randomized Controlled Trial. Telemed e-Health. 2015;21(10):782–92.

62. Telehealth and remote patient monitoring [Internet]. 2022. Available from: https://telehealth.hhs.gov/providers/preparing-patients-for-telehealth/telehealth-and-remote-patient-monitoring/

63. Noah B, Keller MS, Mosadeghi S, Stein L, Johl S, Delshad S, et al. Impact of remote patient monitoring on clinical outcomes: an updated meta-analysis of randomized controlled trials. npj Digit Med [Internet]. 2018;1(1):1–12. Available from: http://dx.doi.org/10.1038/s41746-017-0002-4

64. Taylor ML, Thomas EE, Snoswell CL, Smith AC, Caffery LJ. Does remote patient monitoring reduce acute care use? A systematic review. BMJ Open. 2021;11(3).

65. Omboni S, Gazzola T, Carabelli G, Parati G. Clinical usefulness and cost effectiveness of home blood pressure telemonitoring:Meta-analysis of randomized controlled studies. J Hypertens. 2013;31(3):455–68.

66. Park SH, Shin JH, Park J, Choi WS. An updated meta-analysis of remote blood pressure monitoring in urban-dwelling patients with hypertension. Int J Environ Res Public Health. 2021;18(20).

67. Brahmbhatt DH, Cowie MR. Remote Management of Heart Failure: An Overview of Telemonitoring Technologies. Card Fail Rev. 2019;5(2):86–92.

68. Thomas EE, Taylor ML, Banbury A, Snoswell CL, Haydon HM, Gallegos Rejas VM, et al. Factors influencing the effectiveness of remote patient monitoring interventions: A realist review. BMJ Open. 2021;11(8).

69. Walker RC, Tong A, Howard K, Palmer SC. Patient expectations and experiences of remote monitoring for chronic diseases: Systematic review and thematic synthesis of qualitative studies. Int J Med Inform [Internet]. 2019;124(January):78–85. Available from: https://doi.org/10.1016/j.ijmedinf.2019.01.013

70. Eze CE, West BT, Dorsch MP, Coe AB, Lester CA, Buis LR, et al. Predictors of Smartphone and Tablet Use among Patients with Hypertension: Secondary Analysis of Health Information National Trends Survey Data. J Med Internet Res. 2022;24(1):1–23.

71. Grant S, Hodgkinson J, Schwartz C, Bradburn P, Franssen M, Hobbs FDR, et al. Using mHealth for the management of hypertension in UK primary care: An embedded qualitative study of the TASMINH4 randomised controlled trial. Br J Gen Pract. 2019;69(686):E612–20.

72. Palacholla RS, Fischer N, Coleman A, Agboola S, Kirley K, Felsted J, et al. Provider- And patient-related barriers to and facilitators of digital health technology adoption for hypertension management: Scoping review. J Med Internet Res. 2019;21(3):1–12.

73. Mileski M, Kruse CS, Catalani J, Haderer T. Adopting Telemedicine for the Self-Management of Hypertension: Systematic Review. JMIR Med Informatics. 2017;5(4):e41.

74. Chirra M, Marsili L, Wattley L, Sokol LL, Keeling E, Maule S, et al. Telemedicine in Neurological Disorders: Opportunities and Challenges. Telemed e-Health. 2019;25(7):541–50.

75. Hanley J, Ure J, Pagliari C, Sheikh A, McKinstry B. Experiences of patients and

professionals participating in the HITS home blood pressure telemonitoring trial: A qualitative study. BMJ Open. 2013;3(5):1–10.

76. Padwal R, Wood PW. Digital Health Approaches for the Assessment and Optimisation of Hypertension Care Provision. Can J Cardiol [Internet]. 2021;37(5):711–21. Available from: https://doi.org/10.1016/j.cjca.2020.12.009

77. Abdullah A, Liew SM, Hanafi NS, Ng CJ, Lai PSM, Chia YC, et al. What influences patients' acceptance of a blood pressure telemonitoring service in primary care? A qualitative study. Patient Prefer Adherence [Internet]. 2016 Feb 3;10:99+. Available from: http://link.galegroup.com/apps/doc/A506649874/HRCA?u=umuser&sid=HRCA&xid=4b40c383

78. Sin DYE, Guo X, Yong DWW, Qiu TY, Moey PKS, Falk MR, et al. Assessment of willingness to Telemonitoring interventions in patients with type 2 diabetes and/or hypertension in the public primary healthcare setting. BMC Med Inform Decis Mak. 2020;20(1):1–11.

79. Ware P, Shah A, Ross HJ, Logan AG, Segal P, Cafazzo JA, et al. Challenges of Telemonitoring Programs for Complex Chronic Conditions: Randomized Controlled Trial with an Embedded Qualitative Study. J Med Internet Res. 2022;24(1):1–16.

80. Foster M V., Sethares KA. Facilitators and barriers to the adoption of telehealth in older adults: An integrative review. CIN - Comput Informatics Nurs. 2014;32(11):523–33.

81. Koopman RJ, Wakefield BJ, Johanning JL, Keplinger LE, Kruse RL, Bomar M, et al. Implementing home blood glucose and blood pressure telemonitoring in primary care practices for patients with diabetes: Lessons learned. Telemed e-Health. 2014;20(3):253–60.

82. Citoni B, Figliuzzi I, Presta V, Volpe M, Tocci G. Home Blood Pressure and Telemedicine: A Modern Approach for Managing Hypertension During and After COVID-19 Pandemic. High Blood Press Cardiovasc Prev [Internet]. 2022;29(1):1–14. Available from: https://doi.org/10.1007/s40292-021-00492-4

83. Wood PW, Boulanger P, Padwal RS. Home Blood Pressure Telemonitoring: Rationale for Use, Required Elements, and Barriers to Implementation in Canada. Can J Cardiol [Internet]. 2017;33(5):619–25. Available from: http://dx.doi.org/10.1016/j.cjca.2016.12.018

84. Baratta J, Brown-Johnson C, Safaeinili N, Rosas LG, Palaniappan L, Winget M, et al. Patient and Health Professional Perceptions of Telemonitoring for Hypertension Management: Qualitative Study. JMIR Form Res. 2022;6(6).

85. Aquino M, Griffith J, Vattaparambil T, Munce S, Hladunewich M, Seto E. Patients' and Providers' Perspectives on and Needs of Telemonitoring to Support Clinical Management and Self-care of People at High Risk for Preeclampsia: Qualitative Study. JMIR Hum Factors. 2022;9(1):1–9.

86. Davis FD. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q Manag Inf Syst. 1989;13(3):319–39.

87. Portz JD, Bayliss EA, Bull S, Boxer RS, Bekelman DB, Gleason K, et al. Using the Technology Acceptance Model to Explore User Experience, Intent to Use, and Use Behavior of a Patient Portal Among Older Adults With Multiple Chronic Conditions: Descriptive Qualitative Study. J Med Internet Res [Internet]. 2019;21(4):e11604. Available from: https://www.jmir.org/2019/4/e11604/

88. Dou K, Yu P, Deng N, Liu F, Guan Y, Li Z, et al. Patients' Acceptance of Smartphone

Health Technology for Chronic Disease Management: A Theoretical Model and Empirical Test. JMIR mHealth uHealth [Internet]. 2017;5(12):e177. Available from: https://mhealth.jmir.org/2017/12/e177/

89. Lai P. the Literature Review of Technology Adoption Models and Theories for the Novelty Technology. J Inf Syst Technol Manag. 2017;14(1):21–38.

90. Yiğitalp G, Bayram Değer V, Çifçi S. Health literacy, health perception and related factors among different ethnic groups: a cross-sectional study in southeastern Turkey. BMC Public Health. 2021;21(1):1–10.

91. Paige SR, Krieger JL, Stellefson ML. The Influence of eHealth Literacy on Perceived Trust in Online Health Communication Channels and Sources. J Health Commun. 2017;22(1):53–65.

92. Johnco C, Rapee RM. Depression literacy and stigma influence how parents perceive and respond to adolescent depressive symptoms. J Affect Disord [Internet]. 2018;241(June):599–607. Available from: https://doi.org/10.1016/j.jad.2018.08.062

93. Eysenbach G. What is e-health? J Med Internet Res. 2001;3(2):1–5.

94. Oh H, Rizo C, Enkin M, Jadad A. What is eHealth (3): A systematic review of published definitions. J Med Internet Res. 2005;7(1):1–12.

95. World Health Organization. eHealth. :2–4. Available from: https://www.emro.who.int/health-topics/ehealth/ 1/3

96. Norman CD, Skinner HA. eHealth literacy: Essential skills for consumer health in a networked world. J Med Internet Res. 2006;8(2):1–17.

97. Robert Bautista J. From solving a health problem to achieving quality of life: redefining eHealth literacy. J Lit Technol [Internet]. 2015;16(2):33–54. Available from:

http://www.literacyandtechnology.org/uploads/1/3/6/8/136889/jlt_v16_2_bautista.pdf

98. Griebel L, Enwald H, Gilstad H, Pohl A, Moreland J, Sedlmayr M. eHealth Literacy Research – Quo vadis ? :1–25.

99. Gilstad H. Toward a comprehensive model of eHealth literacy. CEUR Workshop Proc [Internet]. 2014;1251(Pahi):63–72. Available from: http://ceur-ws.org/Vol-1251/paper7.pdf

100. Norman CD, Skinner HA. eHEALS: The eHealth literacy scale. J Med Internet Res. 2006;8(4):1–12.

101. Norgaard O, Furstrand D, Klokker L, Karnoe A, Batterham R, Kayser L, et al. Knowledge Management & E-Learning The e-health literacy framework: A conceptual framework for characterizing e-health users and their interaction with e- health systems. Knowl Manag E-Learning. 2015;7(74):522–40.

102. Lee J, Lee EH, Chae D. eHealth literacy instruments: Systematic review of measurement properties. J Med Internet Res. 2021;23(11):1–27.

103. Lee EH, Lee YW, Lee KW, Kim HJ, Hong S, Kim SH, et al. Development and psychometric evaluation of a new brief scale to measure eHealth literacy in people with type 2 diabetes. BMC Nurs. 2022;21(1):1–13.

104. Van Der Vaart R, Van Deursen AJ, Drossaert CHC, Taal E, Van Dijk JA, Van De Laar MA. Does the eHealth literacy scale (eHEALS) measure what it intends to measure? Validation of a Dutch version of the eHEALS in two adult populations. J Med Internet Res. 2011;13(4):1–17.

105. Chung SY, Park BK, Nahm ES. The Korean eHealth literacy scale (K-eHEALS): Reliability and validity testing in younger adults recruited online. J Med Internet Res.

2018;20(4):1–17.

106. Brørs G, Wentzel-Larsen T, Dalen H, Hansen TB, Norman CD, Wahl A, et al. Psychometric properties of the norwegian version of the electronic health literacy scale (eheals) among patients after percutaneous coronary intervention: Cross-sectional validation study. J Med Internet Res. 2020;22(7):1–25.

107. Wångdahl J, Jaensson M, Dahlberg K, Nilsson U. The swedish version of the electronic health literacy scale: Prospective psychometric evaluation study including thresholds levels. JMIR mHealth uHealth. 2020;8(2):1–20.

108. Xu RH, Zhou L, Lu SY, Wong EL, Chang J, Wang D. Psychometric validation and cultural adaptation of the simplified Chinese eHealth literacy scale: Cross-sectional study. J Med Internet Res. 2020;22(12):1–25.

109. Rathnayake S, Liyanage IP. Cross-cultural adaptation and psychometric properties of the Sinhala version of electronic health literacy scale: A cross-sectional validation study. PLoS One [Internet]. 2022;17(4 April):1–14. Available from: http://dx.doi.org/10.1371/journal.pone.0266515

110. Chaniaud N, Sagnier C, Loup-Escande E. Translation and Validation Study of the French Version of the eHealth Literacy Scale: Web-Based Survey on a Student Population. JMIR Form Res. 2022;6(8):1–12.

111. Baek JJH, Soares GH, Rosa GC da, Mialhe FL, Biazevic MGH, Michel-Crosato E. Network analysis and psychometric properties of the Brazilian version of the eHealth Literacy Scale in a dental clinic setting. Int J Med Inform [Internet]. 2021;153. Available from: https://doi.org/10.1016/j.ijmedinf.2021.104532

112. Norman C. eHealth literacy 2.0: problems and opportunities with an evolving concept. J

Med Internet Res. 2011;13(4):1–6.

113. Eysenbach G. Medicine 2.0: Social networking, collaboration, participation, apomediation, and openness. J Med Internet Res. 2008;10(3):1–13.

114. Soellner R, Huber S, Reder M. The concept of ehealth literacy and its measurement: German translation of the eHEALS. J Media Psychol. 2014;26(1):29–38.

115. Petri G, Atanasova S, Kamin T. Ill literates or illiterates? investigating the ehealth literacy of users of online health communities. J Med Internet Res. 2017;19(10):1–16.

116. Seçkin G, Yeatts D, Hughes S, Hudson C, Bell V. Being an Informed Consumer of Health Information and Assessment of Electronic Health Literacy in a National Sample of Internet Users: Validity and Reliability of the e-HLS Instrument. J Med Internet Res [Internet]. 2016 Jul 11;18(7):e161. Available from: http://www.jmir.org/2016/7/e161/

117. He Y, Guo L, Zauszniewski JA, Wei M, Zhang G, Lei X, et al. A reliability and validity study of the electronic health literacy scale among stroke patients in China. Top Stroke Rehabil. 2021;

118. Van Der Vaart R, Drossaert CHC, De Heus M, Taal E, Van De Laar MAFJ. Measuring actual ehealth literacy among patients with rheumatic diseases: A qualitative analysis of problems encountered using health 1.0 and health 2.0 applications. J Med Internet Res. 2013;15(2).

119. Van Der Vaart R, Drossaert C. Development of the digital health literacy instrument: Measuring a broad spectrum of health 1.0 and health 2.0 skills. J Med Internet Res. 2017;19(1):1–13.

120. Dadaczynski K, Okan O, Messer M, Leung AYM, Rosário R, Darlington E, et al. Digital Health Literacy and Web-Based Information-Seeking Behaviors of University Students in

Germany during the COVID-19 Pandemic: Cross-sectional Survey Study. J Med Internet Res. 2021;23(1):1–17.

121. Park E, Kwon M. Testing the digital health literacy instrument for adolescents: Cognitive interviews. J Med Internet Res. 2021;23(3).

122. Martins S, Augusto C, Martins MRO, José Silva M, Okan O, Dadaczynski K, et al. Adaptation and validation of the Digital Health Literacy Instrument for Portuguese university students. Heal Promot J Aust. 2022;33(S1):390–8.

123. Agormedah EK, Quansah F, Ankomah F, Hagan JE, Srem-Sai M, Abieraba RSK, et al. Assessing the validity of digital health literacy instrument for secondary school students in Ghana: The polychoric factor analytic approach. Front Digit Heal. 2022;4(September):1–12.

124. Rivadeneira MF, Miranda-Velasco MJ, Arroyo H V., Caicedo-Gallardo JD, Salvador-Pinos C. Digital Health Literacy Related to COVID-19: Validation and Implementation of a Questionnaire in Hispanic University Students. Int J Environ Res Public Health. 2022;19(7).

125. Lorini C, Velasco V, Bonaccorsi G, Dadaczynski K, Okan O, Zanobini P, et al. Validation of the COVID-19 Digital Health Literacy Instrument in the Italian Language: A Cross-Sectional Study of Italian University Students. Int J Environ Res Public Health. 2022;19(10).

126. Kim H, Yang E, Ryu H, Kim HJ, Jang SJ, Chang SJ. Psychometric comparisons of measures of eHealth literacy using a sample of Korean older adults. Int J Older People Nurs. 2021;16(3):1–10.

127. Frings D, Sykes S, Ojo A, Rowlands G, Trasolini A, Dadaczynski K, et al. Differences in

digital health literacy and future anxiety between health care and other university students in England during the COVID-19 pandemic. BMC Public Health [Internet]. 2022;22(1):1–9. Available from: https://doi.org/10.1186/s12889-022-13087-y

128. Vitolo M, Ziveri V, Gozzi G, Busi C, Imberti JF, Bonini N, et al. DIGItal Health Literacy after COVID-19 Outbreak among Frail and Non-Frail Cardiology Patients : The DIGI-COVID Study. J Pers Med. 2022;13(1):36675760.

129. Paige SR, Stellefson M, Krieger JL, Miller MD, Cheong J, Anderson-Lewis C. Transactional eHealth Literacy: Developing and Testing a Multi-Dimensional Instrument. J Health Commun. 2019;24(10):737–48.

130. Paige SR, Stellefson M, Krieger JL, Anderson-Lewis C, Cheong JW, Stopka C. Proposing a transactional model of eHealth literacy: Concept analysis. J Med Internet Res. 2018;20(10).

131. Vasquez TS, Bylund CL, Fisher CL, Paige SR. Validation of the transactional eHealth literacy instrument with cancer caregivers. PEC Innov [Internet]. 2022;1(August):100075. Available from: https://doi.org/10.1016/j.pecinn.2022.100075

132. Kayser L, Karnoe A, Furstrand D, Batterham R, Christensen KB, Elsworth G, et al. A multidimensional tool based on the eHealth Literacy Framework: Development and initial validity testing of the eHealth Literacy Questionnaire (eHLQ). J Med Internet Res. 2018;20(2):1–10.

133. Cheng C, Elsworth G, Osborne RH. Validity evidence based on relations to other variables of the eHealth literacy questionnaire (eHLQ): Bayesian approach to test for known-groups validity. J Med Internet Res. 2021;23(10):1–29.

134. Chen YC, Cheng C, Osborne RH, Kayser L, Liu CY, Chang LC. Validity Testing and

Cultural Adaptation of the eHealth Literacy Questionnaire (eHLQ) Among People With Chronic Diseases in Taiwan: Mixed Methods Study. J Med Internet Res. 2022;24(1):1–22.

135. Cheng C, Elsworth GR, Osborne RH. Validity Evidence of the eHealth Literacy Questionnaire (eHLQ) Part 2: Mixed Methods Approach to Evaluate Test Content, Response Process, and Internal Structure in the Australian Community Health Setting. J Med Internet Res. 2022;24(3):1–17.

136. Holt KA, Karnoe A, Overgaard D, Nielsen SE, Kayser L, Røder ME, et al. Differences in the level of electronic health literacy between users and nonusers of digital health services: An exploratory survey of a group of medical outpatients. J Med Internet Res. 2019;21(4).

137. Holt KA, Overgaard D, Engel LV, Kayser L. Health literacy, digital literacy and eHealth literacy in Danish nursing students at entry and graduate level: A cross sectional study. BMC Nurs. 2020;19(1):1–12.

138. Terp R, Kayser L, Lindhardt T. Older patients⇔ competence, preferences, and attitudes toward digital technology use: Explorative study. JMIR Hum Factors. 2021;8(2):1–24.

139. Foley K, Freeman T, Ward P, Lawler A, Osborne R, Fisher M. Exploring access to, use of and benefits from population-oriented digital health services in Australia. Health Promot Int. 2021;36(4):1105–15.

140. Spindler H, Dyrvig AK, Schacksen CS, Anthonimuthu D, Frost L, Gade JD, et al. Increased motivation for and use of digital services in heart failure patients participating in a telerehabilitation program: a randomized controlled trial. mHealth. 2022;8(June).

141. Mather CA, Cheng C, Douglas T, Elsworth G, Osborne R. eHealth Literacy of Australian Undergraduate Health Profession Students: A Descriptive Study. Int J Environ Res Public

Health. 2022;19(17).

142. García-García D, Ajejas Bazán MJ, Pérez-Rivas FJ. Factors Influencing eHealth Literacy among Spanish Primary Healthcare Users: Cross-Sectional Study. Int J Environ Res Public Health. 2022;19(23).

143. Karnoe A, Furstrand D, Christensen KB, Norgaard O, Kayser L. Assessing competencies needed to engage with digital health services: Development of the eHealth literacy assessment toolkit. J Med Internet Res. 2018;20(5):1–25.

144. Marsall M, Engelmann G, Skoda EM, Teufel M, Bäuerle A. Measuring Electronic Health Literacy: Development, Validation, and Test of Measurement Invariance of a Revised German Version of the eHealth Literacy Scale. J Med Internet Res. 2022;24(2):1–26.

145. Liu HX, Chow BC, Liang W, Hassel H, Huang YJW. Measuring a broad spectrum of ehealth skills in the web 3.0 context using an eHealth literacy scale: Development and validation study. J Med Internet Res. 2021;23(9):1–31.

146. Tavousi M, Mohammadi S, Sadighi J, Zarei F, Kermani RM, Rostami R, et al. Measuring health literacy: A systematic review and bibliometric analysis of instruments from 1993 to 2021 [Internet]. Vol. 17, PLoS ONE. 2022. 1–47 p. Available from: http://dx.doi.org/10.1371/journal.pone.0271524

147. Omboni S, Panzeri E, Campolo L. E-Health in Hypertension Management: an Insight into the Current and Future Role of Blood Pressure Telemonitoring. Curr Hypertens Rep. 2020;22(6).

148. Magid DJ, Olson KL, Billups SJ, Wagner NM, Lyons EE, Kroner BA. A pharmacist-led, American heart association Heart360 web-enabled home blood pressure monitoring program. Circ Cardiovasc Qual Outcomes. 2013;6(2):157–63.

149. Thomas KL, Shah BR, Elliot-Bynum S, Thomas KD, Damon K, LaPointe NMA, et al. Check it, change it: A community-based, multifaceted intervention to improve blood pressure control. Circ Cardiovasc Qual Outcomes. 2014;7(6):828–34.

150. Salisbury C, O'Cathain A, Thomas C, Edwards L, Gaunt D, Dixon P, et al. Telehealth for patients at high risk of cardiovascular disease: Pragmatic randomised controlled trial. BMJ. 2016;353.

151. Milani R V., Lavie CJ, Bober RM, Milani AR, Ventura HO. Improving Hypertension Control and Patient Engagement Using Digital Tools. Am J Med [Internet]. 2017;130(1):14–20. Available from: http://dx.doi.org/10.1016/j.amjmed.2016.07.029

152. Ionov M V., Zhukova O V., Yudina YS, Avdonina NG, Emelyanov I V., Kurapeev DI, et al. Value-based approach to blood pressure telemonitoring and remote counseling in hypertensive patients. Blood Press [Internet]. 2021;30(1):20–30. Available from: https://doi.org/10.1080/08037051.2020.1813015

153. Kalańska-Łukasik B, Gładyś A, Jadczyk T, Gruz-Kwapisz M, Wojakowski W, Kowalska M. Readiness for Telemedical Services in Patients With Cardiovascular Diseases: Cross-sectional Study. JMIR Form Res. 2022;6(10):1–9.

154. Teo SH, Chew EAL, Ng DWL, Tang WE, Koh GCH, Teo VHY. Implementation and use of technology-enabled blood pressure monitoring and teleconsultation in Singapore's primary care: a qualitative evaluation using the socio-technical systems approach. BMC Prim Care [Internet]. 2023;24(1):1–15. Available from: https://doi.org/10.1186/s12875-023-02014-8

155. Blood AJ, Cannon CP, Gordon WJ, Mailly C, Maclean T, Subramaniam S, et al. Results of a Remotely Delivered Hypertension and Lipid Program in More Than 10000 Patients

Across a Diverse Health Care Network. JAMA Cardiol. 2023;8(1):12–21.

156. Wang S, Leung M, Leung SY, Han J, Leung W, Hui E, et al. Safety, Feasibility, and Acceptability of Telemedicine for Hypertension in Primary Care: A Proof-of-concept and Pilot Randomized Controlled Trial (SATE-HT). J Med Syst. 2023;47(1).

157. Moseholm E, Rydahl-Hansen S, Lindhardt B, Fetters MD. Health-related quality of life in patients with serious non-specific symptoms undergoing evaluation for possible cancer and their experience during the process: a mixed methods study. Qual Life Res. 2017;26(4):993–1006.

158. Creswell JW, Clark VLP. Designing and Conducting Mixed Methods Research Third Edition. 3rd ed. Sage Publications. SAGE, Thousand Oaks, CA; 2018.

159. Fetters MD, Curry LA, Creswell JW. Achieving integration in mixed methods designs - Principles and practices. Health Serv Res. 2013;48(6 PART2):2134–56.

160. Pluye P, Bengoechea EG, Granikov V, Kaur N, Tang DL. A World of Possibilities in Mixed Methods: Review of the Combinations of Strategies Used to Integrate Qualitative and Quantitative Phases, Results and Data. Int J Mult Res Approaches. 2018;10(1):41–56.

161. Fetters MD. Developing a Joint Display. In: The mixed methods research workbook: Activities for designing, implementing, and publishing projects. Sage Publications; 2020.

162. Guetterman TC, Fàbregues S, Sakakibara R. Visuals in joint displays to represent integration in mixed methods research: A methodological review. Methods Psychol. 2021;5.

163. Guetterman TC, Fetters MD, Creswell JW. Integrating quantitative and qualitative results in health science mixed methods research through joint displays. Ann Fam Med. 2015;13:554–61.

164. Guetterman T, Creswell JW, Kuckartz U. Using joint displays and MAXQDA software to represent the results of mixed methods research. Use Vis displays Res Test Coding, Interpret Report data. 2015;145–75.

165. Clark VLP, Sanders K. The use of visual displays in mixed methods research. In: Use of visual displays in research and testing: Coding, interpreting, and reporting data. Information Age Publishing; 2015. p. 177–206.

166. Younas A, Durante A. Decision tree for identifying pertinent integration procedures and joint displays in mixed methods research. J Adv Nurs. 2022;(April):1–16.

167. Creamer EG. An introduction to fully integrated mixed methods research. sage publications; 2017.

168. Shorten A, Smith J. Mixed methods research: Expanding the evidence base. Evid Based Nurs. 2017;20(3):74–5.

169. de Haan M, van Eijk-Hustings Y, Vrijhoef HJM. Using mixed methods in health services research: A review of the literature and case study. J Heal Serv Res Policy. 2021;26(2):141–7.

170. Hadi MA, Closs SJ. Applications of mixed-methods methodology in clinical pharmacy research. Int J Clin Pharm. 2016;38(3):635–40.

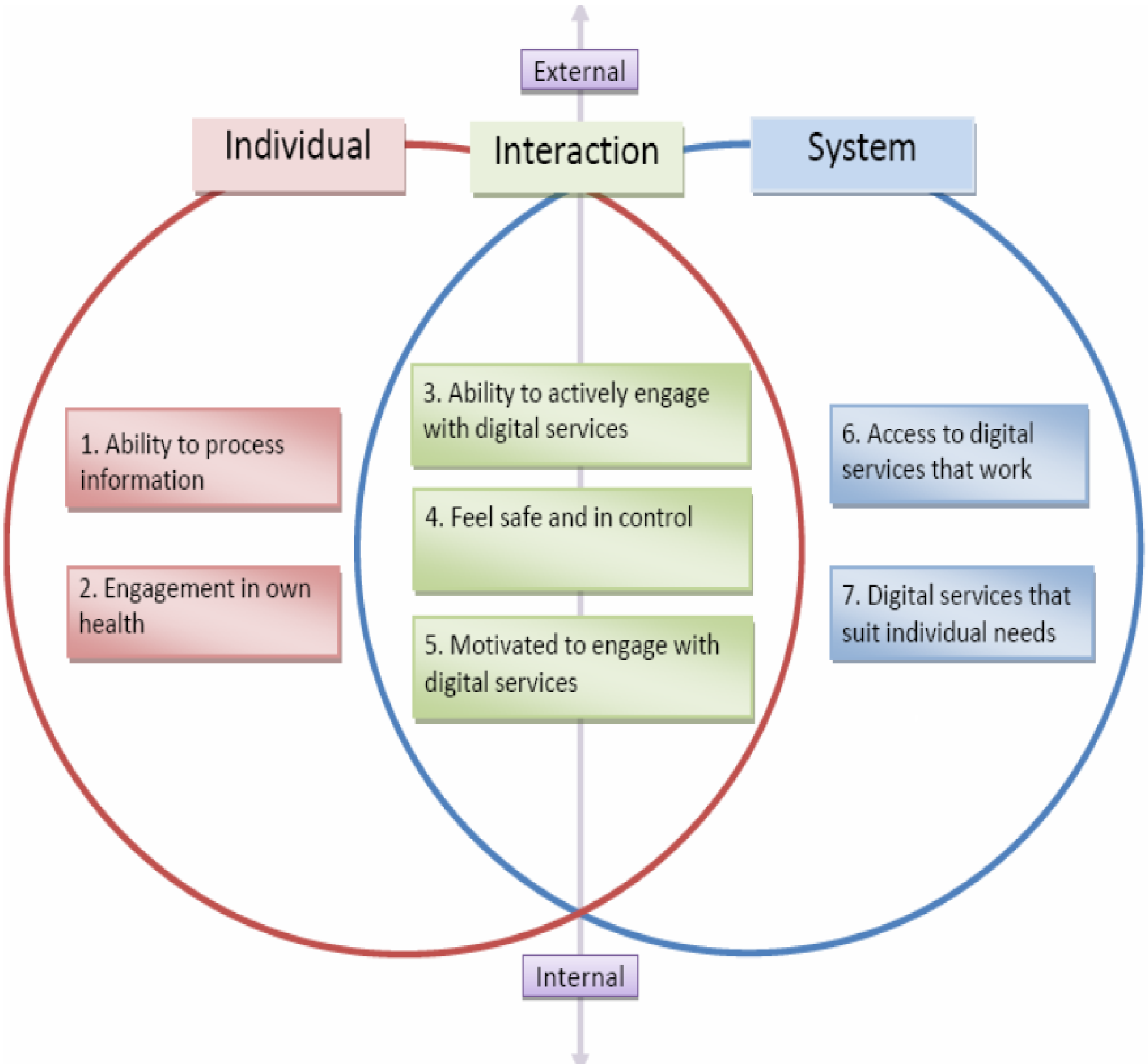
171. Rao D, Shiyanbola OO. Best practices for conducting and writing mixed methods research in social pharmacy. Res Soc Adm Pharm. 2022;18(1):2184–92.

172. Lee SYD, Iott B, Banaszak-Holl J, Shih SF, Raj M, Johnson KE, et al. Application of Mixed Methods in Health Services Management Research: A Systematic Review. Med Care Res Rev. 2022;79(3):331–44.

173. Eze CE, Dorsch MP, Coe AB, Lester CA, Buis LR, Farris KB. Facilitators and barriers to

blood pressure telemonitoring: A mixed-methods study. Digital Health [Internet]. 2023;9. Available from: https://doi.org/10.1177/20552076231187585.

Figure 1.1 Electronic Health Literacy Framework (e-HLF)



Chapter 2 Paper 1 Predictors of Smartphone and Tablet Use among Patients with Hypertension: A Secondary Analysis of HINTS Data

In this chapter, the results from Aim 1 will be provided. These results were published with my committee in Journal of Medical Internet Research as *Eze CE, West BT, Dorsch MP, Coe AB, Lester CA, Buis LR, Farris KB. Predictors of Smartphone and Tablet Use among Patients with Hypertension: Secondary Analysis of Health Information National Trends Survey Data. J Med Internet Res. 2022;24(1):1–23, https://www.jmir.org/2022/1/e33188/.* My role was development of research question, data management and analyses, interpretation of results, lead manuscript writing, and corresponding author. The journal specifically notes "**Note on permission requests:** As disclosed at the bottom of each article, the copyright for all articles in JMIR journals is owned by the respective authors and copyright is NOT transferred to or owned by the publisher. Rather, all articles are published under a Creative Commons Attribution license , essentially giving everybody the right to reproduce the material freely as long as it is properly cited. Please do NOT contact the publisher for permission requests related to individual articles, as permission has already been granted. Authors who have published in JMIR journals also do NOT require our permission to reuse the material for example in a thesis or monograph." [https://support.jmir.org/hc/en-us/articles/115001745328]

2.1 Introduction

Among the 121.5 million adults in the United States with hypertension, 61.2% are aware of their disease condition, and 50.4% are receiving treatment, but only about 22% have their blood pressure (BP) controlled.(1) Uncontrolled hypertension can lead to stroke (2), systemic embolism and bleeding (3), congestive heart failure (4), myocardial infarction (5), renal damage, dementia, aortic aneurysm, angina pectoris, metabolic syndrome, diabetes, blindness, and death.(6,7) The 2021 Heart Disease and Stroke statistics report that 57.2% of all deaths recorded in the US from 2008 to 2018 were attributed to hypertension.(1) Despite effective lifestyle and pharmaceutical treatments, the number of patients with uncontrolled BP in the US is undesirable. There is thus a need to harness every arsenal possible to mitigate this challenge.

One strategy to improve BP control is involving patients in their disease management through technology.(8) Recent innovations in information and communication technology provide excellent opportunities for improvements in hypertension control. There has been a steady increase in internet users and mobile cellular subscribers since the year 2000.(9) According to a 2021 Pew Research Center report, 93% of adult Americans now use the internet, and the increase in internet use is seen across all age groups [9]. Also, 97% of adult Americans own a cellphone, and 85% now use smartphones.(10)

In considering technology and BP control, patients with hypertension can now measure their BP using electronic monitors, transmit the results to their health provider through electronic health record platforms on their smartphones, tablets, or computers and get feedback through the same channels without having to leave the comfort of their homes.(11) Phone calls, text message alerts, health Apps, emails, and alarms have also been used, and collectively this is called telemonitoring. Improvement in BP control has been noted with this type of remote monitoring. For example, a pharmacist-led telemonitoring intervention involving weekly electronic transmission of home-measured BP and regulated telephone visits among 450 patients with uncontrolled BP resulted in a significant decrease in systolic BP at 6, 12, and 18 months of −10.7 mmHg (95% CI, −14.3 to −7.3 mmHg), P < .001, −9.7 mmHg (−13.4 to −6.0 mmHg), P < .001, and −6.6 mmHg (−10.7 to −2.5 mmHg), P =.004, respectively.(11) In addition, this study reported an increase in the proportion of patients with controlled BP in the telemonitoring group (71.8%, 95% CI, 65.0-77.8) compared to the usual care group (57.1%, 95% CI, 51.5-62.6).(12) More generally, the use of text messages as reminders and health education delivery led to improvements in behavior changes, hypertension knowledge, medication adherence, and BP among hypertensive patients.(13–16) A meta-analysis of 46 randomized controlled trials reported that home BP telemonitoring decreased systolic BP -3.99mmHg ((-5.06 to -2.93); P < .001) and diastolic BP -1.99 mmHg ((- 2.60 to - 1.39); P < .001) in the intervention groups compared to usual care.(17) However, these are mostly intervention studies that are not nationally representative.

Though we know the advantages of these technologies in achieving favorable health outcomes, little is known about the predictors of their use among hypertensive patients. Using the Health Information National Trends Survey (HINTS), Langford et al. examined the prevalence of smartphones, basic phones, and tablets and made comparisons between hypertensive and non-hypertensive respondents.(18) They found that 68%, 55%, and 16% of the hypertensive population had smartphones, tablets, and basic mobile phones, respectively. Younger hypertensive respondents were more likely to own a smartphone or tablet and have a health-related app. Ownership of smartphones or tablets increased with increases in educational attainment. Another HINTS study focused on respondents with one or more chronic medical conditions found that gender, age, employment status, and having a health app were associated with achieving a health-related goal with a smartphone or tablet. However, this study did not differentiate the respondents according to disease conditions in the analysis.(19) Other studies on mobile health app usage were not centered on people with hypertension.(20,21) There is, therefore, a need for more hypertension-focused studies to identify factors that impact mHealth technology use among this patient population.

The objective of this study was to quantify predictors of smartphone and tablet use in achieving health goals and communicating with healthcare providers via SMS text messaging among hypertensive patients. Our research question was, "what are the relationships of patients' characteristics with the use of a smartphone or tablet to achieve health goals and sending or receiving SMS text messages to/from healthcare professionals, among a nationally representative sample with hypertension?" This study provides nationally representative estimates regarding the predictors of using a smartphone or tablet to achieve health-related goals and SMS text messaging communication with healthcare professionals among hypertensive respondents. It also illuminates respondents' factors that are associated with the use of these communication approaches. This will help us identify where and how to channel efforts to improve patients' involvement in telemonitoring of BP when healthcare providers work with their patients to increase smartphone and tablet use for health services. These results will also inform our questions for further studies to understand patients' experiences with technology for BP control.

2.2 Method

2.2.1 Design

This study was a cross-sectional, secondary quantitative analysis of the 2017 and 2018 HINTS 5, Cycles 1 & 2 data. We combined the two cycles to provide more robust estimates of our relationships of interest. The study was considered exempt by the University of Michigan

Institutional Review Board with the approval number HUM00208364.

2.2.2 Data Collection

HINTS was developed by the Health Communication and Informatics Research Branch of the National Cancer Institute. It is a publicly available, nationally representative survey that monitors how American adults 18 years and older obtain and use health information. HINTS has been carried out every few years since 2003, and the target population is adult Americans, 18 years and above, in the civilian non-institutionalized population of the United States. HINTS uses a two-stage sampling design, and residents in high minority strata are oversampled. A high minority stratum represents places with ≥ 34% Hispanics or African Americans. The data has both a full sample weight and 50 replicate weights assigned to each completed questionnaire for the adult sample. The 50 replicate weights were computed using the jackknife replication method. The full sample weight enables the calculation of population and sub-population estimates, while the 50 replicate weights allow for the analysis of design-adjusted standard errors for these estimates. The sample weights allow valid inferences from the responding sample to the population, accounting for unequal probability of selection, nonresponse, and non-coverage biases. The details of the sampling methods and weighting approaches are available in HINTS 5, Cycles 1 & 2 Methodology reports.(22,23)

2.2.3 Participants/Sample size

A total of 6,789 respondents completed the HINTS 5 cycles 1 & 2 questionnaires. Respondents to HINTS who answered “Yes” to the question “Has a doctor or other health provider ever told you that you had high blood pressure or hypertension?” were the subpopulation used for this study. Out of the 6,789 respondents, 3,045 belonged to this subpopulation and thus constituted the final sample included in this analysis.

2.2.4 Variable of Interest

The dependent variables were 1. Has your tablet or smartphone helped you track progress on a health-related goal, such as quitting smoking, losing weight, or increasing physical activity? (yes or no), and 2. Have you sent or received a text message from a doctor or other health care professional within the last 12 months? (yes, no, don't know). The "no" and "don't know" responses were combined to a single "no" response for logistic regression analysis. In this study, we described as well as predicted these variables. We selected these two items because they most closely relate to the concept of telemonitoring of BP. We also provided population proportion estimates of the following variables: has your tablet or smartphone helped you make a decision about how to treat an illness or condition? (yes or no); has your tablet or smartphone helped you in discussions with your health care provider? (yes or no); other than a tablet or smartphone, have you used an electronic device to monitor or track your health within the last 12 months? (yes or no); have you shared health information from either an electronic monitoring device or smartphone with a health professional within the last 12 months? (yes or no); and in the past 12 months, have you used a computer, smartphone, or other electronic means to use email or the internet to communicate with a doctor or doctor's office? (yes or no).

The independent variables included respondents' demographics (such as age, educational level, marital status, income) and clinical characteristics (body mass index (BMI), co-morbidities, general health status). Technology-related covariates included technology access such as ownership of smartphones, tablet ownership, ownership of wellness health Apps, and ownership of basic cellphones. Technology-related behaviors such as electronic communication with the doctor or doctor's office through email or the internet were also included. These covariates were selected as they are technology-related items that can apply to BP telemonitoring.

2.2.5 Statistical analysis

We accounted for the sampling weights and the complex sample design features in all analyses to obtain population-level estimates for the United States using the R *survey* package. Variance estimates were computed using the Jackknife replication method, and specialized (unconditional) subpopulation analyses are not needed when using this replication approach.(24) We used descriptive statistics to analyze the characteristics of the respondents based on relevant demographics and covariates. We fit multivariable logistic regression models to the variables of interest to determine the most important predictors of the dependent variables. We first used demographics variables only and then we tested the full model with clinical and technology use variables. The pseudo maximum likelihood estimation method was used in fitting the regression models. To arrive at the final fitted model, we used a step-by-step approach starting from the preliminary bivariate analyses of potential predictors, followed by fitting different models containing all the anticipated predictors and variables of interest as well as interaction terms. We used the *regTermTest* function in the *survey* package to test the significance of the predictors with design-adjusted Wald tests. None of the interaction terms were found to be significant. We identified the best-fitting model by choosing the model with the lowest design-adjusted Akaike information criterion.(25) Some non-significant predictors were retained in the models because they were found to be associated with hypertension in prior studies (26–28) and removing them did not result in a better-fitting model. P values $\leq .05$ were considered statistically significant. We conducted all analyses using the JJ Allaire R Studio, version 3.6.1.

2.3 Results

2.3.1 Demographics and clinical characteristics

Out of the 497,278,883 estimated weighted population surveyed, 183,285,150 (36.9%, SE: 0.9%) responded yes to having hypertension. The 183,285,150 estimated hypertensive population constituted the denominator for all of the analysis in this study. The mean age of the hypertensive population was 58.3 years (SE: 0.48). Among people with hypertension, there were more males (52.7%) than females (47.3%) and most persons were aged 50 to 64 years (Table 2.1). The hypertensive population was predominantly non-Hispanic Whites (66.9%), and most had some college education or more (61.2%). Most were married or living as married (57.1%), and more than three-quarters consider themselves to be in good, very good, or excellent health. Less than half of this subpopulation was employed (46.7%), and more than two-thirds earned yearly household incomes below $75,000. Diabetes was the most common reported co-morbidity (33.7%).

2.3.2 Ownership and use of electronic devices

In the hypertensive subpopulation, the distribution of ownership of electronic devices was smartphones: 69.4%, tablets: 54.7%, and basic cellphones: 21.8% (Table 2.2). Almost three-quarters (74.0%) have accessed the internet; however, lower proportions have utilized their smartphones or tablets to achieve health-related goals (36.1%) and sent or received SMS text messages to/from their healthcare professionals (30.0%). Only a third (33.6%) of the hypertensive population have communicated electronically with their doctor or doctor's office through email or the internet.

2.3.3 Use of tablets or smartphone to achieve health-related goals

In the full model predicting 'achieving health-related goals with the help of tablet or smartphone', age, gender, marital status, ownership of basic cellphone, having a health-related wellness app, making health treatment decisions with mHealth, using other devices apart from tablet or smartphone to monitor or track health, and having a discussion with healthcare provider with the help of tablet or smartphone were significant predictors (Figure 2.1). In terms of the impact on the odds of achieving health-related goals with the help of tablet or smartphone, increasing age decreased the odds (35-49 years, OR 0.41, 95% CI 0.18-0.91; 50-64 years, OR 0.17, 95% CI 0.08-0.38; 65-74 years, OR 0.11, 95% CI 0.04-0.29; 75+ years, OR 0.07, 95% CI 0.02-0.19), being female increased the odds (OR 1.69, 95% CI 1.06-2.68), being married (OR 2.28, 95% CI 1.17-4.47) or previously married (OR 2.39, 95% CI 1.09-5.25) increased the odds, having a basic cellphone (OR 0.43, 95% CI 0.21-0.87) decreased the odds, having a wellness app (OR 8.70, 95% CI 5.81-13.04) increased the odds, making health decisions with mHealth (OR 1.77, 95% CI 1.06-2.94) increased the odds, tracking health with other devices (OR 2.73, 95% CI 1.46-5.12) and having discussion with provider (OR 1.96, 95% CI 1.22-3.17) using tablet or smartphone increased the odds. Age, female gender, being married or previously married were also significant predictors of achieving health-related goals with the help of a tablet or smartphone when we accounted for only demographic variables (Appendix A).

2.3.4 Use of tablet or smartphone to communicate with healthcare provider through text-messaging

In the full model predicting 'send or receive text messages to/from a healthcare professional in the last 12 months', electronic communication with the doctor or doctor's office via email or internet (OR 2.93, 95% CI 1.85-4.63) and having health-related wellness apps (OR

1.82, 95% CI 1.16-2.86) were the only significant predictor variables (Table 2.3). Individuals who used a computer, smartphone, or other electronic means to use email or the internet to communicate with a doctor or doctor's office in the past 12 months had 193% higher odds of sending or receiving text messages from a healthcare professional in the last 12 months than those who have not. Those with health-related wellness apps had 82% higher odds of sending or receiving SMS text messages from a healthcare professional in the last 12 months than those who have not. No other covariates were significant.

Notably, in the model with only demographics, annual household income was the only significant predictor of sending or receiving text messages to/from a healthcare professional in the last 12 months (Appendix B). Compared to the subpopulation with yearly household income of $75,000 or more, the odds of sending or receiving text messages from healthcare professional in the last 12 months decreased by 40.0%, 50.7%, 64.7% and 74.0% among those with $50,000 to < $75,000 (OR 0.60, 95% CI 0.41-0.87, P = .01), $35,000 to < $50,000 (OR 0.49, 95% CI 0.28-0.88, P = .03), $20,000 to < $35,000 (OR 0.35, 95% CI 0.20-0.61, P = .001), and < $20,000 (OR 0.26, 95% CI 0.13-0.51, P < .001) household incomes, respectively. The design-adjusted Wald test indicated that household income remained a significant predictor of sending or receiving text messages to/from a healthcare professional, $F(4,23) = 4.92$, $P = .005$.

2.4 Discussion

2.4.1 Principal Findings and Implications

The purpose of this study was to identify predictors of 'using a smartphone or tablet to achieve health goals' and 'SMS text messaging communication with healthcare professionals' among individuals with hypertension. Most of the hypertensive population have a smartphone, and just over half have tablets. We found that the likelihood of using a smartphone or tablet to achieve health-related goals significantly decreases with increases in age and ownership of a basic cellphone. The use smartphones or tablets to achieve health-related goals was, however, statistically significantly positively associated with being female, married or previously married, having a health-related wellness app, making health treatment decisions with mHealth, using other devices apart from tablet or smartphone to monitor or track health, and having a discussion with a healthcare provider with the help of a tablet or smartphone. Sending or receiving SMS text messages to/from a healthcare provider was statistically significantly positively associated with prior electronic communication with the doctor or doctor's office by email or internet and having a health-related wellness app.

Achieving health-related goals with the help of a tablet or smartphone usually involves having a health-related application installed on the smartphone or tablet.(29) Therefore, it is not surprising that age was a significant predictor of achieving health-related goals with the help of a tablet or smartphone, with the odds decreasing as age increases. This may be because younger people are more likely to have smartphones or tablets and health-related apps.(10,18) Studies have shown that older adults can use technology if they understand the benefits they can get from such use.(30–32) Healthcare providers can recommend that their older patients use their smartphone and tablets in achieving health goals and encourage more utilization. Our findings among people with hypertension on younger age and female gender as significant predictors of achieving health-related goals with the help of a tablet or smartphone agree with another HINTS study (19) among respondents with one or more chronic diseases that found that respondents aged ≥ 65years had lower odds compared to those aged 18-34 years, while females had higher odds compared to males for tracking the progress of health-related goals with their tablet or smartphone. They also found that those having health-related app have higher odds of tracking the progress of health-related goals with their tablet or smartphone than those who do not have the app, which agrees with our findings as well. However, their findings showed that being employed increases the odds and having good health status decreases the odds of tracking the progress of health-related goals with tablet or smartphone differ from ours where employment and health status were not associated with tracking health goals. The difference in results could be because of the differences in the variables included in the regression models, or it could also be because their study was done among respondents with one or more chronic diseases. Another HINTS study (20) on adult respondents also found that the likelihood of achieving health goals with the help of mHealth app decreased with increases in age.

It was not surprising that those who own only basic cellphones had lower odds of achieving health-related goals with the help of a tablet or smartphone compared to those who do not, since it is nearly impossible for basic cellphones to do that. The significance of making health treatment decisions with mHealth, using other devices apart from a tablet or smartphone to monitor or track health, and having a discussion with healthcare provider with the help of a tablet or smartphone as predictors for achieving health-related goals with the help of a tablet or smartphone buttresses the fact that people who are already utilizing a technology device are more likely to increase their utilization than those who are not. This finding suggests that these groups of the hypertensive population can likely benefit from telemonitoring of BP too. Healthcare providers can play a role in creating awareness of these resources and their usefulness among their patients. It is also critical that payment reform adequately recognize providers' time in supporting telemonitoring of BP. The number of hypertensive patients using any of these technology devices could be increased by making them more affordable and accessible, and insurance coverage of such technology is likely necessary for widespread adoption of telemonitoring of BP.

Less than a third of the hypertensive subpopulation have sent or received SMS text messages from their healthcare professionals. Interestingly, annual household income was a significant predictor of sending or receiving SMS text messages from a healthcare professional while considering only demographic variables, with the odds of sending or receiving SMS text messages decreasing with lower household income. SMS text messaging has been portrayed as a low-cost and common resource that can be used to improve health care. It has been shown to be effective in several intervention studies to improve hypertension knowledge and behavior changes, such as medication adherence and BP monitoring leading to better BP control.(13–16) In general, 2-way SMS text messaging communication initiated by the healthcare provider keeps the patient and provider in frequent communication and is more effective in BP targets attainment.(14) Our results show that advantages of SMS text-messaging are not being fully used in everyday life. One would think that text messaging will be widespread across all income levels as it is considered an inexpensive option, but that is not the case. Advocacy for free SMS text-messaging phone subscription for lower income hypertensive patients may increase usage of this technology. It could also be that patients are not aware that they can communicate with their healthcare professionals through SMS text messaging, or the service is not offered by their health providers. With adequate reimbursement, it behooves healthcare providers to initiate SMS text messaging with their patients so that they can both reap its advantages and free office time, to some extent, for more acute or serious visits.

In the full model, electronic communication with the doctor or doctor's office and having a health-related wellness app were significant predictors of sending or receiving SMS text messages from a healthcare professional when we accounted for all covariates. This shows that those already in communication with their healthcare provider are more likely to continue even if there is a change of communication channel. The significance of having a health-related wellness app suggests that those who are already doing a form of self-monitoring are more likely to communicate with their healthcare provider via SMS text messaging. These findings are important because the impact of demographic characteristics such as age, gender, and income were not statistically significant. This suggests that all individuals, not just the young or those with higher incomes, for example, should be targeted to use remote BP monitoring. An essential first step may be a first electronic communication with the doctor or doctor's office, including email or electronic health portal messaging or phone SMS text messaging. Having a health-related wellness app predicted both using a tablet or smartphone to achieve health goals and communication with a healthcare provider through SMS text messaging. These findings underscore the importance of these technology applications in improving health and the importance of the willingness of the patients to be more involved in their care through technology use. Healthcare systems could offer user-friendly health-related wellness apps to patients on a secure platform to boost patient trust and increase uptake.

2.4.2 Study Limitations

Our study results are limited by the cross-sectional nature of the data, and the subpopulation used is based on self-reported hypertension. Yet, our robust analytic approach, accounting for the HINTS sampling design, is positive. We also may not have accounted for all factors needed to predict the dependent variables because we used secondary data.

2.4.3 Future Studies

Effective engagement with health technology requires that patients have some eHealth literacy.(33) eHealth literacy expresses a person's understanding of the knowledge, skill and resources needed to properly use health technology services. Future research should consider how factors such as the eHealth literacy status of the patients or healthcare resources available to the patients are associated with the use of tablet or smartphone to achieve health goals and communicate with a healthcare provider through SMS text messaging in patients with hypertension. For example, mobile SMS text messages aimed at control of child dental caries among parents with low eHealth literacy led to improvement in health outcomes and an increase in parental eHealth literacy in the intervention group at six months.(34) Further studies are needed to understand how these predictors correlate with objective BP control and patient-provider communication preferences among patients with hypertension.

2.5 Conclusion

The use of mHealth to achieve health goals and communicate with healthcare professionals by patients with hypertension is significantly associated with having health-related wellness apps. Achieving health goals is also associated with demographics such as age, gender, marital status, technology access, and other technology-related behavior. Communication with healthcare providers through SMS text messaging is associated with previous electronic communication with the doctor or doctor's office. It is essential to consider these factors in tandem when planning telemonitoring for patients with hypertension. Measures accounting for these factors are required to increase smartphone and tablet use and their benefits in routine care of patients with hypertension.

2.6 References

1. Virani SS, Alvaro A, Aparicio HJ, et al. Heart Disease and Stroke Statistics-2021 Update A Report from the American Heart Association. *Circulation*. 2021;143(8):E254-E743. doi:10.1161/CIR.0000000000000950

2. Uhlig K, Patel K, Ip S, Kitsios GD, Balk EM. Self-Measured Blood Pressure Monitoring in the Management of Hypertension: A Systematic Review and Meta-analysis. *Ann Intern Med*. 2013;159(3):185-194. doi:10.7326/0003-4819-159-3-201308060-00008

3. Ishii M, Ogawa H, Abe M, et al. Relationship of Hypertension and Systolic Blood Pressure With the Risk of Stroke or Bleeding in Patients With Atrial Fibrillation: The Fushimi AF Registry. *Am J Hypertens*. 2017;30(11):1073-1082. doi:10.1093/ajh/hpx094

4. Kannan A, Janardhanan R. Hypertension as a Risk Factor for Heart Failure. *Curr Hypertens Rep*. 2014;16(7):447. doi:10.1007/s11906-014-0447-7

5. Yandrapalli, Srikanth Nabors C, Goyal A, Aronow WS, Frishman WH. Modifiable Risk Factors in Young Adults With First Myocardial Infarction. *J Am Coll Cardiol*. 2019;73(5):573-584. doi:10.1016/j.jacc.2018.10.084

6. Aronow WS. Treatment of systemic hypertension. *Am J Cardiovasc Dis*. 2012;2(3):160-170. doi:10.1016/0002-9149(87)90535-2

7. Billups SJ, Saseen JJ, Vande Griend JP, Schilling LM. Blood pressure control rates measured in specialty vs primary care practices within a large integrated health system. *J Clin Hypertens*. 2018;20(9):1253-1259. doi:10.1111/jch.13345

8. Chandak A, Joshi A. Self-management of hypertension using technology enabled

interventions in primary care settings. Technol Health Care. 2015;23(2):119-28. doi: 10.3233/THC-140886. PMID: 25515051.

9. Pew Research Center. Internet Use Over Time. *Pew Res Cent*. April 7, 2021. https://www.pewresearch.org/internet/fact-sheet/internet-broadband/.

10. Pew Research Center. Mobile Phone Ownership over time. *Mob Fact Sheet*. April 7,2021. https://www.pewresearch.org/internet/fact-sheet/mobile/

11. Omboni S, Caserini M, Coronetti C. Telemedicine and M-Health in Hypertension Management: Technologies, Applications and Clinical Evidence. *High Blood Press Cardiovasc Prev*. 2016;23(3):187-196. doi:10.1007/s40292-016-0143-6

12. Margolis KL, Asche SE, Bergdall AR, et al. Effect of home blood pressure telemonitoring and pharmacist management on blood pressure control a cluster randomized clinical trial. *JAMA - J Am Med Assoc*. 2013;310(1):46-56. doi:10.1001/jama.2013.6549

13. Hacking D, Haricharan HJ, Brittain K, Lau YK, Cassidy T, Heap M. Hypertension Health Promotion via Text Messaging at a Community Health Center in South Africa: A Mixed Methods Study. *JMIR mHealth uHealth*. 2016;4(1):e22-e22. doi:10.2196/mhealth.4569

14. Vargas G, Cajita MI, Whitehouse E, Han HR. Use of short messaging service for hypertension management: A systematic review. *J Cardiovasc Nurs*. 2017;32(3):260-270. doi:10.1097/JCN.0000000000000336

15. Buis L, Hirzel L, Dawood RM, et al. Text Messaging to Improve Hypertension Medication Adherence in African Americans From Primary Care and Emergency Department Settings: Results From Two Randomized Feasibility Studies. *JMIR mHealth uHealth*. 2017;5(2):e9-e9. doi:10.2196/mhealth.6630

16. Zhai P, Hayat K, Ji W, et al. Efficacy of Text Messaging and Personal Consultation by Pharmacy Students Among Adults With Hypertension: Randomized Controlled Trial. *J Med Internet Res*. 2020;22(5):e16019. doi:10.2196/16019

17. Duan Y, Xie Z, Dong F, et al. Effectiveness of home blood pressure telemonitoring: A systematic review and meta-analysis of randomised controlled studies. *J Hum Hypertens*. 2017;31(7):427-437. doi:10.1038/jhh.2016.99

18. Langford AT, Solid CA, Scott E, et al. Mobile phone ownership, health apps, and tablet use in US adults with a self-reported history of hypertension: Cross-sectional study. *J Med Internet Res*. 2019;21(1). doi:10.2196/12228

19. Mahmood A, Kedia S, Wyant DK, Ahn SN, Bhuyan SS. Use of mobile health applications for health-promoting behavior among individuals with chronic medical conditions. *Digit Heal*. 2019;5:1-17. doi:10.1177/2055207619882181

20. Bhuyan SS, Lu N, Chandak A, et al. Use of Mobile Health Applications for Health-Seeking Behavior Among US Adults. *J Med Syst*. 2016;40(6). doi:10.1007/s10916-016-0492-7

21. Krebs P, Duncan DT. Health app use among US mobile phone owners: A national survey. *JMIR mHealth uHealth*. 2015;3(4). doi:10.2196/mhealth.4924

22. National Cancer Institute. Health Information National Trends Survey 5 (HINTS 5) Cycle 1 Methodology Report. 2017;5(July). https://hints.cancer.gov/data/methodology-reports.aspx.

23. National Cancer Institute. Health Information National Trends Survey 5 (HINTS 5) Cycle 2 Methodology Report. 2018;5(July). https://hints.cancer.gov/data/methodology-

reports.aspx.

24. Heeringa SG, West BT, Berglund PA. Preparation for Complex Sample Survey Data Analysis. *Appl Surv Data Anal New York Chapman Hall/CRC*. 2017:116-123. doi:10.1201/9781420080674-c4

25. Lumley T, Scott A. AIC and BIC for modeling with complex survey data. *J Surv Stat Methodol*. 2015;3(1):1-18. doi:10.1093/jssam/smu021

26. Echouffo-Tcheugui JB, Batty GD, Kivimäki M, Kengne AP. Risk Models to Predict Hypertension: A Systematic Review. *PLoS One*. 2013;8(7). doi:10.1371/journal.pone.0067370

27. Ware LJ, Chidumwa G, Charlton K, Schutte AE, Kowal P. Predictors of hypertension awareness, treatment and control in South Africa: results from the WHO-SAGE population survey (Wave 2). *J Hum Hypertens*. 2019;33(2):157-166. doi:10.1038/s41371-018-0125-3

28. Acheampong K, Nyamari JM, Ganu D, et al. Predictors of Hypertension among Adult Female Population in Kpone-Katamanso District, Ghana. *Int J Hypertens*. 2019;2019. doi:10.1155/2019/1876060

29. Omboni S. Connected Health in Hypertension Management. *Front Cardiovasc Med*. 2019;6(June):1-17. doi:10.3389/fcvm.2019.00076

30. Peek STM, Luijkx KG, Rijnaard MD, et al. Older Adults' Reasons for Using Technology while Aging in Place. *Gerontology*. 2016;62(2):226-237. doi:10.1159/000430949

31. Pruchno R. Technology and Aging: An Evolving Partnership. *Gerontologist*. 2019;59(1):1-5. doi:10.1093/geront/gny153

32. Pelizaus-Hoffmeister H. Motives of the Elderly for the Use of Technology in their Daily Lives. In: Dominguez-Rue E, Nierling L, eds. *Ageing and Technology Book Subtitle : Perspectives from the Social Sciences*. Bielefeld: Transcript Verlag; 2016:27-46. http://www.jstor.org/stable/j.ctv1xxrwd.4.

33. Norgaard O, Klokker Bispebjerg L, Hospital F, Astrid Karnoe D, Kayser L, Osborne RH. Knowledge Management & E-Learning The e-health literacy framework: A conceptual framework for characterizing e-health users and their interaction with e- health systems. *Knowl Manag E-Learning*. 2015;7(74):522-540.

34. Lotto M, Strieder AP, Ayala Aguirre PE, et al. Parental-oriented educational mobile messages to aid in the control of early childhood caries in low socioeconomic children: A randomized controlled trial. *J Dent*. 2020;101:103456. doi:10.1016/j.jdent.2020.103456

Table 2.1 Design-adjusted estimates of demographics and clinical characteristics among the hypertensive population

		Sample size = 3,045		
		Estimated Population size = 183,285,150		
Variable	Category	% or Mean	SE	95% CI
Age (yrs)				
		58.3	0.48	57.31, 59.21
Age groups (yrs)				
	18-34	6.0%	1.0	4.1, 8.0
	35-49	22.2%	1.5	19.2, 25.2
	50-64	37.6%	1.4	34.8, 40.3
	65-74	18.8%	0.6	17.6, 19.9
	75+	15.4%	0.6	14.2, 16.6
Gender				
	Male	52.7%	1.3	50.1, 55.3
	Female	47.3%	1.3	44.7, 49.9
Education levels				
	Less than high school	10.8%	1.0	8.8, 12.8
	High school graduate	28.0%	1.4	25.3, 30.8
	Some college	37.4%	1.4	34.6, 40.2
	College graduate or more	23.8%	1.0	21.9, 25.6
Race/ Ethnicity				
	Non-Hispanic White	66.9%	1.1	64.7, 69.1
	Non-Hispanic Black or African American	13.9%	0.8	12.4, 15.4
	Hispanic	12.8%	0.9	11.1, 14.5
	Non-Hispanic Asian	3.2%	0.5	2.2, 4.2
	Non-Hispanic Other	3.1%	0.4	2.4, 3.9
Marital status				
	Married	54.7%	1.2	52.3, 57.1
	Living as married	2.4%	0.4	1.6, 3.2
	Divorced	11.4%	0.6	10.2, 12.3
	Widowed	9.2%	0.6	8.0, 10.4
	Separated	1.6%	0.3	1.0, 2.7
	Never married	20.7%	1.3	18.1, 23.4

Variable	Category	% or Mean	SE	95% CI
Household yearly income				
	<$20,000	21.1%	1.2	18.7, 23.5
	$20,000 to <$35,000	13.2%	0.8	11.6, 14.8
	$35,000 to <$50,000	15.2%	1.1	13.0, 17.3
	$50,000 to <$75,000	19.4%	1.2	17.0, 21.9
	$75,000 or more	31.1%	1.2	28.6, 33.5
Employment status				
	Employed	46.7%	1.6	46.7, 49.7
	Unemployed	53.3%	1.6	50.1, 56.4
Smoked at least 100 cigarettes				
	Yes	44.7%	1.6	41.6, 47.7
	No	55.3%	1.6	52.3, 58.4
BMI				
		31.1	19.1	30.7, 31.4
General health				
	Excellent	5.5%	0.6	4.4, 6.6
	Very good	28.0%	1.5	25.0, 30.9
	Good	42.0%	1.5	38.9, 45.0
	Fair	20.3%	1.3	17.9, 22.8
	Poor	4.3%	0.6	3.1, 05.4
Diabetes				
	Yes	33.7%	1.4	31.0, 36.4
	No	66.3%	1.4	63.6, 69.0
Heart condition				
	Yes	15.8%	1.0	13.8, 17.7
	No	84.2%	1.0	82.3. 86.2
Depression				
	Yes	27.8%	1.3	25.4, 30.3
	No	72.2%	1.3	69.7, 74.6

SE = Standard error; CI = Confidence interval; BMI = Body mass index

Table 2.2 Design-adjusted proportions for ownership and use of mobile health (mHealth) electronic devices among the hypertensive population

	Sample size = 3,045 Estimated Population size = 183,285,150			
Variable	Category	%	SE	95% CI
Technology access and use				
Have only basic Cellphone				
	Yes	21.8%	1.1	19.7, 24.0
	No	78.2%	1.1	76.0, 80.3
Have Smartphone				
	Yes	69.4%	1.4	66.7, 72.0
	No	30.6%	1.4	28.0, 33.3
Have Tablet				
	Yes	54.7%	1.4	51.8, 57.5
	No	45.3%	1.4	42.5, 48.2
Use Internet				
	Yes	74.0%	1.3	71.4, 76.6
	No	26.0%	1.3	23.4, 28.6
Have Health Apps				
	Yes	40.6%	1.8	37.1, 44.0
	No	59.4%	1.8	56.0, 62.9
Technology-related health behaviors				
Make health treatment decision with mHealth				
	Yes	34.2%	2.0	30.4, 38.1
	No	65.8%	2.0	61.9, 69.6
Discuss with health provider with help of tablet or smartphone				
	Yes	33.7%	1.5	30.7, 36.6
	No	66.3%	1.5	63.4, 69.3
Used other devices apart from tablet and smartphone to monitor/track health				
	Yes	41.6%	1.3	39.1, 44.0
	No	58.4%	1.3	56.0, 60.9
Shared health Info from electronic device, tablet or smartphone with health provider				
	Yes	21.2%	1.0	19.2, 23.2
	No	70.9%	1.4	68.1, 73.6
	Not applicable	7.9%	0.9	6.2, 9.7

Variable	Category	%	SE	95% CI
Electronic communication with doctor or doctor's office via email or internet				
	Yes	33.6%	1.3	31.0, 36.2
	No	66.4%	1.3	63.8, 69.0
Dependent variables				
Achieve health goal with tablet or smartphone				
	Yes	36.1%	1.6	33.0, 39.2
	No	63.9%	1.6	60.6, 67.0
Sent or received a text message from doctor				
	Yes	30.0%	1.4	27.3, 32.8
	No	70.0%	1.4	67.2, 72.7

SE = Standard error; CI = Confidence interval

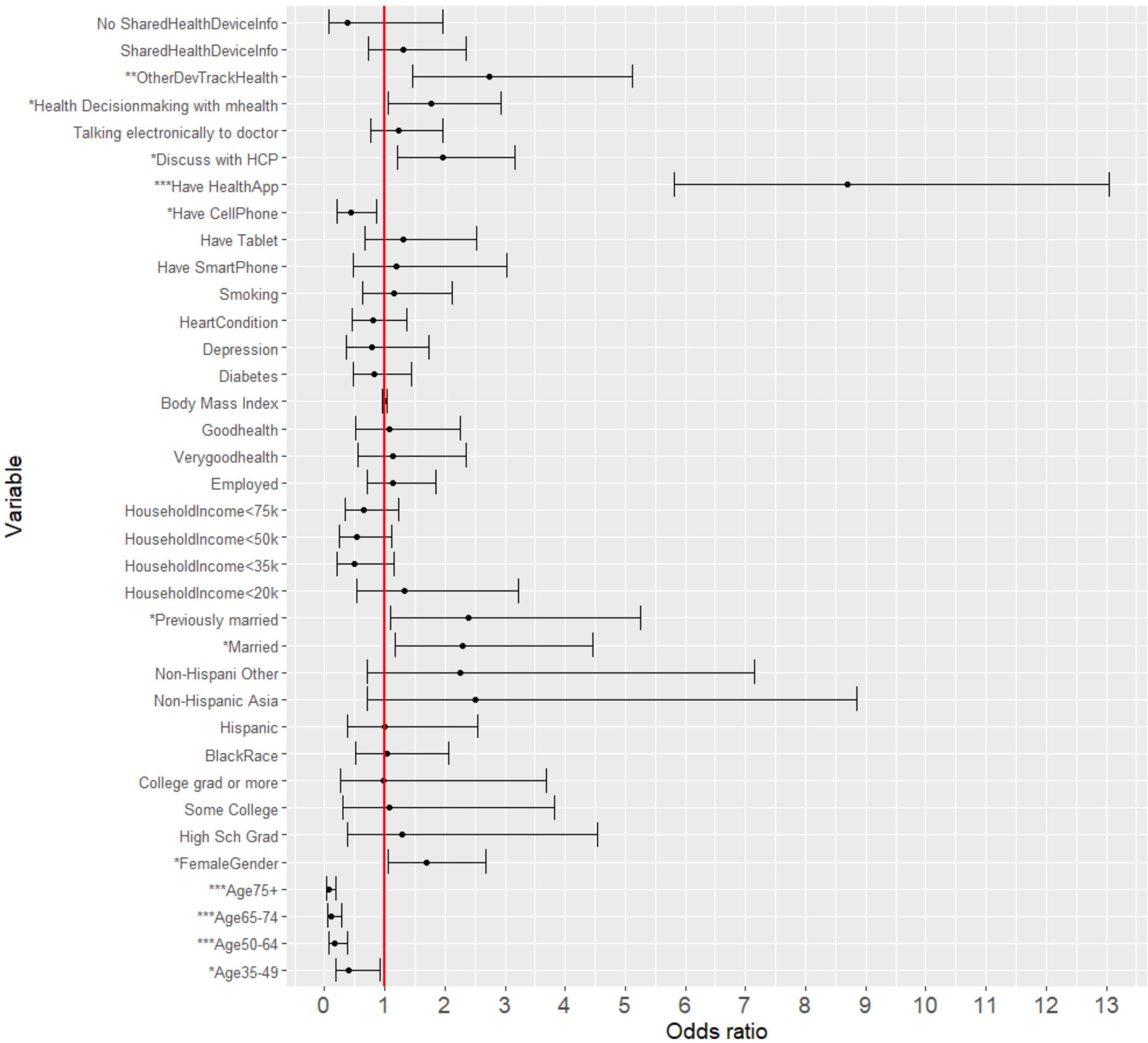
Table 2.3 Full model with design -adjusted estimates of odds ratios for sending or receiving text messages from healthcare provider in the last 12 months among hypertensive population

		Sample size = 3,045 Estimated Population size = 183,285,150		
Predictor	Category	Odds Ratio (95% CI)	SE	*P*-value
[a]**Age groups (yrs)**				
	35-49	2.22 (0.749, 6.581)	0.554	.174
	50-64	1.56 (0.535, 4.532)	0.545	.431
	65-74	1.48 (0.452, 4.844)	0.605	.528
	75+	1.55 (0.429, 5.585)	0.655	.516
[b]**Gender**				
	Female	1.20 (0.825, 1.743)	0.192	.359
[c]**Education levels**				
	High Sch grad	0.84 (0.374, 1.871)	0.411	.670
	Some college	0.68 (0.300, 1.521)	0.415	.360
	College grad or more	0.61 (0.242, 1.535)	0.471	.313
[d]**Race/Ethnicity**				
	Non-Hispanic Black or African American	0.75 (0.426, 1.311)	0.287	.329
	Hispanic	0.90 (0.467, 1.744)	0.336	.765
	Non-Hispanic Asian	0.67 (0.217, 2.056)	0.573	.495
	Non-Hispanic Other	1.57 (0.368, 6.744)	0.742	.551
[e]**Marital status**				
	Married	1.37 (0.680, 2.766)	0.358	.394
	Previously married	1.54 (0.648, 3.647)	0.441	.347
[f]**House-hold yearly income**				
	<$20,000	0.50 (0.221, 1.152)	0.422	.128
	$20,000 to <$35,000	0.55 (0.312, 0.977)	0.291	.062
	$35,000 to <$50,000	0.63 (0.341, 1.157)	0.311	.160
	$50,000 to <$75,000	0.82 (0.536, 1.253)	0.217	.374
[g]**Employment status**				
	Employed	0.80 (0.443, 1.427)	0.299	.456
[h]**Smoked at least 100 cigarettes**				
	No	1.21 (0.868, 1.682)	0.168	.282
[i]**Health status**				
	Very good	1.17 (0.660, 2.087)	0.294	.595
	Good	1.28 (0.789, 2.087)	0.248	.333
BMI				
		1.00 (0.962, 1.029)	0.017	.780
[j]**Diabetes**				
	Yes	1.05 (0.691, 1.595)	0.213	.822
[j]**Heart condition**				
	Yes	1.04 (0.661, 1.627)	0.230	.876
[j]**Depression**				
	Yes	1.19 (0.696, 2.046)	0.275	.532

Predictor	Category	Odds Ratio (95% CI)	SE	*P*-value
[j]**Have Smartphone**				
	Yes	1.53 (0.618, 3.803)	0.463	.373
[j]**Have Tablet**				
	Yes	1.08 (0.676, 1.735)	0.240	.746
[j]**Have basic cellphone**				
	Yes	0.79 (0.350, 1.772)	0.414	.573
[j]**Have Health Apps**				
	Yes	1.82 (1.163, 2.857)	0.229	.021
[j]**Make treatment decision with mHealth**				
	Yes	1.31 (0.836, 2.043)	0.228	.261
[j]**Discuss with Health Provider with help of tablet or smartphone**				
	Yes	0.98 (0.640, 1.509)	0.219	.938
[j]**Used other devices apart from tablet and smartphone to monitor or track health**				
	Yes	1.20 (0.789, 1.839)	0.216	.404
[j]**Shared health Info from electronic device, tablet or smartphone with health provider**				
	Yes	1.62 (1.023, 2.564)	0.234	.060
	Not applicable	0.74 (0.222, 2.493)	0.617	.639
[j]**Electronic communication with doctor or doctor's office via email or internet**				
	Yes	2.93 (1.852, 4.628)	0.234	.0005

[a-j]Reference categories for categorical predictors.
[a] =18-34yrs; [b] =Male; [c] =Less than high school; [d] =Non-Hispanic White; [e] =Never married; [f] =$75,000 or more; [g] =Unemployed; [h] =Yes response; [i] =Fair; [j] =No response

Figure 2.1 Full model with design-adjusted estimates of odds ratios for achieving health-related goal with the help of a tablet or smartphone among the hypertensive population



P-values: *** 0.001, ** 0.01, * 0.05

SharedHealthDeviceInfo: Shared health info from electronic device, smartphone or tablet with healthcare provider; OtherDevTrackHealth: Used other devices apart from tablet or smartphone to track health; DiscussHCP: Discuss with healthcare provider with the help of tablet or smartphone.

Reference categories for categorical predictors:

Age=18-34yrs; Gender=Male; Education level=Less than high school; Race/Ethnicity=Non-Hispanic White; Marital status=Never married; HouseholdIncome=$75,000 or more; Employment status=Unemployed; Smoking=Yes response; Health status=Fair; Other variables=No response

Chapter 3 Paper 2 Facilitators and Barriers to Blood Pressure Telemonitoring: A Mixed-methods Study

In this chapter, the results from Aim 2 will be provided. These results have been published in Digital Health as *Eze CE, Dorsch MP, Coe AB, Lester CA, Buis LR, Farris KB. Facilitators and Barriers to Blood Pressure Telemonitoring: A Mixed-methods Study. DIGITAL HEALTH 2023;9. doi:10.1177/20552076231187585*. This paper is protected under Creative Commons Attribution – Non-Commercial license (CC BY – NC 4.0) and reuse is restricted to non-commercial, and no derivative uses. My role was development of research question, data management and analyses, interpretation of results, lead manuscript writing, and corresponding author.

3.1 Introduction

About half of adult Americans have hypertension and less than 25% have it under control (1). Multifaceted approaches are required to control blood pressure (BP) including consolidated use of health technology, empowering and equipping patients to use self-measured BP monitoring, medication adherence strategies, and maintenance of patient-healthcare provider communications (2). Advancements in technology such as electronic communication tools and monitoring devices as well as experiences with the global COVID-19 pandemic have made telehealth a viable option in the management of various diseases including hypertension (3–5).

The four major forms of technologies used in telehealth include mobile health apps, store and forward electronic transmission of data, video conferencing, and remote patient monitoring (6).

Remote patient monitoring (RPM), also known as telemonitoring, is simply monitoring of patients from a distance (7,8). It comprises the use of electronic communication devices such as mobile monitoring devices, wearables, smartphone apps, and computers, usually from a patient's home to collect and transmit the patient's health data to a healthcare provider for evaluation and appropriate intervention (6,9). The health data transmission can be automated or manually entered by the patient. Telemonitoring can be accompanied by structured telephone support (human or machine-delivered phone calls) (10) or text messages (11,12) that provide reminders and self-care health education to the patient. According to the Telehealth.HHS.gov website, conditions such as diabetes, heart conditions, chronic obstructive pulmonary disease, sleep apnea, and asthma, and symptoms like high BP, weight loss or gain can be telemonitored (13).

Telemonitoring has evolved in both the components and processes of administration. Several systematic reviews published from 2003 to 2022 about telemonitoring in varying diseases exist, and the results are mixed. A systematic review of 272 publications on telemonitoring from 2000 to 2018 showed that it is effective in improving patient outcomes in 209 (76.8%) of the papers (8). Most of the papers reviewed were on telemonitoring of cardiovascular (47.8%) and endocrinologic (18.0%) diseases. A meta-analysis of 7,138 patients with hypertension found that BP self-monitoring led to an overall reduction in clinic systolic BP (-3.2 mmHg, 95% CI -4.9, -1.6) compared with usual care at 12 months. However, self-monitoring combined with telemonitoring including medication titration or lifestyle counseling led to a greater reduction in systolic BP (-6.1 mmHg, 95% CI -9.0, -3.2) (14). Finally, another meta-analysis of 32 randomized controlled studies done in patients with hypertension living in urban areas demonstrated higher BP control rates among the remote BP monitoring group (relative ratio 1.226, $P < 0.001$) compared to the usual care group (15).

Despite mixed evidence of effectiveness in improving patient outcomes, support for telemonitoring is still growing (16). The focus is now on how to overcome the challenges of telemonitoring, especially related to patient experiences. Some of the challenges limiting the widespread adoption of telemonitoring include the lack of skill required to operate the technology, acceptability, beliefs, long-term adherence, and cost of the technology (17,18). Among patients with various chronic diseases, remote monitoring was facilitated by the disease-specific knowledge gained, early identification of disease decline triggers, improved self-management skills, and shared decision-making with providers (19). Nonetheless, there is still fear of losing in-person contact and apathy towards technology caused by a lack of trust and skill (19). These studies provide good insight into barriers and facilitators of remote monitoring adoption; however, they are non-specific to patients with hypertension.

A scoping review of 36 studies on digital health technology adoption for hypertension management reported technology usability and support, better patient-provider communication, improved self-management, and fewer clinic visits as patient-related facilitators (20). The barriers to digital health technology adoption for patients were cost, data privacy and security concerns, anxiety, loss of the patient-provider relationship, and lack of technology trust, skills, and support (20). A weighted analysis of the health information national trends survey (HINTS) showed that among adults with hypertension, previous electronic communication with healthcare providers through email or the internet and access to health Apps were important predictors of interacting with healthcare providers through short message service (SMS) text messages (21). A randomized controlled study of patients with hypertension in telemonitoring and non-telemonitoring groups showed that BP telemonitoring was facilitated by the acceptability of the intervention, data safety, and timely communication with the healthcare provider. The barriers were concerns about data safety, lack of motivation, and technology skills (22). Another systematic review of the adoption of telemedicine for the management of hypertension reported similar facilitators and barriers, in addition to the availability of access to care, improved patient knowledge, and involvement (23). Though these studies are specific to patients with hypertension, they do not explore the role of e-health literacy among patients, which is necessary for the adoption of RPM.

Fundamental to technology adoption is the understanding of the skills, knowledge, and resources needed to apply them; a concept known as e-health literacy (e-HL) (24). Several models of e-HL have been proposed (24–28) along with different e-HL assessment scales (29), with variations in sample populations and concepts. The e-HL framework (24) developed by systematic inductive methods involving inputs from patients and e-health professionals provides a comprehensive view of all the elements that impact a patient's decision to use a particular technology for their health management. The objective of our study was to determine the facilitators and barriers experienced by patients with hypertension in telemonitoring of BP using the e-HL framework. Our research question was "what are the facilitators and barriers that affect the use of technology in remote monitoring of BP?". To fully capture all the intricacies regarding patients' experiences in telemonitoring of BP, our study employed a mixed-methods framework to assess the relationship between the participants' qualitative responses and quantitative e-HL mean scores.

3.2 Methods

3.2.1 Design

The study was a prospective mixed methods study using a convergent parallel design. The quantitative section was an online survey while the qualitative section was phone or online in-depth semi-structured interviews. The consolidated criteria for reporting qualitative research (COREQ) were followed (30). The study was approved by the University of Michigan Institutional Review Board (HUM00179130).

3.2.2 Study Setting and Participants

This was a single-center study at Michigan Medicine, a large academic health institution associated with University of Michigan. Study participants were selected using purposive and convenience sampling. The participants were adults with hypertension who were seen at one of the institution's primary care clinics at least twice in the past one year, had a prescription for at least one hypertension medication, understood the English language, and had phone numbers. Participants were excluded if they had active cancer, a diagnosis of cognitive impairment, or had been admitted to the intensive care unit in the past six months.

Several sources of recruitment were used. An invitation to participate in the study was sent through text messages to prospective participants' phone numbers. Non-respondents received two more messages on two different days after which we did not contact them again. Those who responded to the text message invitation were called, screened for eligibility, and provided with further study details. Consenting participants were sent the survey and interview date scheduled. We first contacted a list of patients who participated in the interactive voice response (IVR) or the MiChart Patient Outreach Text Application (MPOTA) systems within the institution, which utilized automated voice calls and text messages, respectively. The IVR and MPOTA are remote BP monitoring intervention systems set up by health providers at Michigan Medicine. Only 5 of the potential 61 patients chose to participate in the study. We then sought more participants using the institution's online platform for research volunteers. We received 72 interested participants, and 16 were eligible to participate. A total of 21 individuals signed the consent form and participated (Figure 3.1).

3.2.3 Data collection and analysis

The approach of the convergent mixed-methods design used was a parallel collection of the quantitative and qualitative data (31). Quantitative data were collected using an online survey with questions on patients' demographics, patient-provider communication channel preferences, and e-HL. Demographics included age, sex, race, marital status, educational level, employment status, income and co-morbidities, self-rated general health status, and length of time diagnosed with hypertension. Patient-provider communication channel preferences included in-person clinic visits, electronic health records, phone calls, email, video visits, and SMS text messages. Participation in remote BP monitoring was defined as self-measurement of BP and any form of electronic transmission of the measurement to health providers through electronic means such as automatic transfer, text-messaging, phone call, electronic health portal, email, or smartphone apps.

The e-HL was assessed using a validated e-HL questionnaire (e-HLQ), which is a 35-item questionnaire with seven domains (32,33) developed from the e-HL Framework. The seven domains of the e-HL framework have been categorized into three parts representing the individual, the system, and the interaction between the individual and the system. The first two domains provide information on the patient's capability (individual part), the next three domains show the interaction between the patient and digital services (interaction part), and the last two are about the patient's experiences with digital services (system part). The 35 items in the e-HLQ are mapped under the seven domains of the e-HL framework. Each item was rated on a 4-point Likert scale (strongly disagree, disagree, agree, strongly agree). The e-HLQ was validated using both classical test theory and item response theory psychometrics, and the domain items were found to have strong composite scale reliability (CSR). The seven e-HL domain variables include 1. Using technology to process health information (5 items, CSR: 0.84), 2. Understanding health concepts and language (5 items, CSR: 0.75), 3. Ability to actively engage with digital services (5 items, CSR: 0.86), 4. Feel safe and in control (5 items, CSR: 0.87), 5. Motivated to engage with digital services (5 items, CSR: 0.84), 6. Access to digital services that work (6 items, CSR: 0.77), 7. Digital services that suit individual needs (4 items, CSR: 0.85). Each domain score is the average of the individual item scores in the domain. The e-HLQ license was obtained from Swinburne University of Technology, Denmark. The online survey was administered using the Qualtrics® platform and it took about 10 minutes to complete.

Descriptive statistics were used to describe patients' demographics and e-HL domains. Categorical variables were reported as frequencies and percentages while continuous variables were reported as means and standard deviation. The Mann-Whitney U test and Kruskal Wallis test were used to assess the association between e-HL domains, demographics, users, and non-users of remote BP monitoring. All analyses were performed using JJ Allaire R Studio, version 3.6.1.

Qualitative data were collected through an in-depth interview using a phone call or Zoom®. The semi-structured interview guide (Appendix C) was developed from the e-HL framework and literature, piloted and expert-reviewed to establish face validity. Participants were asked questions about hypertension and their experiences with technology in telemonitoring of BP. The patients' interviews were transcribed verbatim using Microsoft® transcription software and verified manually. The transcripts were analyzed by thematic analysis (34). They were first coded using Microsoft® Excel followed by NVivo (Release 1.6) software to ensure validity. CEE and KBF coded the transcripts independently and then met to discuss and agree on the codes. Themes and subthemes were generated from the codes. The themes were grouped accordingly as facilitators or barriers to BP telemonitoring and mapped to the seven domains of the e-HL framework where possible.

3.2.4 Mixed-methods data integration and analysis

The seven domains of the e-HL framework were adapted to remote BP monitoring and used to integrate the quantitative and qualitative results. Integration of the quantitative and qualitative results occurred at the analysis level by connecting the mean e-HL scores with the qualitative responses, merging, and presenting the results in a joint display with meta-inferences. A joint display is a tabular or graphical representation showing how quantitative and qualitative results are integrated to provide a better understanding of the mixed-methods results (35). The individual mean e-HL score ranges for e-HL domains were matched with the corresponding qualitative responses for a side-by-side comparison to assess for concordance or discordance between results and draw meta-inferences. The mean e-HL score ranges were used because the domain mean scores cannot be tied to any participant's response, but the range allows for examination of interview responses of the lowest and highest scoring participants and provides a better understanding and reasonable comparison of the qualitative and quantitative data. Concordance happens when the qualitative and quantitative findings support each other leading to same interpretation, while discordance occurs when the two findings contradict or conflict with each other (36). We examined everyone's transcript and their e-HL scores to be able to draw a comparison between what they experienced and what they answered in the survey. We used the range of e-HL scores such as highest score and lowest score for ease of presentation and understanding. Concordance occurred when the comments from the lower and higher-scoring participants matched the theme being considered. Discordance occurred when there was a disagreement between the participants' scores and their comments regarding the theme in question.

3.3 Results

Thirteen (61.9%) of the 21 participants were aged between 50 and 74 years, and 7 (33.3%) were less than 50 years old (Table 3.1). There were similar numbers of males (52.4%) and females (47.6%). Most participants were non-Hispanic (95.2%), and White (76.2%). All participants had either attempted some college or higher education. About two-thirds of the participants were married and had an annual household income of US $75,001 or more. The mean years of hypertension diagnosis was 8.33 (SD 1.28). Two-thirds of participants (66.7%) had participated in remote BP monitoring.

In-person clinic visits (89%) were the most preferred mode of interaction between participants and their healthcare providers. Electronic health record (87%), phone call (77%), email (74%) and video call (62%) were also included. Convenience and accessibility were the most common reasons for the most preferred interaction method. The least preferred mode of interaction was SMS text messaging (52%), which the participants considered the least satisfying.

The mean scores for the seven domains of e-HLQ for all participants ranged from 3.29 to 3.53. The individual scores ranged from average (2.00) to the highest point possible (4.00). The Mann-Whitney test comparison of the mean (SD) e-HL scores among those who participated in BP remote monitoring and those who did not show statistically significant differences in domains five (Motivated to engage with digital services) and seven (Digital services that suit individual needs) (Table 3.2). No statistically significant differences were found in mean e-HL domain scores compared by demographics (age, gender, ethnicity, race, education level, marital status, patient-rated general health status, income, and comorbidity).

The thematic analysis of the qualitative data identified five main themes including knowledge, motivation, skills, systems, and behaviors along with 28 subthemes comprising facilitators or barriers of BP telemonitoring (Table 3.3). The themes were also grouped into factors that are intrinsic to the individuals (knowledge, motivation, skills, and behaviors) and those that are external to the individual (systems). Exemplary quotes for the themes are provided. Some themes are outright facilitators of BP telemonitoring, e.g., a clinical decision-making tool, where a participant said *"I think it's a great value because it gives the doctor a lot of data. Um, from those three days a week over multiple weeks. That she can make an accurate descriptor recommendation for my health."* Some themes are barriers, e.g., challenge with message timing because of work, with participant's statements such as *"It seemed easy, except that I would forget, say, the message came in and maybe I was at work, I would forget to do it when I get home."* However, some themes can fit into both facilitator and barrier depending on their presence or absence, e.g., awareness of BP telemonitoring, where a participant said *"Well, I would do it anyway, like if I knew about it. I didn't know about that, so"* (barrier) while another participant said *"It's just like you know, like I knew I needed to track my blood pressure and I* *didn't do a good job of it. So it took the technology to get me to track it"* (facilitator). The seven domains of the e-HL framework were adapted to remote BP monitoring. For example, domain 1 became Ability to process BP measurements and information. Domains 1 and 2 align with the knowledge theme, domain 3 aligns with skills, domains 4 and 5 align with motivation, and domains 6 and 7 align with systems. The behavior theme did not fall into any of the domains.

The mixed-methods results were based on the seven domains of the e-HL framework adapted to remote BP monitoring themes (Table 3.4). The mean e-HL score ranges were aligned with the corresponding individual qualitative responses. The meta-inference showed concordance in qualitative and quantitative data for domain 3 and discordance for other domains. For example, in the first domain (ability to process BP measurements and information), and second domain (understanding hypertension as it relates to own health), both the lowest and highest-scoring participants' comments suggest a higher ability to process information and understand hypertension, showing a discordance. In domain four (Feel that they have ownership of their BP measurements and other health data in the systems and the data are safe and only accessible to relevant persons), the participant with the highest mean e-HL score of 4 with a conflicting corresponding response, *"Just, Well, it's just discomforting to know with the concern that the data they take may or may not be safe from hackers"* shows discordance. Participants were asked to rate their proficiency in technology use on a scale of 1 to 10, 10 being the highest proficiency. In domain three (ability to actively engage with BP monitoring and managing digital services), the comment of the highest scoring participant, *"Extremely comfortable Ten. I've written programs for these. I have been a software developer at one time, so I feel very comfortable with the technology",* and that of the lowest scoring participant, *"Mmmm, So you* *know, like not too fancy, but not too horrible, you know, proficiency of 5."* match their mean e-HL scores of 4 and 2.4 respectively, showing a concordance.

3.4 Discussion

In this study, participants involved in remote BP monitoring had significantly higher motivation to engage with digital services and had digital services that suited their individual needs compared to non-participants. We identified five main themes (knowledge, motivation, skills, systems, and behaviors) which included facilitators and barriers to remote BP monitoring. The most referenced facilitators of remote BP monitoring were e-health systems experience, self-efficacy with technology, access to home BP monitor, BP self-monitoring (checking BP by self at home), and convenience and ease of use of the remote BP monitoring process. We included BP self-monitoring as one of the parameters because not everyone who monitors their BP by themselves engages in remote monitoring. Notable barriers to remote BP monitoring included lack of awareness of BP telemonitoring, challenges with message timing due to work schedule, lack of access to a home BP monitor, and trust in the technology. Participants recommended the provision of an accurate wearable BP monitor, automatic transmission of home-measured BP, and peer support as some of the measures to improve engagement with remote BP monitoring.

Within the knowledge theme, our exploratory study found that the understanding of participants' disease condition such as knowing the benefits of management and complications that could arise from uncontrolled hypertension, knowing medications, being aware of body cues, and knowing their BP goals facilitated involvement in remote BP monitoring. Knowledge gain was reported as a facilitator of engagement in remote monitoring in patients with chronic diseases (19) and hypertension (23). This implies that educating patients on their hypertension condition and what is expected to control it (37) is an important basis for participation in remote BP monitoring. Motivation is also an essential factor in getting patients engaged in their health management (38,39). We found that the motivation to engage with remote BP monitoring digital services is facilitated by awareness of BP telemonitoring, convenience and ease of use of the digital services, the value gained by engagement such as improved communication with a health care provider, and clinical decision making. Similar facilitators such as improved motivation, ease of use monitoring devices, better patient-provider communication, reduction in office visits, shared decision making, and timely and accessible care have been reported to increase patient involvement in remote disease monitoring (19–20,22). Having the appropriate skills to use any remote monitoring services facilitates engagement with the service (24,40). There should be adequate training of patients and provision of readily available technical support to boost their comfort with the remote monitoring service. In addition to knowledge, motivation, and skill, external factors may also impact remote BP monitoring.

Engagement in remote BP monitoring services is not solely dependent on the patient's knowledge and skills. The health system has an important role to play by increasing access to digital resources, improving trust in technology, and ensuring the e-health system that suits individual patient needs. Access to digital services can be increased by reducing the cost of technology devices and providing insurance coverage for technology used by patients in BP telemonitoring. Remote BP monitoring could be integrated into health providers' routine workflow and reimbursement offered for the monitoring services. Remote BP monitoring interventions should be designed with patient input and tailored toward individual patient requirements. Studies have shown that selecting the right patient for remote monitoring interventions is essential for adherence and positive health outcomes (41). Patients' behaviors such as BP self-monitoring, medication adherence, and healthy lifestyle adherence play a significant role in BP control and overall health (42–44). A study of participants with hypertension showed that those already engaged in a behavior such as electronic communication with their healthcare provider were more likely to engage in another level of behavior like sending or receiving SMS text messages from their healthcare provider (21). In essence, the exhibition of positive behaviors towards BP control may facilitate engagement in remote BP monitoring and can be used by providers to identify potential participants.

The barriers to engagement in BP telemonitoring are essentially the opposite of the facilitators mentioned above. Some patients also expressed trust in their clinic visits with their healthcare provider, such that they do not feel they need to engage in an extra activity like remote BP monitoring. The challenges with technology usage such as security, accessibility, and operational issues in this study aligned with patients' highest preference for direct in-person contact as a means of interaction with their healthcare providers. Direct contact physician care preferences have been reported in other studies (45,46). Technology is here to augment in-person services and should be made easy, accessible, and secure in a way that spurs an increase in usage to free up clinic time for necessary in-person services. Patients are more willing to use digital services if they understand the benefits it adds to their health (47,48).

Patients with hypertension in this study collectively had high e-HL in all domains of the e-HL framework, and this high e-HL may explain why two-thirds of them were engaged in remote BP monitoring. Higher e-HL has been linked to greater engagement in digital services (49,50). The e-HL was not significantly associated with the participants' demographics such as age, gender, race, marital status, income, or educational level. Our findings differ from a study of 110 older Thai adults ≥ 60 years with hypertension and mostly (76%) income below US $30,000

(51), where higher e-HL was associated with being male and having higher income but not with age, educational level, or marital status. Studies on 247 patients with hypertension or diabetes, ≥ 50 years and mostly White-Hispanic (40), and that of Asian patients with hypertension, diabetes and coronary heart disease, mean age 47 years (SD 12.51) and mostly female (56.5%) (52) reported low e-HL to be associated with older age and lower educational levels. Similar association was also found among 453 Australian people with cardiovascular disease diagnosis or risk including systolic BP ≥ 180mmHg, diastolic BP ≥ 110mmHg, heart disease, stroke or transient ischemic attack, peripheral vascular disease (53). All these studies used the eHealth literacy scale (eHEALS) to measure e-HL. A study on 246 Danish adult patients with diabetes and/or gastrointestinal diseases and mean age of 56.5 years (range 18-89) that utilized e-HLQ found that lower age was associated with a higher ability to engage with digital services while lower educational status was weakly associated with an increase in feeling safe, in control and access to digital services that work (54). The differences between our study findings and these studies could be due to differences in study population characteristics, sample size, or the disease conditions accounted for. Our study is the first to our knowledge to use e-HLQ to assess e-HL among people with hypertension. We found, however, that those who telemonitor their BP were significantly more motivated to use remote BP monitoring services (domain 5) and tended to have remote BP monitoring services that suit their needs (domain 7) than those who do not telemonitor BP. Though we could not find a comparable study on remote BP monitoring, Holt et al. who used e-HLQ in their study found that adult patients with diabetes and/or gastrointestinal diseases who are users of the national health portal have significantly higher e-HL in all domains except domain 4 (feel safe and in control of health data) when compared with non-users (54).

This underscores the importance of willingness on the part of patients to take charge of their health and the health system providing the necessary resources to boost that motivation.

In our mixed-methods joint display (Table 4), the lack of alignment of the participants' e-HLQ scores to their qualitative responses could be because the questionnaire was not specific to remote BP monitoring. It could also be due to participants' perception of their knowledge and skills at the different times of answering the survey and the interview questions. Based on our findings, we recommend more studies on patients with hypertension using the e-HL framework to fully understand the relationship between patient's e-HL and their remote BP monitoring experiences. Future studies could adapt the e-HLQ to remote BP monitoring to ensure participants have the same context in the qualitative and quantitative study.

Our study has some limitations. We used a convenience sample of 21 participants with hypertension who were mostly White, have some college or higher education and have an annual household income in the middle or upper class. The participants may have responded from experiences unique to them. Sampling participants digitally and using electronic survey may have biased our sample in favor of those with higher e-HL. It is possible we may not have captured all the factors affecting e-HL, such as social or cultural context with the instrument we used. The findings may not be generalizable to all the hypertension population, but it provides a good insight into what may be obtainable. Our mixed-methods approach makes the study more robust.

Future studies should explore remote BP monitoring practices and their relationship with e-HL in a larger and more diverse hypertension population. With the availability of several e-HL assessment scales, testing two or more on the same hypertension sample may be worthwhile to provide a better inference on e-HL status.

3.5 Conclusion

Patients with higher e-HL are more likely to use BP telemonitoring. Patients may engage with BP telemonitoring when they feel the usefulness of concurrent access to telemonitoring services that suit their needs.

3.6 References

1. Tsao CW, Aday AW, Almarzooq ZI, Alonso A, Beaton AZ, Bittencourt MS, et al. Heart Disease and Stroke Statistics—2022 Update: A Report From the American Heart Association. Circulation [Internet]. 2022 Feb 22;145(8):e153–639. Available from: https://doi.org/10.1161/CIR.0000000000001052
2. U.S. Department of Health and Human Services. The Surgeon General's Call to Action to Control Hypertension. Washington, DC: U.S. Department of Health and Human Services, Office of the Surgeon General; 2020. 2020;
3. Telehealth is here to stay. Nat Med [Internet]. 2021;27(7):1121. Available from: https://doi.org/10.1038/s41591-021-01447-x
4. Blandford A, Wesson J, Amalberti R, AlHazme R, Allwihan R. Opportunities and challenges for telehealth within, and beyond, a pandemic. Lancet Glob Heal. 2020;8(11):e1364–5.
5. Omboni S, McManus RJ, Bosworth HB, Chappell LC, Green BB, Kario K, et al. Evidence and recommendations on the use of telemedicine for the management of arterial hypertension: An international expert position paper. Hypertension. 2020;76(5):1368–83.
6. What is Telehealth ? NEJM Catal Innov Care Deliv [Internet]. 2018;8. Available from: https://catalyst.nejm.org/doi/full/10.1056/CAT.18.0268
7. Meystre S. The Current State of Telemonitoring: A Comment on the Literature. Telemed e-Health [Internet]. 2005 Feb 1;11(1):63–9. Available from: https://doi.org/10.1089/tmj.2005.11.63
8. De Farias FACD, Dagostini CM, Bicca YDA, Falavigna VF, Falavigna A. Remote patient monitoring: A systematic review. Telemed e-Health. 2020;26(5):576–83.

9. Paré G, Jaana M, Sicotte C. Systematic Review of Home Telemonitoring for Chronic Diseases: The Evidence Base. J Am Med Informatics Assoc. 2007;14(3):269–77.

10. Pandor A, Thokala P, Gomersall T, Baalbaki H, Stevens JW, Wang J, et al. Home telemonitoring or structured telephone support programmes after recent discharge in patients with heart failure: systematic review and economic evaluation. Health Technol Assess. 2013;17(32):1-207

11. Logan AG, Jane Irvine M, McIsaac WJ, Tisler A, Rossos PG, Easty A, et al. Effect of home blood pressure telemonitoring with self-care support on uncontrolled systolic hypertension in diabetics. Hypertension. 2012;60(1):51–7.

12. Wang JB, Cadmus-Bertram LA, Natarajan L, White MM, Madanat H, Nichols JF, et al. Wearable Sensor/Device (Fitbit One) and SMS Text-Messaging Prompts to Increase Physical Activity in Overweight and Obese Adults: A Randomized Controlled Trial. Telemed e-Health. 2015;21(10):782–92.

13. Telehealth and remote patient monitoring [Internet]. 2022. Available from: https://telehealth.hhs.gov/providers/preparing-patients-for-telehealth/telehealth-and-remote-patient-monitoring/

14. Tucker KL, Sheppard JP, Stevens R, Bosworth HB, Bove A, Bray EP, et al. Self-monitoring of blood pressure in hypertension: A systematic review and individual patient data meta-analysis. PLoS Med. 2017;14(9):1–29.

15. Park SH, Shin JH, Park J, Choi WS. An updated meta-analysis of remote blood pressure monitoring in urban-dwelling patients with hypertension. Int J Environ Res Public Health. 2021;18(20):10583

16. Brahmbhatt DH, Cowie MR. Remote Management of Heart Failure: An Overview of

Telemonitoring Technologies. Card Fail Rev. 2019;5(2):86–92.

17. Chirra M, Marsili L, Wattley L, Sokol LL, Keeling E, Maule S, et al. Telemedicine in Neurological Disorders: Opportunities and Challenges. Telemed e-Health. 2019;25(7):541–50.

18. Sin DYE, Guo X, Yong DWW, Qiu TY, Moey PKS, Falk MR, et al. Assessment of willingness to Telemonitoring interventions in patients with type 2 diabetes and/or hypertension in the public primary healthcare setting. BMC Med Inform Decis Mak. 2020;20(1):1–11.

19. Walker RC, Tong A, Howard K, Palmer SC. Patient expectations and experiences of remote monitoring for chronic diseases: Systematic review and thematic synthesis of qualitative studies. Int J Med Inform [Internet]. 2019;124(January):78–85. Available from: https://doi.org/10.1016/j.ijmedinf.2019.01.013

20. Palacholla RS, Fischer N, Coleman A, Agboola S, Kirley K, Felsted J, et al. Provider-And patient-related barriers to and facilitators of digital health technology adoption for hypertension management: Scoping review. J Med Internet Res. 2019;21(3):1–12.

21. Eze CE, West BT, Dorsch MP, Coe AB, Lester CA, Buis LR, et al. Predictors of Smartphone and Tablet Use among Patients with Hypertension: Secondary Analysis of Health Information National Trends Survey Data. J Med Internet Res. 2022;24(1):1–23.

22. Grant S, Hodgkinson J, Schwartz C, Bradburn P, Franssen M, Hobbs FDR, et al. Using mHealth for the management of hypertension in UK primary care: An embedded qualitative study of the TASMINH4 randomised controlled trial. Br J Gen Pract. 2019;69(686):E612–20.

23. Mileski M, Kruse CS, Catalani J, Haderer T. Adopting Telemedicine for the Self-

Management of Hypertension: Systematic Review. JMIR Med Informatics. 2017;5(4):e41.

24. Norgaard O, Furstrand D, Klokker L, Karnoe A, Batterham R, Kayser L, et al. Knowledge Management & E-Learning The e-health literacy framework: A conceptual framework for characterizing e-health users and their interaction with e- health systems. Knowl Manag E-Learning. 2015;7(74):522–40.

25. Norman CD, Skinner HA. eHealth literacy: Essential skills for consumer health in a networked world. J Med Internet Res. 2006;8(2):1–17.

26. Gilstad H. Toward a comprehensive model of eHealth literacy. CEUR Workshop Proc [Internet]. 2014;1251(Pahi):63–72. Available from: http://ceur-ws.org/Vol-1251/paper7.pdf

27. Robert Bautista J. From solving a health problem to achieving quality of life: redefining eHealth literacy. J Lit Technol [Internet]. 2015;16(2):33–54. Available from: http://www.literacyandtechnology.org/uploads/1/3/6/8/136889/jlt_v16_2_bautista.pdf

28. Paige SR, Stellefson M, Krieger JL, Anderson-Lewis C, Cheong JW, Stopka C. Proposing a transactional model of eHealth literacy: Concept analysis. J Med Internet Res. 2018;20(10).

29. Lee J, Lee EH, Chae D. eHealth literacy instruments: Systematic review of measurement properties. J Med Internet Res. 2021;23(11):1–27.

30. Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): A 32-item checklist for interviews and focus groups. Int J Qual Heal Care. 2007;19(6):349–57.

31. Fetters MD, Curry LA, Creswell JW. Achieving integration in mixed methods designs - Principles and practices. Health Serv Res. 2013;48(6 PART2):2134–56.

32. Kayser L, Karnoe A, Furstrand D, Batterham R, Christensen KB, Elsworth G, et al. A multidimensional tool based on the eHealth Literacy Framework: Development and initial validity testing of the eHealth Literacy Questionnaire (eHLQ). J Med Internet Res. 2018;20(2):1–10.

33. Cheng C, Elsworth G, Osborne RH. Validity evidence based on relations to other variables of the eHealth literacy questionnaire (eHLQ): Bayesian approach to test for known-groups validity. J Med Internet Res. 2021;23(10):1–29.

34. Kiger ME, Varpio L. Thematic analysis of qualitative data: AMEE Guide No. 131. Med Teach [Internet]. 2020;42(8):846–54. Available from: https://doi.org/10.1080/0142159X.2020.1755030

35. Creswell JW, Clark VLP. Designing and Conducting Mixed Methods Research Third Edition. 3rd ed. Sage Publications. SAGE, Thousand Oaks, CA; 2018.

36. Fetters MD. Developing a joint display. In MD Fetters, The mixed methods research workbook- Activities for designing, implementing, and publishing projects. Sage Publication. SAGE, Thousand Oaks, CA; 2020 (pp. 193-210).

37. Paterick TE, Patel N, Tajik J, Chandrasekaran K. Improving health outcomes through Patient education and Partnerships with patients. Proc (Bayl Univ Med Cent). 2017;30(1):112–3.

38. McCarron TL, Noseworthy T, Moffat K, Wilkinson G, Zelinsky S, White D, et al. Understanding the motivations of patients: A co-designed project to understand the factors behind patient engagement. Heal Expect. 2019;22(4):709–20.

39. Hosseini F, Alavi NM, Mohammadi E, Sadat Z. Scoping review on the concept of patient motivation and practical tools to assess it. Iran J Nurs Midwifery Res. 2021;26(1):1–10.

40. Price-Haywood EG, Harden-Barrios J, Ulep R, Luo Q. EHealth Literacy: Patient Engagement in Identifying Strategies to Encourage Use of Patient Portals Among Older Adults. Popul Health Manag. 2017;20(6):486–94.

41. Thomas EE, Taylor ML, Banbury A, Snoswell CL, Haydon HM, Gallegos Rejas VM, et al. Factors influencing the effectiveness of remote patient monitoring interventions: A realist review. BMJ Open. 2021;11(8).

42. AlHadlaq RK, Swarelzahab MM, AlSaad SZ, AlHadlaq AK, Almasari SM, Alsuwayt SS, et al. Factors affecting self-management of hypertensive patients attending family medicine clinics in Riyadh, Saudi Arabia. J Fam Med Prim Care [Internet]. 2019;8(12):4003–9. Available from: http://www.jfmpc.com/article.asp?issn=2249-4863;year=2017;volume=6;issue=1;spage=169;epage=170;aulast=Faizi

43. Etminani K, Engström AT, Göransson C, Sant'Anna A, Nowaczyk S. How Behavior Change Strategies are used to Design Digital Interventions for Improving Medication Adherence and Blood Pressure among Patients with Hypertension: A Systematic Review (Preprint). J Med Internet Res. 2020;22(4).

44. Allen ME, Irizarry T, Einhorn J, Kamarck TW, Suffoletto BP, Burke LE, et al. SMS-facilitated home blood pressure monitoring: A qualitative analysis of resultant health behavior change. Patient Educ Couns. 2019;102(12):2246–53.

45. Vo V, Auroy L, Sarradon-Eck A. Patients' perceptions of mhealth apps: Meta-ethnographic review of qualitative studies. JMIR mHealth uHealth. 2019;7(7):1–20.

46. Breil B, Salewski C, Apolinário-Hagen J. Comparing the Acceptance of Mobile Hypertension Apps for Disease Management Among Patients Versus Clinical Use Among Physicians: Cross-sectional Survey. JMIR Cardio. 2022;6(1).

47. Holderried M, Hoeper A, Holderried F, Heyne N, Nadalin S, Unger O, et al. Attitude and potential benefits of modern information and communication technology use and telemedicine in cross-sectoral solid organ transplant care. Sci Rep [Internet]. 2021;11(1):9037. Available from: https://doi.org/10.1038/s41598-021-88447-6

48. Terp R, Kayser L, Lindhardt T. Older patients⇔ competence, preferences, and attitudes toward digital technology use: Explorative study. JMIR Hum Factors. 2021;8(2):1–24.

49. Madrigal L, Escoffery C. Electronic health behaviors among US adults with chronic disease: Cross-sectional survey. J Med Internet Res. 2019;21(3).

50. Ghaddar S, Vatcheva KP, Alvarado SG, Mykyta L. Understanding the intention to use telehealth services in underserved hispanic border communities: Cross-sectional study. J Med Internet Res. 2020;22(9):1–23.

51. Rojanasumapong A, Jiraporncharoen W, Nantsupawat N, Gilder ME, Angkurawaranon C, Pinyopornpanish K. Internet use, electronic health literacy, and hypertension control among the elderly at an urban primary care center in thailand: A cross-sectional study. Int J Environ Res Public Health. 2021;18(18).

52. Lee WL, Lim ZJ, Tang LY, Yahya NA, Varathan KD, Ludin SM. Patients' technology readiness and ehealth literacy implications for adoption and deployment of eHealth in the Covid-19 era and beyond. CIN - Comput Informatics Nurs. 2022;40(4):244–50.

53. Richtering SS, Hyun K, Neubeck L, Coorey G, Chalmers J, Usherwood T, et al. EHealth literacy: Predictors in a population with moderate-to-high cardiovascular risk. JMIR Hum Factors. 2017;4(1):1–15.

54. Holt KA, Karnoe A, Overgaard D, Nielsen SE, Kayser L, Røder ME, et al. Differences in the level of electronic health literacy between users and nonusers of digital health

services: An exploratory survey of a group of medical outpatients. J Med Internet Res. 2019;21(4).

Table 3.1 Participants' demographics

Variable and Category		Total N=21, (%)	Remote BP monitoring, n= 14, (%)	Not Remote BP monitoring, n = 7, (%)	P-value
Age in years					0.19
	<50	7 (33.3)	6 (42.9)	1 (14.3)	
	50 -74	13 (61.9)	8 (57.1)	5 (71.4)	
	75+	1 (4.8)	0 (0.0)	1 (14.3)	
Gender					0.88
	Male	11(52.4)	8 (57.1)	3 (42.9)	
	Female	10 (47.6)	6 (42.9)	4 (57.1)	
Ethnicity					1.00
	Hispanic	1 (4.8)	1 (7.1)	0 (0.0)	
	Non-Hispanic	20 (95.2)	13 (92.9)	7 (100.0)	
Race					0.47
	White	16 (76.2)	11 (78.6)	5 (71.4)	
	Black or African American	1 (4.8)	1 (7.1)	0 (0.0)	
	Asian	1 (4.8)	0 (0.0)	1 (14.3)	
	Other	3 (14.3)	2 (14.3)	1 (14.3)	
Education level					0.19
	Some college	6 (28.6)	4 (28.6)	2 (28.6)	
	Bachelor’s degree	8 (38.1)	7 (50.0)	1 (14.3)	
	Post-Baccalaureate	7 (33.3)	3 (21.4)	4 (57.1)	
Marital status					0.16
	Married	13 (61.9)	10 (71.4)	3 (42.9)	
	Single	1 (4.8)	0 (0.0)	1 (14.3)	
	Divorced	5 (23.8)	2 (14.3)	3 (42.9)	
	Living as married	2 (9.5)	2 (14.3)	0 (0.0)	
General health status					0.33
	Very good	6 (28.6)	3 (21.4)	3 (42.9)	
	Good	12 (57.1)	8 (57.1)	4 (57.1)	
	Fair	3 (14.3)	3 (21.4)	0 (0.0)	
Annual household Income					0.54
	Less than US$20,000	2 (9.5)	1 (7.1)	1 (14.3)	
	US$20,000 - US$35,000	2 (9.5)	1 (7.1)	1 (14.3)	
	US$35,001 - US$50,000	1 (4.8)	0 (0.0)	1 (14.3)	
	US$50,001 - US$75,000	3 (14.3)	2 (14.3)	1 (14.3)	
	US$75,001 or more	13 (61.9)	10 (71.4)	3 (42.9)	
Comorbidity					0.55
	Heart disease and diabetes	1 (4.8)	0 (0.0)	1 (14.3)	
	Diabetes	1 (4.8)	1 (7.1)	0 (0.0)	
	Diabetes and Depression or anxiety	1 (4.8)	1 (7.1)	0 (0.0)	
	Depression or anxiety	3 (14.3)	1 (7.1)	2 (28.6)	
	Depression or anxiety and other	3 (14.3)	2 (14.3)	1 (14.3)	
	Other	5 (23.8)	4 (28.6)	1 (14.3)	
	None	7 (33.3)	5 (35.7)	2 (28.6)	
Hypertension history in years (mean (SD))		8.33 (1.28)	8.14 (1.46)	8.71 (0.76)	0.35
Hypertension medications (mean (SD))		1.48 (0.75)	1.57 (0.85)	1.29 (0.49)	0.42
Other medications (mean (SD))		2.43 (2.16)	2.64 (2.41)	2.00 (1.63)	0.53

BP: Blood pressure; N: Total number of study participants; n: number of participants in subgroups

Table 3.2 e-HL mean scores dichotomized by those who use RBPM versus not

e-HLQ Domains	Total Participants Mean (SD) scores, N=21	RBPM participants' mean (SD) scores, n= 14	Non-RBPM participants' mean (SD) scores, n =7	P-value
1. Using technology to process health information	3.38 (0.53)	3.50(0.53)	3.14(0.49)	0.15
2. Understanding health concepts and language	3.33 (0.46)	3.43(0.44)	3.14(0.49)	0.23
3. Ability to actively engage with digital services	3.53 (0.53)	3.64(0.45)	3.31(0.63)	0.30
4. Feel safe and in control	3.30 (0.53)	3.41(0.45)	3.09(0.65)	0.16
5. Motivated to engage with digital services	3.44 (0.49)	3.63(0.32)	3.06(0.56)	0.02
6. Access to digital services that work	3.38 (0.54)	3.55(0.40)	3.05(0.65)	0.08
7. Digital services that suit individual need	3.29 (0.61)	3.50(0.49)	2.86(0.63)	0.03
Average		3.52 (0.09)	3.09(0.13)	0.04

e-HLQ: e-Health literacy questionnaire; RBPM: Remote blood pressure monitoring; N: Total number of study participants; n: number of participants in subgroups; SD: standard deviation.

Table 3.3 Facilitators and barriers of technology use in RBPM

Themes	e-HLF adapted domains	Subthemes	Facilitator	Barrier
Internal factors				
1. Knowledge				
	Ability to process blood pressure measurements and information	Knowledge of blood pressure goals *"They gave me a target. They said that anything below that is good and anything above that is bad. So I've been keeping track of it" (RBPM participant)*	√	√
		Self-health information seeking with technology. *"you have to go searching for it, so that's exactly what I did in the Example that I gave. In taking a look at particularly white coat hypertension" (Non-RBPM participant)*	√	√
	Understanding hypertension as it relates to own health	Knowledge of benefits hypertension management. *"To keep my blood pressure down Um? Just so I don't have further complications as time goes along." (RBPM participant)*	√	√
		Knowledge of complications of uncontrolled hypertension. *"my family background, Uhm, my parents and siblings have hypertension and I know It's made other organs, It's affected other organs like my dad had kidney disease from that and when he was older, Uhm, he had a stroke and they were unable to control his hypertension and I know the stroke resulted from his having high blood pressure that was hard to control" (RBPM participant)*	√	√
		Hypertension medication knowledge. *"it's important that you keep track of you know your medication, how much you take, how often you take" (Non-RBPM participant)*	√	
		Body changes awareness/cues. *"I can typically tell when it's not because I will either get lightheaded or I can feel my heart racing and uhm, I don't have either of those symptoms. Those are the symptoms that kind of Clue me in on whether or not my blood pressure is either way rarely low, but if it's high you know, I'll get the fluttering failure and then" (Non-RBPM participant)*	√	

Themes	e-HLF adapted domains	Subthemes	Facilitator	Barrier
2. Motivation				
	Motivated to engage with remote blood pressure digital services	Awareness of BP telemonitoring. *"No, I was not aware of that [remote BP monitoring]" (Non-RBPM participant)*	√	√
		Convenience and ease of use. *"I think this is convenient and easy." (RBPM participant)*	√	√
		Better communication with healthcare providers. *"It allows me to Communicate better with my Health care providers". (RBPM participant)*	√	√
		Challenge with message timing because of work schedule. *"It seemed easy, except that I would forget, say, the message came in and maybe I was at work, I would forget to do it when I get home." (RBPM participant)*		√
		Clinical decision-making tool. *"I think it's a I think it's a great value because it gives the doctor a lot of data. Um, from those three days a week over multiple weeks. That she can make an accurate descriptor recommendation for my health." (RBPM participant)*	√	
	Feel that they have ownership of their blood pressure measurements and other health data in the systems and the data are safe and only accessible to relevant persons.	Health care provider trust. *"I could do a better job of Getting on the online portal at U of M and signing up for that so that I have access to my all my overall health more readily I I, but I trust my doctors there" (RBPM participant)*		√
		Concern for data security and integrity. *"Just, Well, it's just discomforting to know with the concern that the data they take may or may not be safe from hackers Knowing a lot about that." (RBPM participant)*		√

Themes	e-HLF adapted domains	Subthemes	Facilitator	Barrier
3. Skills				
	Ability to actively engage with blood pressure monitoring and managing digital services	Excellent home BP self-monitoring technique. *"Oh OK, so I have one that's electronic. I would get the monitor and sit. Where my legs weren't crossed. And where I was calm and comfortable, but with my arms resting, put some monitor on my arm and let it you know, hit the button. So it started. It would pump up and take the pressure" (RBPM participant)*	√	√
		Self-efficacy with technology. *"Extremely comfortable Ten. I've written programs for these. I have been a software developer at one time, so I feel very comfortable with the technology" (RBPM participant)*	√	√
		Training. *"I'm very comfortable (with technology) as long as you train me" (RBPM participant)*	√	√

Themes	e-HLF adapted domains	Subthemes	Facilitator	Barrier
External factors				
4. Systems				
	Access to remote blood pressure monitoring digital services that work	Access to home BP monitor. *“Uh, well, you know before I never had a machine at home, so I really, I mean, originally I didn't have a blood pressure machine at home, so I would have to go to the doctor or I would have to go to like a pharmacy that had the uhm, They used to have Machines at the pharmacy you could use, but, Then you don't really know. You have to get something consistent. If I can use the one at home, I know how it is, uhm, consistently.” (RBPM participant)*	√	√
		Technology trust. *“I don't think that they gave accurate readings, so I never really knew if my blood pressure was too high or not because I could take two readings 10 minutes apart or 20 minutes apart and one would be kind of low and the other will be high. You know, I never trusted it. So I felt that I I really wasn't learning anything about my actual blood pressure.” (Non-RBPM participant)*	√	√
		Access to Smartphone. *“I have an Android phone which is a smartphone and that allows me to use the portal.” (RBPM participant)*	√	√
		Access to tablet. *“I have a tablet” (Non-RBPM participant)*	√	√
		Access to computer. *“OK, I have a computer.” (RBPM participant)*	√	√
	Remote BP monitoring digital services that suit individual needs	Adapting services to patients’ needs. *“It started out, I had to do it every week and then it reduced down to every I think like once every three weeks. And then now it just went down to once in a Quarter.” (RBPM participant)*	√	
		Ehealth system experience. *“It's gotten better and better the patient portal. Um, it, you know, I've been a patient at U of M for about 20 years I think, and maybe longer. Yeah, early 90s. Um? It's gotten so much better” (RBPM participant)*	√	√

Themes	e-HLF adapted domains	Subthemes	Facilitator	Barrier
5. Behaviors				
		BP self-monitoring. *"I have a blood pressure cuff here at home. I monitor it myself once a week." (RBPM participant)*	√	
		Action/action plan to aid BP monitoring. *"I went and looked for anything technology wise that could help me with that. And I found A blood pressure device." (RBPM participant)*	√	
		Medication adherence. *"I have a pill box with Monday through Sunday and I take them every morning when I go to work." (RBPM participant)*	√	
		Diet, Exercise and related behaviors "*We have mainly a plant-based diet and we cook almost all of our own food, so we're able to greatly limit the salt intake as compared to buying Prepared foods or eating out. The other is I exercise daily." (RBPM participant)*	√	
		Advocacy *"So I mean, if people had the proper equipment. You know, and some more knowledge to go with that. I mean, you know we probably could knock the numbers down a little bit." (Non-RBPM participant)*	√	

RBPM: Remote Blood Pressure Monitoring; e-HLF: e-Health literacy framework.

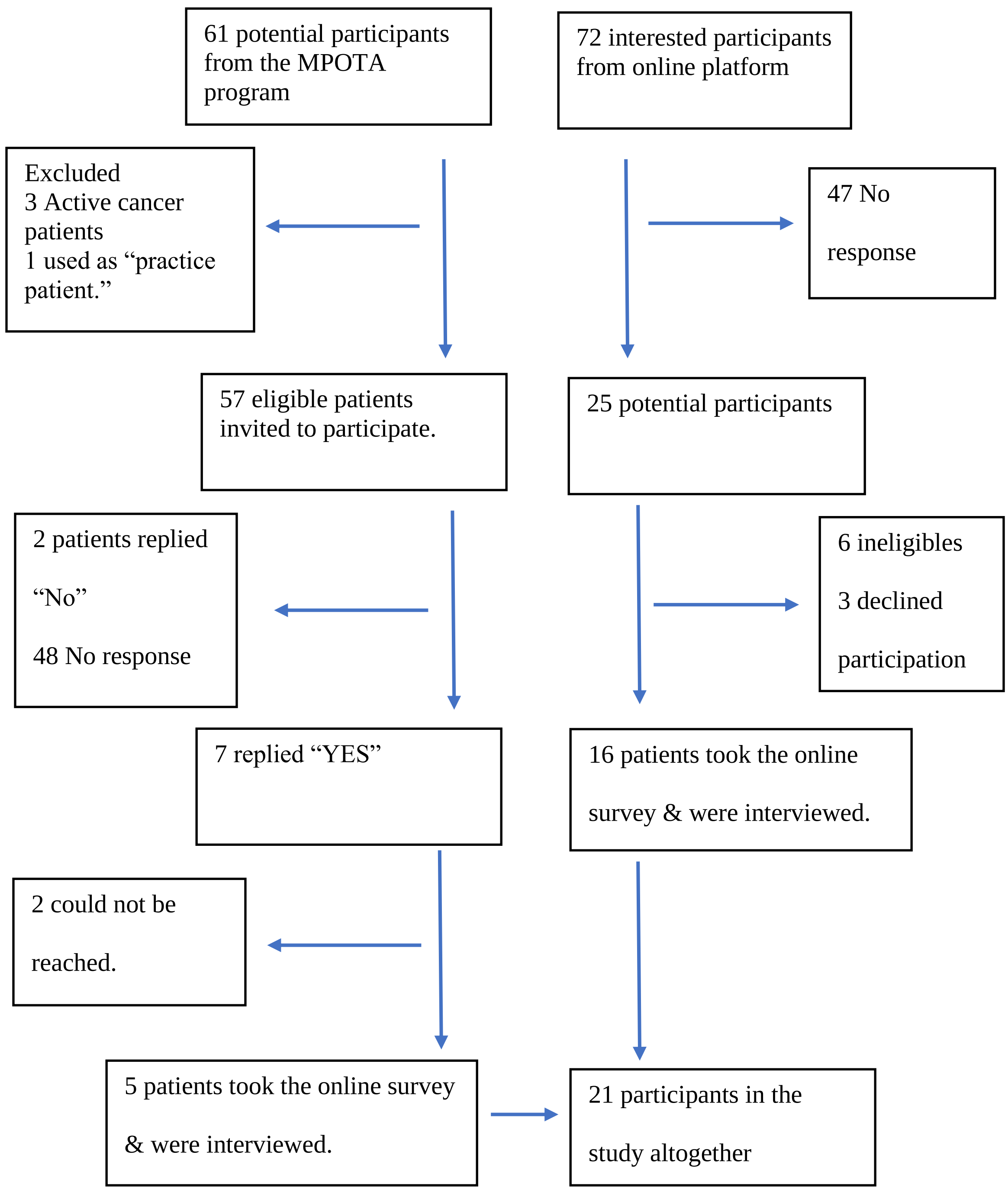
Table 3.4 Joint display of the relationship between e-HL mean scores and RBPM themes

Remote BP monitoring Themes	Average eHL mean (SD) scores [Mean (SD) score range]	Example quotes from the interview	Meta inference
Ability to process BP measurements and information	3.38 (0.53) [2.40(0.55) – 4.00 (0.00)]	*"They gave me a target. They said that anything below that is good and anything above that is bad. So I've been keeping track of it" (RBPM participant)* *"It (BP) is under control now…I check my blood pressure Monday, Wednesday and Friday" (RBPM participant)*	Discordance The participants' comments suggest a higher ability to process information that does not match the lower range score.
Understanding hypertension as it relates to own health	3.33 (0.46) [2.40 (0.55) – 4.00 (0.00)]	*"I know that with the hypertension there can be a lot of really bad effects further down the line up heart can heart problems. It can also interact with diabetes. You can have strokes. Uhm, so there are number of side effects to just hypertension that can be really bad if you don't take care of it and keep it under control." (Non-RBPM participant)* *"Because if you are monitoring yourself and your blood pressure is high, You're gonna do something probably try to take that down. That would have made you probably get up and go Because you know, nobody wanna die." (Non-RBPM participant)*	Discordance The participants' comments suggest a higher understanding of hypertension which does not match the lower-range score
Ability to actively engage with BP monitoring and management digital services	3.53 (0.53) [2.40 (0.55) – 4.00 (0.00)]	*"Extremely comfortable Ten. I've written programs for these. I have been a software developer at one time, so I feel very comfortable with the technology" (RBPM participant)* *"Mmmm, So you know, like not too fancy, but not too horrible, you know, proficiency of 5." (Non-RBPM participant)*	Concordance The comments of the lower and higher-scoring participants match their level of engagement with technology
Feel that they have ownership of their BP measurements and other health data in the systems and the data are safe and only accessible to relevant persons	3.30 (0.53) [2.40 (0.55) – 4.00 (0.00)]	*"Just, Well, it's just discomforting to know with the concern that the data they take may or may not be safe from hackers Knowing a lot about that." (RBPM participant)* *"No comment" (Non-RBPM participant)*	Discordance The higher-scoring participants' comments expresses concern for data safety while there was no record of such concerns expressed by those in the lower-score range

Remote BP monitoring Themes	Average eHL mean (SD) scores [Mean (SD) score range]	Example quotes from the interview	Meta inference
Motivated to engage with remote BP digital services	3.44 (0.49) [2.20 (0.45) – 4.00 (0.00)]	*"Well, I would do it (remote BP monitoring) anyway, like if I knew about it. I didn't know about that, so. Because I tend to get, I think that is common thing for a lot of people, when your blood pressure is controlled for a long time and you're doing great, you kind of push it to the side. And as soon as you do that, that's when you fall off the wagon so the text messaging would definitely help me". (RBPM participant)* *"To I mean, to a certain degree, yeah, I mean they do help. I mean by supplying you with knowledge, you know But I think ultimately It's up to the individual, you know to. I believe in that lifestyle change. You know, I think ultimately it's up to the individual to do some soul searching, make some changes in their life. You know technology can definitely help assist you in that you know that you know the journey. But ultimately, yeah, it does. So it does answer the question. Yeah, it helps, so it is a valuable tool." (Non-RBPM participant)*	Discordance The participants' comments suggest higher motivation to engage with digital services which does not match the lower-range score
Access to remote BP monitoring digital services that work	3.38 (0.54) [2.00 (0.63) – 4.00 (0.00)]	*"So I use the blood pressure monitor that is like on my wrist. And turn it's Bluetooth enabled so I can connect to my phone." (RBPM participant)* *"I have computer, smartphone, Sphyg and stethoscope" (Non-RBPM participant)*	Discordance The participants' comments suggest they have digital services that work which does not match the lower range score
Remote BP monitoring digital services that suit individual needs	3.29 (0.61) [2.25 (0.50) – 4.00 (0.00)]	*"I would record it at home and then I would input all of my weekly blood pressure measurements in and then send it so it would be like every week." (RBPM participant)* *"No comment" (Non-RBPM participant)*	Discordance The higher-scoring participants' comments suggest they have services that suit their needs while there was no record of comments to support the lower score range

Note: The green texts are participants' quotes corresponding to the highest e-HL score range while the red texts correspond to the lowest e-HL score range. e-HL: e-Health literacy.
"No comment" means there was no statement by the lower scoring participants against the remote BP monitoring theme under consideration to match the lower scores.

Figure 3.1 Flow Chart of Recruitment



Chapter 4 Paper 3 Remote Blood Pressure Monitoring: Electronic Health Literacy and Behavioral Factors related to Participation

4.1 Introduction

Remote blood pressure monitoring (RBPM) or blood pressure (BP) telemonitoring is an important hypertension (HTN) management strategy that involves electronic transfer of self-measured BP from the patient's home to their doctor or doctor's office with subsequent feedback based on the transmitted BP measurements.(1) RBPM offers many benefits to both patients and healthcare providers.(1–3) The patients are able to save time and cost of healthcare by reducing clinic visits, be more engaged in their disease management, and gain better understanding of their HTN and how to keep it under control. The healthcare providers can follow their patients more closely, make timely health decisions and so provide improved quality of care to their patients. Various studies have demonstrated greater improvement in BP control among patients engaged in RBPM compared to those in usual care.(1,2,4–8) However, to reap the benefits of RBPM, patients need to engage in the RBPM program.(9–11) Patients' engagement in RBPM is dependent on various factors which may be technological-, health system-, or patient-related. The technology needs to be simple and user-friendly. The health system has the responsibility of making these technological services available with adequate resources and manpower to operate them.(12,13)

Patient-related factors that may influence RBPM engagement include patient's demographics, technology health behaviors, poor electronic health literacy (e-HL), lack of understanding of the risks associated with uncontrolled HTN, lack of access to simple adequate technologies, concerns about privacy, health data integrity and security.(2,5,12,14–16) Technology health behaviors refer to technology-related actions taken by patients to improve their health. Technology health behaviors such as electronic health information sharing between patients and their healthcare providers have helped to improve communication and shared decision making between both parties.(17) The health information sharing could be done through the electronic health portals, or mHealth devices including tablet computers and mobile phones. Adults with one or more chronic disease conditions including HTN, are more likely to use mHealth to access Web-based health support from their healthcare providers compared to those without any chronic diseases.(18) Patients with chronic diseases are also more likely to track health goals electronically, make health decisions and hold discussions with their healthcare providers based on electronically found health information.(19) A study on people with HTN who responded to the Health Information National Trends Survey (HINTS) found that patients who are already engaging with their healthcare providers electronically via email or internet have a higher odds of also communicating through SMS text messages with them compared to those who are not.(20) These studies however, are not specific to RBPM.

The electronic health literacy framework (e-HLF)(21) and the corresponding electronic health literacy questionnaire (eHLQ)(22) developed from it provide an essential tool to measure patient's e-HL status. eHLQ takes into account a patient's health knowledge and technology skills, motivation to engage in technology, access to technology, and health data security concerns. eHLQ reflects most of the patient-related factors that may influence RBPM engagement.(22) The assessment of a patient's e-HL status is essential to ensure maximum benefit from any health digital services including RBPM.

However, patients' e-HL status is seldom assessed in electronic health intervention studies (23,24) and RBPM studies are not an exception. The few electronic health management studies involving patients with HTN utilized non-validated tool (25) or the electronic health literacy scale (eHEALS) to measure e-HL status (3,12,19,26) and a small number of these studies are focused on RBPM.(3,25) eHEALS(27) centers mainly on patients' ability to use the internet and does not have the robustness of eHLQ.

Moreover, most studies on RBPM are intervention studies. There is a dearth of data on the prevalence of RBPM participation among people with HTN in everyday life situations. Patient-related factors that influence engagement in RBPM have been driven mostly by qualitative studies (28–33) and less by the quantitative assessment of patients' characteristics to identify predictors of engagement.(25) Data on concurrent assessment of RBPM participation predictors and e-HL are also limited. Studies focused on RBPM using eHLQ are therefore warranted. The objectives of this study were to 1. Assess participation and non-participation in RBPM among adults with HTN, 2. Assess patients' characteristics and technology health behaviors that predict participation in RBPM, and 3. Assess e-HLF domains that predict participation in RBPM. We hypothesized that participation in RBPM is associated with patients' characteristics, technology health behaviors, and e-HL status.

4.2 Methods

4.2.1 Design

The study was a quantitative cross-sectional survey of patients with HTN in the United States. The study was approved by the University of Michigan Institutional Review Board with the approval number HUM00205760.

4.2.2 Participants

Participants were recruited and surveyed using an online Qualtrics® panel. The inclusion criteria were patients aged ≥ 18 years who self-reported HTN diagnosis, had at least one prescription HTN medication, understand English language, and were willing to participate. Exclusion criteria included active cancer, diagnosis of cognitive impairment or having been to the intensive care unit (ICU) in the past six months. We used the exclusion criteria because people with active cancer, cognitive impairment or were recently in ICU were more likely to be closely monitored by their healthcare providers and may not provide the general RBPM practice obtainable in the hypertension population.

4.2.3 Sample size

With the 47.3% adult population with HTN in the US in 2021(34), using 5% type 1 error (P = 0.05), the minimum sample size required to estimate participation in RBPM was calculated to be 383 participants.(35) A minimum of 500 sample size has been recommended for detection of difference between sample estimates and the population in observational studies involving logistic regression.(36) We therefore recruited a sample of 507 participants with HTN using the quota sampling explained in the recruitment section.

4.2.4 Recruitment

Participants were recruited using an online Qualtrics® panel. Based on our first study of a secondary analysis of the 2018 Health Information National Trends Survey (HINTS) 5 Cycle 2, age and education were associated with electronic health information seeking among respondents with HTN. We therefore used a priori quota sampling based on age and educational levels. To ensure adequate representation within the age and education groups, the following proportions were used; less than 50 years (15%), 50 – 74 years (64%), 75 years and above (21%), less than college education (32%), some college education (34%), college graduate and above (34%). The study, extent of participation, as well as incentive for participation were described to the participants meeting the inclusion criteria. Participants were screened for study inclusion eligibility, and consented online before they completed the survey.

4.2.5 Data collection

The online survey (Appendix D) had four parts, was self-administered, and took about 15 minutes to complete. The survey was in the field from November to December 2021.

Demographics and clinical characteristics. This included respondents' demographics (including age, sex, ethnicity, race, educational level, marital status, income, clinic distance from residence, and residential area), general health status, co-morbidities, length of time since being diagnosed with HTN, number of HTN medications, number of other medications different from the HTN medications, BP control status, and the last measured systolic and diastolic BP values.

BP Self-monitoring and Telemonitoring Behaviors. These were questions focused on BP self-monitoring and remote monitoring strategies formulated from activities that patients are usually required to do in home BP monitoring and RBPM programs.(4–7) The questions included 1. Routine measurement of BP at home, clinic, pharmacy, work or not at all, 2. Frequency of home BP self-measurements (ranging from daily to never), 3. Self-measured BP tracking strategy (ranging from paper tracking, electronic tracking to not tracking at all), 4. How self-measured BP is shared with healthcare provider (whether in person or electronically through automatic transfer, email, electronic patient portal or text messages), 5. Self BP control behaviors such as medication adherence, exercise, alcohol intake reduction etc., 6. Awareness of RBPM (yes/no), 7. RBPM offered in clinic (yes/no/don't know), 8. Participation in RBPM (yes/no) defined as current self-measuring of BP accompanied by any form of electronic transmission of the measurements to the healthcare provider regardless of transmission frequency (outcome variable), 9. RBPM providers (doctor, nurse, pharmacist, physician assistant, don't know/unsure), 10. Means of electronic communication with healthcare provider in RBPM (email, electronic health records, health apps, phone call or automatic transfer), 11. Frequency of electronic communication with healthcare provider in RBPM (ranging from daily to less than once a month), and 12. RBPM feedback received. We also asked those not participating in RBPM to state their reasons for not participating and their likelihood of participation if RBPM were offered to them (very likely, somewhat likely, neither likely nor unlikely, somewhat unlikely, very unlikely).

e-Health Literacy. We used the validated e-health literacy questionnaire (eHLQ)(22), which is a 35 item questionnaire with seven domains developed from e-health literacy framework. The first two domains provide information on the patient's capability, the next three domains show interaction between the patient and digital services, and the last two are about patient's experiences with digital services. Each item is rated on a 4-point Likert scale (strongly disagree, disagree, agree, strongly agree) with lowest score of 1 and highest score of 4. The eHLQ was validated using both classical test theory and item response theory psychometrics, and the domains items were found to have strong composite scale reliability (CSR).(22) The e-health literacy domains variables include 1. Using technology to process health information (5 items, CSR: 0.84), 2. Understanding health concepts and language (5 items, CSR: 0.75), 3. Ability to actively engage with digital services (5 items, CSR: 0.86), 4. Feel safe and in control (5 items, CSR: 0.87), 5. Motivated to engage with digital services (5 items, CSR: 0.84), 6. Access to digital services that work (6 items, CSR: 0.77), 7. Digital services that suit individual need (4 items, CSR: 0.85). Each domain score is the average of the individual item scores in the domain. The highest and lowest mean scores possible were 4 and 1 respectively. The eHLQ license was obtained from Swinburne University of Technology, Denmark (Appendix E).

Technology Health Behaviors. These are variables from HINTS(37) focusing on technology ownership and use within a 12 month recall period. These variables included ownership of basic cellphone (yes/no), ownership of smartphone (yes/no), ownership of tablet computer (yes/no), ownership of laptop or desktop computer, ownership of home BP monitoring device (yes and use or not use it/no), how home BP device was obtained (self-payment, gifted, insurance, other), having health Apps (yes/no). The behaviors included use of computer, smartphone, or other electronic means to communicate with doctor or doctor's office through email or internet (yes/no); electronic checking of medical tests results (yes/no); use of computer, smartphone, tablet to monitor and achieve health goals (yes/no); use of computer, smartphone, tablet to make health decisions (yes/no); use of computer, smartphone, tablet helped discussion with healthcare provider (yes/no); shared information from an electronic monitoring device or smartphone with healthcare provider (yes/no); and sent or received text message from healthcare provider (yes/no). We also asked for patient-provider communication or interaction preferences regarding BP management, whether it is in-person clinic visits or through electronic means including email, phone call, SMS text messages, electronic health record, and video visit. Participants who responded “no” to ownership of home BP monitoring device were asked to state their reasons for not having the device.

Pilot testing. The online survey was first piloted among twelve volunteers from staff and graduate students at the University of Michigan College of Pharmacy and revised for clarity. The second pilot was through the Qualtrics® panel to confirm the content validity and reliability before the full launch.

4.2.6 Statistical analysis

The outcome variable was participation in RBPM. Independent variables included demographics, general health status, clinic distance from residence, RBPM awareness, e-HL domains, and technology health behaviors.

Descriptive statistics were used to describe patient’s demographics, e-HL status, and BP telemonitoring behaviors, and health technology behaviors. Categorical variables were reported as frequencies (%) while continuous variables as means and standard deviation. Bivariate analysis using chi-square tests compared patients' characteristics between RBPM and non-RBPM groups. The Mann-Whitney U test was used to compare the e-HL domains scores between RBPM and non-RBPM groups.

Firth’s (38,39) logistic regression was used to assess the predictors of participation in RBPM. Firth’s logistic regression uses penalized likelihood approach to account for any separation in the categorical variables due to small sample size and reduces bias in the parameter estimates. Demographics and technology behaviors were included in the regression model. Age and education interaction variables were also included. Education variables were re-coded into three categories: less than college, some college, and college graduate or more. Race variables were re-coded to two categories: White and other races. Marital status variables were re-coded into three categories: never married, married, and previously married. Time since HTN diagnosis was recoded to two categories: less than 5 years and 5 years or more. Various regression models were fitted and the model with the lowest Akaike information criterion (AIC)(40) was chosen for the prediction. We also assessed the seven e-HL domains as predictors of RBPM participation using Firth's logistic regression. All analyses were performed using the JJ Allaire R Studio software, version 4.2.1.

4.3 Results

4.3.1 Description of participants' demographics and clinical characteristics

A total of 507 people with HTN meeting the study criteria were consented to the study and surveyed. The mean age for all participants was 60 years (SD 14.7) (Table 4.1). The respondents were mostly female (60.4%), non-Hispanic (95.3%), and White (84.6%). About two-thirds have some college education or more (66.9%), while almost half were married or living as married (47.9%). Most of the respondents (78.5%) live within 10 miles distance from their clinics in urban (25.6%), and suburban (48.3%) areas. More than half reported having had HTN for 5 years or more (56.6%) with the majority reporting their HTN under control (83.3%). Depression or anxiety was the most common reported comorbidity (40.0%). Other clinical characteristics are presented in Table 4.2.

Sixty respondents out of the 507 reported participation in remote BP monitoring giving a prevalence of 11.8% (Table 4.1). The RBPM participation group had a significantly lower mean age (46.2 years, SD 14.7) compared to non-RBPM participation group (62 years, SD 13.7). The RBPM participation group also had more people in the married category (53.3% vs 39.1%). The majority (75.1%) of those participating in RBPM reported less than 5 years since diagnosis of HTN compared to 39.1% in the non-RBPM group (Table 4.2).

4.3.2 BP self-monitoring and telemonitoring behaviors

Overall, about two-thirds (66.1%) of the respondents measured their BP routinely at home with varying frequencies of BP measurement (Table 4.3). About 21% of all respondents did not measure their BP routinely. However, most respondents in the RBPM group measured their BP at home (91.7%) and 61.7% of them engage in daily BP measurement (Table 4.3). A greater number of those in RBPM group reported tracking their BP measurements with mHealth (61.7%) than those in the non-RBPM group (15.6%). Sharing of BP measurements with the healthcare provider through automatic transfer from BP device, email, or electronic health records was higher in the RBPM group (51.7%) versus non-RBPM group (3.6%) (Table 4.3). Taking BP medications as prescribed by the healthcare provider was the most common self BP control behavior overall and in both RBPM and non-RBPM groups (Table 4.4).

Overall, 67.5% of the respondents were not aware of RBPM and 68.8% do not know if their clinic offers remote BP monitoring services. Awareness of RBPM was reported in 32.5% of the respondents. RBPM participation was reported in 11.8%, and non-participation in 88.2% of the respondents (Table 4.3). Among those who were participating in RBPM, the most reported RBPM provider was doctors, while RBPM frequency was mostly daily and several times per week (Table 4.5). The electronic health records or patient portal was the most common channel of RBPM communication between the respondents and their healthcare providers. The feedback message to the respondents were mainly acknowledgement of BP measurement receipt and interpretation of measurement as low, high, or normal (Table 4.5). The top two reasons for not participating in RBPM were: doctors have not asked them to participate and lack of awareness of RBPM (Table 4.6). About three-quarters of those not participating in RBPM reported that they would likely participate in RBPM if offered.

4.3.3 e-Health literacy (e-HL)

The calculated Cronbach's alpha for our sample for the eHLQ domains one to seven are shown in Table 4.7. Collectively, the respondents reported e-HL mean scores above 2 in all the seven domains of the eHLQ (Table 4.7) including 1. Using technology to process health information, 2. Understanding health concepts and language, 3. Ability to actively engage with digital services, 4. Feel safe and in control, 5. Motivated to engage with digital services, 6. Access to digital services that work, 7. Digital services that suit individual needs. However, the RBPM participating group had significantly higher e-HL mean scores compared to the non-RBPM group in all seven domains.

4.3.4 Technology health behaviors

Most of the 507 respondents reported having a smartphone (92.5%), tablet computer (63.7%), laptop or desktop computer (86.8%), health-related apps (59%), and home BP monitoring device (78.7%) (Table 4.8). The ownership of tablet computers and health-related apps were significantly higher among the RBPM group compared to non-RBPM groups (85% vs 60.9%; 93.3% vs 54.4%, $P < 0.001$ respectively). The RBPM group also had significantly higher proportion of people that own and use home BP monitoring device compared to non-RBPM group (96.7% vs 64.7%, P < 0.001). The top reasons for not owning a home BP monitoring device included dependence on health provider for BP measurement (42.6%), and not being able to afford one (35.2%) (Table 4.10).

About three-quarters of the respondents have communicated with their doctor or doctor's office through emails (74.4%) or internet and checked their medical test results electronically (75.1%). About half reported that they made health decisions (54.6%) and achieved health goals (46.4%) with mHealth, and shared health information electronically with their healthcare providers (49.7%). Moreover, more than half of the 507 respondents reported that they have sent or received SMS text messages from their healthcare provider (61.3%) and that mHealth use has helped in their discussion with their healthcare provider (54.6%). All these behaviors were observed more significantly in the RBPM group compared to non-RBPM group (Table 4.9).

Figure 4.1 shows the patients' interaction preferences with their healthcare provider regarding their BP management. Overall, the most preferred mode of patient-provider interaction was in-person clinic visits, while the least preferred was video visits. Among the electronic communication methods, phone calls were the most preferred, followed by email, then SMS text messages. Video visits remained the least preferred interaction method. There was no difference in the order of interaction preferences across age and educational groups. The order of preferences for patient-provider interaction channels remained the same in the RBPM and non-RBPM groups as in the overall participants.

4.3.5 Predictors of RBPM participation

For objective 2, the statistically significant predictors of participation in RBPM were awareness of RBPM (adjusted odds ratio (AOR) 36.98, 95% CI 12.30 – 157.75, P < 0.0001) and sharing electronic health information with a healthcare provider (AOR 6.37, 95% CI 1.79 –

29.42, P = 0.003) (Table 4.11). Age, education level, marital status, clinic distance, ownership of technology, and other behavioral variables were not statistically significant predictors.

For objective 3, the univariate regression of each of the e-HL domains with RBPM participation yielded significantly positive association RBPM participation (Table 4.12). The unadjusted odds ratios include 1. Using technology to process health information (OR 3.62, 95% CI 2.15 – 6.23, P < 0.0001), 2. Understanding health concepts and language (OR 2.54, 95% CI 1.41 – 4.62, P = 0.001), 3. Ability to actively engage with digital services (OR 2.54, 95% CI 1.56 – 4.24, P = 0.0001), 4. Feel safe and in control (OR 2.81, 95% CI 1.64 – 4.91, P = 0.0001), 5. Motivated to engage with digital services (OR 3.09, 95% CI 1.82 – 5.37, P < 0.0001), 6. Access to digital services that work (OR 3.69, 95% CI 2.07 – 6.71, P < 0.0001), 7. Digital services that suit individual needs (OR 4.18, 95% CI 2.52 – 7.15, P < 0.0001). When participation in RBPM was regressed with all the seven domains of e-HLQ, higher scores on having digital services that suit individual needs (domain 7) was associated with higher odds of RBPM participation (AOR 4.49, 95% CI 1.65 – 13.28, P = 0.003) (Table 4.13). The other six domains were not statistically significant predictors in the adjusted model.

4.4 Discussion

4.4.1 Main Findings

We found that more than three-quarters of patients with HTN were not participating in RBPM. Non-participation in RBPM was mostly due to not being asked to participate by their healthcare providers and lack of awareness of RBPM, as only 32.5% of the patients were aware of RBPM. These findings show the important role healthcare providers can play in helping their patients take up health improving strategies. Doctor’s referral or recommendation has been identified as an influential factor in patient's telemedicine utilization.(41) A related study on utilization of tele-consultation among adult epileptic patients in a low income setting showed that only about 32% have used tele-consultation and more than half (58%) of the patients were not aware of tele-consultation services.(42) Patients will likely take up health improving programs like RBPM if they are made aware of the program and the benefits. A review of impact of telemedicine during the COVID-19 pandemic by Omboni et al.,(43) identified patients' awareness as an important factor in the uptake of digital health services. This finding is also supported by the high number (74.9%) of non-RBPM patients in our study who reported they would likely participate in RBPM if offered. Another study(25) assessing willingness to take up telemonitoring program among patients with diabetes and /or HTN found that more than half (52.5%) of the respondents were willing to take up telemonitoring program. Despite the differences in proportions of patients willing to participate in BP telemonitoring in these two studies, it shows that a sizeable number will likely participate had it been brought to their awareness or recommendation. A concerted effort among all healthcare providers (physicians, nurses, pharmacists etc.) towards RBPM recommendation to their patients could provide the encouragement and support needed to get more patients with HTN to participate in RBPM. However, the recommendation of RBPM program is dependent on its availability and accessibility in the healthcare institutions.(5,31) It therefore calls for the provision of the technical infrastructure (e.g. adequate RBPM system, home BP monitoring device for patients) and appropriate reimbursements to aid healthcare providers in rendering RBPM services.

Our study showed that phone calls were the most preferred electronic communication method regardless of participation or non-participation in RBPM. This could be because of the simplicity of making and answering calls as easy-to-use technology is one of the necessary required features of digital services.(13,44) It could also be because over 80% of our participants were aged 50 years and above. Older patients have been found to prefer phone call interactions over other electronic modes of communication.(45–47) It is important for healthcare providers or office staff to identify the preferred electronic communication preferences by the patients regarding their health management.(48) Reimbursement of phone-based care during the COVID-19 pandemic greatly improved patient care.(49) Healthcare policy makers could be extend similar reimbursement to RBPM services to help healthcare providers improve their patients' health. Alternatively, the RBPM data can be integrated in the patients' electronic medical record. Engaging patients electronically through their preferred medium will likely promote adherence to health management protocols.

In addition to awareness, having shared health information from electronic devices with healthcare providers was positively associated with RBPM participation in the adjusted analyses. This previous technology-related health behavior shows that experience with an action makes it more likely to engage in similar action. This finding is supported by a study among patients with HTN where prior communication with the doctor or doctors' office through email or internet was a significant predictor of communicating with the doctor via SMS text messaging.(20) Measures to improve awareness of RBPM among patients with HTN as well as encourage use of electronic health devices and sharing their health information may increase participation in RBPM.

e-HL is a key resource for engagement in any digital health services. However, e-HL is not often assessed in telemedicine studies.(50) Our study is the first to our knowledge to utilize the robustness of eHLQ to assess participation in RBPM. As expected, patients in the RBPM group had higher e-HL mean scores in all the seven domains compared to those in the non-RBPM group. However, we found that having digital services that suit individual needs (domain

7) was the only significant predictor of RBPM participation when adjusting for all the seven domains of e-HL framework. This result suggests that though it is imperative for a patient to have knowledge of one's health, be motivated and actively engaged in digital services, have sense of safety and access to digital services that work, if an RBPM digital service does not fit the individual needs of the patient, the likelihood of taking part is greatly reduced. Personalization of technology interventions has been highlighted as a crucial strategy to improve patients' engagement and adherence to digital health services.(14,51–54) It is therefore necessary to tailor RBPM services to individual patients by considering for example, what frequency and time of self-BP measurement is suitable for the patient?; what mode of electronic transmission of self-measured BP works best for the patient?; what degree of feedback is needed by the patient and the communication channel preferred by the patient to get the feedback?, among other things.(51,54)

RBPM is a valuable way of engaging patients with HTN in their disease management to achieve BP control and mitigate the consequences of uncontrolled BP. However, more needs to be done in terms of getting patients to embrace this digital service option. Availability of secure RBPM infrastructure accessible to patients is essential. Proactive actions like building RBPM into routine healthcare and ensuring that every patient diagnosed with HTN has access to it could go a long way in increasing participation. Reimbursement of RBPM services and insurance coverage of home BP monitoring devices could help increase RBPM accessibility to patients. It may be helpful for health systems to spread the good news of RBPM to the general population of patients with HTN but start the RBPM service with the most severe cases and gradually expand to all patients according to what they need.

4.4.2 Study limitations

This study is limited by its cross-sectional design, and the generalizability may be limited because the sample included mostly non-Hispanic White patients with HTN living mainly in the urban and suburban areas. Over 80% of our sample reported having their BP under control and most (72%) reported being in good health. Therefore, a more diverse population based on race, ethnicity, residential area, BP control status, and health status is warranted for future studies. Using a self-administered electronic survey may have excluded those who are not technology savvy from participation and introduced bias in the responses. As the study is related to technology use, respondents could be overly positive or supportive of the RBPM. However, our study is strengthened by having large sample size to make predictions. We also recruited representatives from all age brackets and educational levels to mitigate age and education biases. Our study is the first quantitative study on RBPM utilizing the robustness of eHLQ based on the e-HL framework to assess RBPM participation among patients with HTN.

4.5 Conclusion

Currently, these results suggest there is low RBPM participation among patients with HTN in the United States. Creating the awareness of RBPM and encouraging patients to share their health information electronically with their healthcare providers may increase RBPM participation. It is also important to extend treatment personalization to health services like RBPM by providing patients with services that suit their peculiar situations. This calls for healthcare policies ensuring RBPM availability, accessibility, and service reimbursement in our healthcare systems.

4.6 References

1. Omboni S, Ferrari R. The Role of Telemedicine in Hypertension Management: Focus on Blood Pressure Telemonitoring. Curr Hypertens Rep [Internet]. 2015;17(4):21. Available from: https://doi.org/10.1007/s11906-015-0535-3
2. Omboni S, Panzeri E, Campolo L. E-Health in Hypertension Management: an Insight into the Current and Future Role of Blood Pressure Telemonitoring. Curr Hypertens Rep. 2020;22(6):42.
3. Wang S, Leung M, Leung SY, Han J, Leung W, Hui E, et al. Safety, Feasibility, and Acceptability of Telemedicine for Hypertension in Primary Care: A Proof-of-concept and Pilot Randomized Controlled Trial (SATE-HT). J Med Syst. 2023;47(1):34.
4. Tucker KL, Sheppard JP, Stevens R, Bosworth HB, Bove A, Bray EP, et al. Self-monitoring of blood pressure in hypertension: A systematic review and individual patient data meta-analysis. PLoS Med. 2017;14(9):1–29.
5. Parati G, Dolan E, McManus RJ, Omboni S. Home blood pressure telemonitoring in the 21st century. J Clin Hypertens. 2018;20(7):1128–32.
6. Milani R V., Lavie CJ, Bober RM, Milani AR, Ventura HO. Improving Hypertension Control and Patient Engagement Using Digital Tools. Am J Med [Internet]. 2017;130(1):14–20. Available from: http://dx.doi.org/10.1016/j.amjmed.2016.07.029
7. Magid DJ, Olson KL, Billups SJ, Wagner NM, Lyons EE, Kroner BA. A pharmacist-led, American heart association Heart360 web-enabled home blood pressure monitoring program. Circ Cardiovasc Qual Outcomes. 2013;6(2):157–63.
8. Kaihara T, Intan-Goey V, Scherrenberg M, Falter M, Kario K, Akashi Y, et al. Automatic transmission of home blood pressure data can be effective in managing hypertension: a

systematic review and meta-analysis. Eur Hear J - Digit Heal [Internet]. 2022;3(4):638–53. Available from: https://doi.org/10.1093/ehjdh/ztac049

9. Wu D, An J, Yu P, Lin H, Ma L, Duan H, et al. Patterns for patient engagement with the hypertension management and effects of electronic health care provider follow-up on these patterns: Cluster analysis. J Med Internet Res. 2021;23(9):1–15.

10. Hallberg I, Ranerup A, Bengtsson U, Kjellgren K. Experiences, expectations and challenges of an interactive mobile phone-based system to support self-management of hypertension: Patients' and professionals' perspectives. Patient Prefer Adherence. 2018;12:467–76.

11. Kalańska-Łukasik B, Gładyś A, Jadczyk T, Gruz-Kwapisz M, Wojakowski W, Kowalska M. Readiness for Telemedical Services in Patients With Cardiovascular Diseases: Cross-sectional Study. JMIR Form Res. 2022;6(10):1–9.

12. Price-Haywood EG, Harden-Barrios J, Ulep R, Luo Q. EHealth Literacy: Patient Engagement in Identifying Strategies to Encourage Use of Patient Portals Among Older Adults. Popul Health Manag. 2017;20(6):486–94.

13. Wood PW, Boulanger P, Padwal RS. Home Blood Pressure Telemonitoring: Rationale for Use, Required Elements, and Barriers to Implementation in Canada. Can J Cardiol [Internet]. 2017;33(5):619–25. Available from: http://dx.doi.org/10.1016/j.cjca.2016.12.018

14. Khanijahani A, Akinci N, Quitiquit E. A Systematic Review of the Role of Telemedicine in Blood Pressure Control: Focus on Patient Engagement. Curr Hypertens Rep [Internet]. 2022;24(7):247–58. Available from: https://doi.org/10.1007/s11906-022-01186-5

15. Nozato Y, Yamamoto K, Rakugi H. Hypertension management before and under the

COVID-19 pandemic: lessons and future directions. Hypertens Res. 2023;46:1471–7.

16. Yatabe J, Yatabe MS, Ichihara A. The current state and future of internet technology-based hypertension management in Japan. Hypertens Res [Internet]. 2021;44(3):276–85. Available from: http://dx.doi.org/10.1038/s41440-020-00591-0

17. Roberts S, Chaboyer W, Gonzalez R, Marshall A. Using technology to engage hospitalised patients in their care: a realist review. BMC Health Serv Res. 2017;17(1):1–15.

18. Bosak K, Park SH. Characteristics of adults seeking health care provider support facilitated by mobile technology: Secondary data analysis. JMIR Hum Factors. 2017;4(4):1–9.

19. Madrigal L, Escoffery C. Electronic health behaviors among US adults with chronic disease: Cross-sectional survey. J Med Internet Res. 2019;21(3):e11240.

20. Eze CE, West BT, Dorsch MP, Coe AB, Lester CA, Buis LR, et al. Predictors of Smartphone and Tablet Use among Patients with Hypertension: Secondary Analysis of Health Information National Trends Survey Data. J Med Internet Res. 2022;24(1):e33188.

21. Norgaard O, Furstrand D, Klokker L, Karnoe A, Batterham R, Kayser L, et al. Knowledge Management & E-Learning The e-health literacy framework: A conceptual framework for characterizing e-health users and their interaction with e- health systems. Knowl Manag E-Learning. 2015;7(74):522–40.

22. Kayser L, Karnoe A, Furstrand D, Batterham R, Christensen KB, Elsworth G, et al. A multidimensional tool based on the eHealth Literacy Framework: Development and initial validity testing of the eHealth Literacy Questionnaire (eHLQ). J Med Internet Res. 2018;20(2):1–10.

23. Cheng C, Beauchamp A, Elsworth GR, Osborne RH. Applying the electronic health literacy lens: Systematic review of electronic health interventions targeted at socially disadvantaged groups. J Med Internet Res. 2020;22(8):e18476.

24. Park T, Muzumdar J, Kim HM. Digital Health Interventions by Clinical Pharmacists: A Systematic Review. Int J Environ Res Public Health. 2022;19(1):532.

25. Sin DYE, Guo X, Yong DWW, Qiu TY, Moey PKS, Falk MR, et al. Assessment of willingness to Telemonitoring interventions in patients with type 2 diabetes and/or hypertension in the public primary healthcare setting. BMC Med Inform Decis Mak. 2020;20(1):1–11.

26. Bhanvadia SB, Brar MS, Delavar A, Tavakoli K, Radha Saseendrakumar B, Weinreb RN, et al. Assessing Usability of Smartwatch Digital Health Devices for Home Blood Pressure Monitoring among Glaucoma Patients. Informatics. 2022;9(4):1–13.

27. Norman CD, Skinner HA. eHealth literacy: Essential skills for consumer health in a networked world. J Med Internet Res. 2006;8(2):1–17.

28. Hanley J, Ure J, Pagliari C, Sheikh A, McKinstry B. Experiences of patients and professionals participating in the HITS home blood pressure telemonitoring trial: A qualitative study. BMJ Open. 2013;3(5):1–10.

29. Grant S, Hodgkinson J, Schwartz C, Bradburn P, Franssen M, Hobbs FDR, et al. Using mHealth for the management of hypertension in UK primary care: An embedded qualitative study of the TASMINH4 randomised controlled trial. Br J Gen Pract. 2019;69(686):E612–20.

30. Koopman RJ, Wakefield BJ, Johanning JL, Keplinger LE, Kruse RL, Bomar M, et al. Implementing home blood glucose and blood pressure telemonitoring in primary care

practices for patients with diabetes: Lessons learned. Telemed e-Health. 2014;20(3):253–60.

31. Ware P, Shah A, Ross HJ, Logan AG, Segal P, Cafazzo JA, et al. Challenges of Telemonitoring Programs for Complex Chronic Conditions: Randomized Controlled Trial with an Embedded Qualitative Study. J Med Internet Res. 2022;24(1):1–16.
32. Baratta J, Brown-Johnson C, Safaeinili N, Rosas LG, Palaniappan L, Winget M, et al. Patient and Health Professional Perceptions of Telemonitoring for Hypertension Management: Qualitative Study. JMIR Form Res. 2022;6(6):e32874.
33. Aquino M, Griffith J, Vattaparambil T, Munce S, Hladunewich M, Seto E. Patients' and Providers' Perspectives on and Needs of Telemonitoring to Support Clinical Management and Self-care of People at High Risk for Preeclampsia: Qualitative Study. JMIR Hum Factors. 2022;9(1):1–9.
34. Virani SS, Alvaro A, Aparicio HJ, Benjamin EJ, Bittencourt MS, Callaway CW, et al. Heart Disease and Stroke Statistics-2021 Update A Report from the American Heart Association. Circulation. 2021;143(8):E254–743.
35. Charan J, Biswas T. How to calculate sample size for different study designs in medical research? Indian J Psychol Med. 2013;35(2):121–6.
36. Bujang MA, Sa'at N, Tg Abu Bakar Sidik TMI, Lim CJ. Sample size guidelines for logistic regression from observational studies with large population. Malaysian J Med Sci. 2018;25(4):122–30.
37. Institute NC. Health Information National Trends Survey 5 (HINTS 5) Cycle 2 Methodology Report. 2018;5(July). Available from: https://hints.cancer.gov/data/methodology-reports.aspx

38. Puhr R, Heinze G, Nold M, Lusa L, Geroldinger A. Firth's logistic regression with rare events: accurate effect estimates and predictions? Stat Med. 2017;36(14):2302–17.

39. Mansournia MA, Geroldinger A, Greenland S, Heinze G. Separation in Logistic Regression: Causes, Consequences, and Control. Am J Epidemiol. 2018;187(4):864–70.

40. Lumley T, Scott A. AIC and BIC for modeling with complex survey data. J Surv Stat Methodol. 2015;3(1):1–18.

41. Leach WD. If you bill it, they will come: A literature review on clinical outcomes, cost-effectiveness, and reimbursement for telemedicine. Calif Telemed eHealth Cent [Internet]. 2009;(January):1–20. Available from: https://cdn.zephyrcms.com/

42. Choudhary N, Chakravarty K, Kharbanda PS, Lal V, Baishya J. Satisfaction and effectiveness of tele-medicine in follow-up of people with epilepsy in a resource-poor setting during COVID-19. Epilepsy Behav [Internet]. 2022;128:108569. Available from: https://doi.org/10.1016/j.yebeh.2022.108569

43. Omboni S, Padwal RS, Alessa T, Benczúr B, Green BB. Europe PMC Funders Group The worldwide impact of telemedicine during COVID-19 : current evidence and recommendations for the future. Connect Heal. 2022;1:7–35.

44. Harst L, Lantzsch H, Scheibe M. Theories Predicting End-User Acceptance of Telemedicine Use: Systematic Review. J Med Internet Res [Internet]. 2019;21(5):e13117. Available from: http://www.jmir.org/2019/5/e13117/

45. Yuan S, Hussain SA, Hales KD, Cotten SR. What do they like? Communication preferences and patterns of older adults in the United States: The role of technology. Educ Gerontol [Internet]. 2016;42(3):163–74. Available from: http://dx.doi.org/10.1080/03601277.2015.1083392

46. Clarke MA, Fruhling AL, Sitorius M, Windle TA, Bernard TL, Windle JR. Impact of age on patients' communication and technology preferences in the era of meaningful use: Mixed methods study. J Med Internet Res. 2020;22(6):1–25.

47. Alexander KE, Ogle T, Hoberg H, Linley L, Bradford N. Patient preferences for using technology in communication about symptoms post hospital discharge. BMC Health Serv Res. 2021;21(1):1–11.

48. Chow R, Forde B, Sawatzky R, Patiño AG, Tran KC, Bittman J, et al. Digital health technology and hypertension management: a qualitative analysis of patient and specialist provider preferences on data tracking. Connect Heal. 2022;1(2):72–84.

49. Kichloo A, Albosta M, Dettloff K, Wani F, El-Amir Z, Singh J, et al. Telemedicine, the current COVID-19 pandemic and the future: a narrative review and perspectives moving forward in the USA. Fam Med community Heal. 2020;8(3):1–9.

50. Knapp A, Harst L, Hager S, Schmitt J, Scheibe M. Use of patient-reported outcome measures and patient-reported experience measures within evaluation studies of telemedicine applications: Systematic review. J Med Internet Res. 2021;23(11):e30042.

51. Rezai LS, Torenvliet G, Burns CM. Increasing Patient Adherence to Home Health-Monitoring Systems. Proc Int Symp Hum Factors Ergon Heal Care. 2014;3(1):8–14.

52. de Ridder M, Kim J, Jing Y, Khadra M, Nanan R. A systematic review on incentive-driven mobile health technology: As used in diabetes management. J Telemed Telecare. 2017;23(1):26–35.

53. Scherrenberg M, Marinus N, Giallauria F, Falter M, Kemps H, Wilhelm M, et al. The need for long-term personalized management of frail CVD patients by rehabilitation and telemonitoring: A framework. Trends Cardiovasc Med. 2023;33(5):283-297.

54. Khalid A, Dong Q, Chuluunbaatar E, Haldane V, Durrani H, Wei X. Implementation Science Perspectives on Implementing Telemedicine Interventions for Hypertension or Diabetes Management: Scoping Review. J Med Internet Res. 2023;25:e42134.

Table 4.1 Participants' demographics

Variable	Category	All Participants N = 507	RBPM Participation n= 60 (11.8%)	No RBPM Participation n= 447 (88.2%)	P-value
Age (mean, SD)		60.09 (14.7)	46.17 (14.71)	61.96 (13.67)	<0.001
Age groups					<0.001
	Less than 50	83 (16.4)	32 (53.3)	51 (11.4)	
	50-74	318 (62.7)	25 (41.7)	293 (65.5)	
	75 and above	106 (20.9)	3 (5.0)	103 (23.0)	
Sex					0.297
	Male	201 (39.6)	28 (46.7)	173 (38.7)	
	Female	306 (60.4)	32 (53.3)	274 (61.3)	
Ethnicity					0.085
	Hispanic	24 (4.7)	6 (10.0)	18 (4.0)	
	Non-Hispanic	483 (95.3)	54 (90.0)	429 (96.0)	
Race					0.029
	American Indian or Alaska Native	4 (0.8))	2 (3.3)	2 (0.4)	
	Asian	7 (1.4)	1 (1.7)	6 (1.3)	
	Black or African American	61 (12.0)	12 (20.0)	49 (11.0)	
	White	429 (84.6)	45 (75.0)	384 (85.9)	
	Other	6 (1.2)	0 (0.0)	6 (1.3)	
Education level					0.053
	Less than High School	15 (3.0)	2 (3.3)	13 (2.9)	
	High School Graduate	153 (30.2)	17 (28.3)	136 (30.4)	
	Some College	176 (34.7)	13 (21.7)	163 (36.5)	
	Bachelor’s	148 (29.2)	24 (40.0)	124 (27.7)	
	Graduate and /or Prof degree	15 (3.0)	4 (6.7)	11 (2.5)	
Marital Status					0.003
	Single	86 (17.0)	14 (23.3)	72 (16.1)	
	Married	207 (40.8)	32 (53.3)	175 (39.1)	
	Living as married	36 (7.1)	7 (11.7)	29 (6.5)	
	Separated	18 (3.6)	2 (3.3)	16 (3.6)	
	Divorced	94 (18.5)	3 (5.0)	91 (20.4)	
	Widowed	66 (13.0)	2 (3.3)	64 (14.3)	
Annual household income					0.999
	Less than $20,001	77 (15.2)	9 (15.0)	68 (15.2)	
	$20,001 to $35,000	120 (23.7)	15 (25.0)	105 (23.5)	
	35,001 to $50,000	94 (18.5)	11 (18.3)	83 (18.6)	
	$50,001 to $75,000	99 (19.5)	11 (18.3)	88 (19.7)	
	$75,001 or more	106 (20.9)	13 (21.7)	93 (20.8)	
	Prefer not to say	11 (2.2)	1 (1.7)	10 (2.2)	
Clinic Distance					0.037
	Less than 5 miles	204 (40.2)	19 (31.7)	185 (41.4)	
	Between 5 and 10 miles	194 (38.3)	32 (53.3)	162 (36.2)	
	More than 10 miles	109 (21.5)	9 (15.0)	100 (22.4)	
Area					0.010
	Urban	130 (25.6)	24 (40.0)	106 (23.7)	
	Suburban	245 (48.3)	22 (36.7)	223 (49.9)	
	Exurban	15 (3.0)	1 (1.7)	14 (3.1)	
	Rural	104 (20.5)	9 (15.0)	95 (21.3)	
	Blank answer	13 (2.6)	4 (6.7)	9 (2.0)	

Table 4.2 Clinical characteristics

Variable	Category	All Participants N = 507	RBPM Participation n= 60 (11.8%)	No RBPM Participation n= 447 (88.2%)	P-value
General Health Status					0.103
	Poor	22 (4.3)	1 (1.7)	21 (4.7)	
	Fair	120 (23.7)	11 (18.3)	109 (24.4)	
	Good	238 (46.9)	26 (43.3)	212 (47.4)	
	Very good	113 (22.3)	18 (30.0)	95 (21.3)	
	Excellent	14 (2.8)	4 (6.7)	10 (2.2)	
Comorbidity					0.011
	Heart Condition	0 (0.0)	0 (0.0)	0 (0.0)	
	Diabetes	128 (25.2)	18 (30.0)	110 (24.6)	
	Depression or Anxiety	203 (40.0)	35 (58.3)	168 (37.6)	
	Chronic kidney disease	24 (4.7)	1 (1.7)	23 (5.1)	
	Other diseases	99 (19.5)	8 (13.3)	91 (20.4)	
	No comorbidity	137 (27.0)	7 (11.7)	130 (29.1)	
HTN History					<0.001
	Less than 1 year	22 (4.3)	0 (0.0)	22 (4.9)	
	1 year – less than 2 years	44 (8.7)	16 (26.7)	28 (6.3)	
	2 years – less than 3 years	63 (12.4)	15 (25.0)	48 (10.7)	
	3 years – less than 4 years	47 (9.3)	10 (16.7)	37 (8.3)	
	4 years – less than 5 years	44 (8.7)	4 (6.7)	40 (8.9)	
	5 years or more	287 (56.6)	15 (25.0)	272 (60.9)	
HTN Meds (mean, SD)		1.61 (0.96)	1.65 (0.73)	1.61 (0.98)	0.740
Other Meds (mean, SD)		2.92 (2.83)	2.42 (2.32)	2.98 (2.88)	0.146
BP under control					0.525
	Yes	422 (83.2)	53 (88.3)	369 (82.6)	
	No	46 (9.1)	4 (6.7)	42 (9.4)	
	Don’t know or Not sure	39 (7.7)	3 (5.0)	36 (8.1)	
Systolic BP (mean, SD)		131.77 (18.15)	129.24 (23.39)	132.11 (17.34)	0.254
Diastolic BP (mean, SD)		80.15 (11.80)	81.64 (13.62)	79.96 (11.555)	0.308

Table 4.3 Self BP monitoring behaviors

Variable	Category	All Participants N = 507	RBPM Participation n= 60 (11.8%)	No RBPM Participation n= 447 (88.2%)	P-value
Routine BP measurement venue					<0.001
	At home	335 (66.1)	55 (91.7)	280 (62.6)	
	At the pharmacy	83 (16.4)	16 (26.7)	67 (15.0)	
	At the clinic	109 (21.5)	18 (30.0)	91 (20.4)	
	At work	20 (3.9)	12 (20.0)	8 (1.8)	
	Some other places	6 (1.2)	1 (1.7)	5 (1.1)	
	Do not measure BP routinely	106 (20.9)	0 (0.0)	106 (23.7)	
Frequency of Home BP measurement					<0.001
	Daily	149 (29.4)	37 (61.7)	112 (25.1)	
	Several times a week	108 (21.3)	19 (31.7)	89 (19.9)	
	Once a week	33 (6.5)	1 (1.7)	32 (7.2)	
	1 to 3 times a month	46 (9.1)	1 (1.7)	45 (10.1)	
	Once in 3 months	9 (1.8)	0 (0.0)	9 (2.0)	
	Once in 6 months	2 (0.4)	0 (0.0)	2 (0.4)	
BP tracking strategy					<0.001
	Writing on paper	163 (32.1)	19 (31.7)	144 (32.2)	
	Writing on calendar	35 (6.9)	12 (20.0)	23 (5.1)	
	Writing on App on phone/tablet/computer	59 (11.6)	24 (40.0)	35 (7.8)	
	Writing on Excel sheet or Notepad on phone/tablet/computer	13 (2.6)	1 (1.7)	12 (2.7)	
	Do not keep track	51 (10.1)	1 (1.7)	50 (11.2)	
	Other strategies	26 (5.1)	1 (1.7)	25 (5.6)	
How Self- measured BP is shared with health provider					<0.001
	By taking them to doctor visits	235 (46.4)	33 (55.0)	202 (45.2)	
	By device automatic transfer to doctor	19 (3.7)	15 (25.0)	4 (0.9)	
	By email to doctor	19 (3.7)	12 (20.0)	7 (1.6)	
	By electronic health record/patient portal to doctor	9 (1.8)	4 (6.7)	5 (1.1)	
	By text messages to doctor	2 (0.4)	0 (0.0)	2 (0.4)	
	Do not share with health provider	77 (15.2)	2 (3.3)	75 (16.8)	
RBPM awareness					<0.001
	Yes	165 (32.5)	57 (95.0)	108 (24.2)	
	No	342(67.5)	3 (5.0)	339 (75.8)	
RBPM offered in clinic					<0.001
	Yes	66 (13.0)	57 (95.0)	9 (2.0)	
	No	92 (18.1)	0 (0.0)	92 (20.6)	
	Don’t know	349 (68.8)	3 (5.0)	346 (77.4)	

Table 4.4 Self BP control behaviors

Variable	Category	All Participants N = 507	RBPM Participation n= 60 (11.8%)	No RBPM Participation n= 447 (88.2%)
Behaviors				
	Taking BP meds as prescribed	448 (88.4)	47 (78.3)	401 (89.7)
	Exercise	243 (47.9)	36 (60.0)	207 (46.3)
	Low sodium diet	216 (42.6)	24 (40.0)	192 (43.0)
	Low carbohydrate diet	80 (15.8)	13 (21.7)	67 (15.0)
	Adequate hydration with lots of water	204 (40.2)	19 (31.7)	185 (41.4)
	Adequate sleep	195 (38.5)	21 (35.0)	174 (38.9)
	Reduction in coffee intake	88 (17.4)	6 (10.0)	82 (18.3)
	Meditation	58 (11.4)	10 (16.7)	48 (10.7)
	Breathing exercises	70 (13.8)	13 (21.7)	57 (12.8)
	Stress reduction	117 (23.1)	25 (41.7)	92 (20.6)
	Reducing alcohol consumption	98 (19.3)	7 (11.7)	91 (20.4)
	Periodic health checks	211 (41.6)	17 (28.3)	194 (43.4)
	None of the above	0 (0.0)	0 (0.0)	0 (0.0)
	Other behaviors not listed	3 (0.6)	0 (0.0)	3 (0.7)

Table 4.5 Remote BP monitoring (RBPM) strategies

Variable	Category	Frequency (%), N = 60
RBPM Providers		
	Doctor	47 (78.3)
	Nurse	22 (36.7)
	Pharmacist	4 (6.7)
	Physician assistant	12 (20.0)
	Don't know or unsure	1 (1.7)
RBPM Frequency		
	Daily	21 (35.0)
	Several times a week	24 (40.0)
	Once a week	9 (15.0)
	One to three times a month	2 (3.3)
	Less than once a month	4 (6.7)
RBPM Method		
	Text messages	0 (0.0)
	Email	19 (31.7)
	Electronic health record or patient portal	21 (35.0)
	Health Apps	15 (25.0)
	Phone call	13 (21.7)
	Automatic transfer from BP device to doctor	10 (16.7)
RBPM Feedback type		
	None	5 (8.3)
	Readings received/acknowledgement	30 (50.0)
	Interpretation of readings as normal, high or low	26 (43.3)
	Changes in hypertension medication	14 (23.3)
	Changes in frequency of blood pressure monitoring	11 (18.3)
	Other feedback	1 (1.7)

Table 4.6 Reasons for not participating and likelihood of participating in RBPM

Variable		Category	(N = 447) n (%)
Reasons for not participating in RBPM			
	1	My doctor has not asked me to do that	247 (55.3)
	2	I am not aware I can do that	190 (42.5)
	3	My blood pressure is under control	92 (20.6)
	4	I prefer face-to-face human interaction	72 (16.1)
	5	My doctor does not offer electronic communication means	46 (10.3)
	6	My doctor prefers to measure my blood pressure by himself/herself	46 (10.3)
	7	I do not have a blood pressure monitoring device	46 (10.3)
	8	I do not know how to do that/need training	39 (8.7)
	9	I do not measure my blood pressure	38 (8.5)
	10	I do not need to do that	30 (6.7)
	11	I do not have smartphone/tablet/computer	5 (1.1)
	12	Other reasons	5 (1.1)
	13	I do not have internet access	2 (0.4)
	14	I am too busy to do that	1 (0.2)
Likelihood of participating in RBPM if offered			
		Very likely	183 (40.9)
		Somewhat likely	152 (34.0)
		Neither likely nor unlikely	75 (16.8)
		Somewhat unlikely	18 (4.0)
		Very unlikely	19 (4.3)

Table 4.7 Mean electronic health literacy (e-HL) scores (comparison by Mann-Whitney U test)

e-HL domains	e-HL domains' Cronbach alpha (95% CI)	All Participants N = 507	RBPM Participation n= 60 (11.8%)	No RBPM Participation n= 447 (88.2%)	P-value
1.Using technology to process health information	0.80 (0.76, 0.83)	2.96 (0.56)	3.29 (0.55)	2.92 (0.55)	<0.001
2. Understanding health concepts and language	0.77 (0.73, 0.80)	3.11 (0.46)	3.28 (0.51)	3.09 (0.44)	0.001
3. Ability to actively engage with digital services	0.82 (0.79, 0.85)	3.00 (0.60)	3.27 (0.56)	2.96 (0.59)	<0.001
4. Feel safe and in control	0.80 (0.77, 0.84)	3.09 (0.52)	3.33 (0.52)	3.06 (0.51)	<0.001
5. Motivated to engage with digital services	0.81 (0.77, 0.84)	3.01 (0.55)	3.29 (0.51)	2.97 (0.55)	<0.001
6. Access to digital service that work	0.81 (0.77, 0.83)	3.08 (0.48)	3.34 (0.47)	3.05 (0.47)	<0.001
7. Digital services that suit individual need	0.80 (0.75, 0.83)	2.89 (0.61)	3.30 (0.60)	2.83 (0.59)	<0.001
Average		3.02 (0.46)	3.30 (0.49)	2.98 (0.44)	<0.001

Table 4.8 Technology ownership

Variable	Category	All Participants N = 507	RBPM Participation n= 60 (11.8%)	No RBPM Participation n= 447 (88.2%)	P-value
Have Basic cellphone only					0.004
	Yes	89 (17.6)	19 (31.7)	70 (15.7)	
	No	418 (82.4)	41 (68.3)	377 (84.)	
Have Smartphone					0.118
	Yes	469 (92.5)	59 (98.3)	410 (91.7)	
	No	38 (7.5)	1 (1.7)	37 (8.3)	
Have Tablet Computer					<0.001
	Yes	323 (63.7)	51 (85.0)	272 (60.9)	
	No	184 (36.3)	9 (15.0)	175 (39.1)	
Have Desktop or Laptop Computer					0.324
	Yes	440 (86.8)	55 (91.7)	385 (86.1)	
	No	67 (13.2)	5 (8.3)	62 (13.9)	
Have home BP monitoring device					<0.001
	Yes, I use it	347 (68.4)	58 (96.7)	289 (64.7)	
	Yes, don't use it	52 (10.3)	1 (1.7)	51 (11.4)	
	No	108 (21.3)	1 (1.7)	107 (23.9)	
Home BP device payment					<0.001
	Paid by self	286 (56.4)	35 (58.3)	251 (56.2)	
	Gifted	25 (4.9)	1 (1.7)	24 (5.4)	
	Insurance paid	78 (15.4)	23 (38.3)	55 (12.3)	
	Other	10 (2.0)	0 (0.0)	10 (2.2)	
	No Home BP device	108 (21.3)	1 (1.7)	107 (23.9)	
Have Health Apps					<0.001
	Yes	299 (59.0)	56 (93.3)	243 (54.4)	
	No	208 (41.0)	4 (6.7)	204 (45.6)	

Table 4.9 Technology use

Variable	Category	All Participants N = 507	RBPM Participation n= 60 (11.8%)	No RBPM Participation n= 447 (88.2%)	P-value
Electronic communication with doctor or doctor's office via email or internet					<0.001
	Yes	377 (74.4)	58 (96.7)	319 (71.4)	
	No	130 (25.6)	2 (3.3)	128 (28.6)	
Electronic checking of medical tests					0.041
	Yes	381 (75.1)	52 (86.7)	329 (73.6)	
	No	126 (24.9)	8 (13.3)	118 (26.4)	
Achieving health goals with mHealth					<0.001
	Yes	235 (46.4)	51 (85.0)	184 (41.2)	
	No	272 (53.6)	9 (15.0)	263 (58.8)	
Health decision making with mHealth					<0.001
	Yes	277 (54.6)	51 (85.0)	226 (50.6)	
	No	230 (45.4)	9 (15.0)	221 (49.4)	
mHealth helps discussion with health care provider					<0.001
	Yes	305 (60.2)	56 (93.3)	249 (55.7)	
	No	202 (39.8)	4 (6.7)	198 (44.3)	
Shared health information electronically with health care provider					<0.001
	Yes	252 (49.7)	56 (93.3)	196 (43.8)	
	No	255 (50.3)	4 (6.7)	251 (56.2)	
Text messaging with doctor					<0.001
	Yes	311 (61.3)	54 (90.0)	257 (57.5)	
	No	196 (38.7)	6 (10.0)	190 (42.5)	

Table 4.10 Reasons for not having home BP monitoring device

Variable	Category	(N = 108) n (%)
Reasons for no home BP device		
	My doctor measures my blood pressure	46 (42.6)
	I cannot afford it	38 (35.2)
	My blood pressure is under control	23 (21.3)
	I don't think I need it	20 (18.5)
	I haven't seen one that works well	20 (18.5)
	Am not sure how to use it/too complicated	7 (6.5)
	Other reasons	4 (3.7)

Table 4.11 Predictors of RBPM participation using Firth's logistic regression

Predictor Variables	Categories	Adjusted odds ratio (95% Confidence interval)	P-values
Age		0.99 (0.93, 1.05)	0.68
Gender[a]			
	Male	0.95 (0.39, 2.27)	0.91
Education level[b]			
	Some college	0.73 (0.01, 36.93)	0.88
	College graduate or more	12.87 (0.22, 853.47)	0.22
Race[c]			
	American Indian or Alaska Native/ Asian/ Black or African American/ Other races	0.65 (0.23, 1.74)	0.39
Marital status[d]			
	Married	1.54 (0.53, 4.71)	0.43
	Previously married	0.51 (0.11, 2.05)	0.34
Clinic distance from residence[e]			
	Between 5 and 10 miles	1.47 (0.59, 3.73)	0.41
	More than 10 miles	0.65 (0.19, 2.12)	0.48
RBPM Awareness[f]			
	Yes	36.98 (12.30, 157.75)	< 0.0001
BP under control[g]			
	Yes	0.35 (0.06, 2.00)	0.23
	Don’t know or unsure	0.24 (0.02, 2.92)	0.26
Have Tablet[h]			
	Yes	1.24 (0.43, 3.70)	0.69
Have Smartphone[i]			
	Yes	0.70 (0.04, 29.49)	0.82
Have Basic cellphone only[j]			
	Yes	2.43 (0.87, 6.99)	0.09
Have Computer[k]			
	Yes	0.96 (0.28, 3.74)	0.95
Have health Apps[l]			
	Yes	2.31 (0.59, 12.25)	0.24
Electronic communication with doctor or doctor’s office via email or internet[m]			
	Yes	1.06 (0.17, 9.71)	0.95
Sent or received SMS text message from doctor[n]			
	Yes	1.69 (0.58, 5.48)	0.34
Shared health information from electronic device, tablet, or smartphone with health provider[o]			
	Yes	6.37 (1.79, 29.41)	0.003
Made health decision with mHealth[p]			
	Yes	0.31 (0.07, 1.23)	0.09
Achieved health goals with mHealth[q]			
	Yes	2.58 (0.78, 9.42)	0.12
Have checked medical test results electronically[r]			
	Yes	0.32 (0.07, 1.39)	0.13

Predictor Variables	Categories	Adjusted odds ratio (95% Confidence interval)	P-values
Time since Hypertension diagnosis[s]			
	5 years or more	1.0 (0.36, 2.84)	0.99
Age and Education interaction[t]			
	Age and some college education	0.98 (0.91, 1.05)	0.54
	Age and college graduate or more	0.94 (0.86, 1.01)	0.07

Reference variables: Reference variables: a- female gender; b- less than college education; c- White race; d- never married; e- clinic distance less than 5 miles from residence; f- No response; g- No response; h- No response; i- No response; j- No response; k- No response; l- No response; m- No response; n- No response; o- No response; p- No response; q- No response; r- No response; s- less than 5 years; t- Age and less than college education

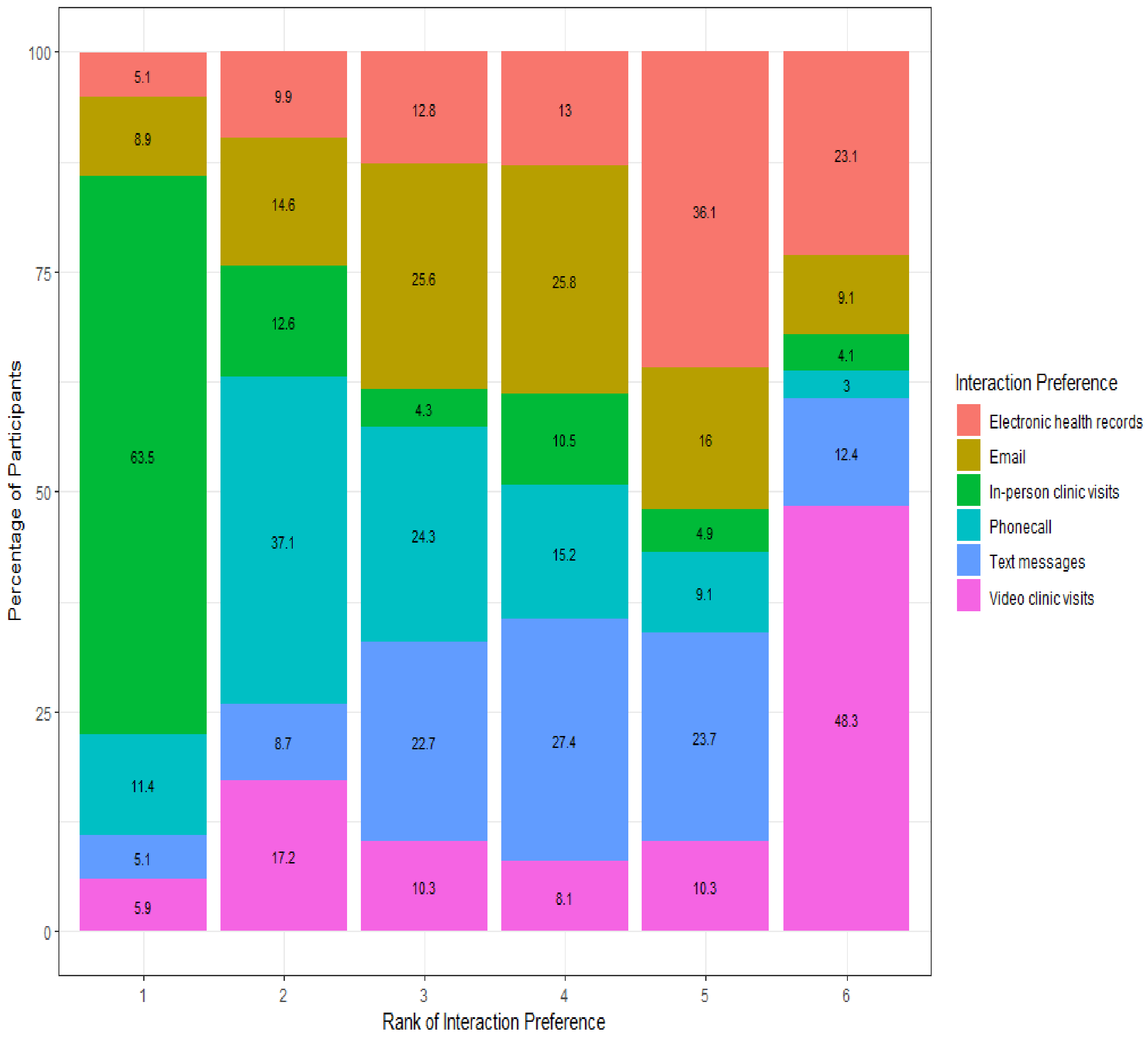
Table 4.12 Univariate regression of RBPM with e-HL domains (Firth's logistic regression)

Predictor Variables	Unadjusted odds ratio (95% Confidence interval)	P-values
1.Using technology to process health information	3.62 (2.15, 6.23)	< 0.0001
2. Understanding health concepts and language	2.54 (1.41, 4.62)	0.001
3. Ability to actively engage with digital services	2.54 (1.56, 4.24)	0.0001
4. Feel safe and in control	2.81 (1.64, 4.91)	0.0001
5. Motivated to engage with digital services	3.09 (1.82, 5.37)	< 0.0001
6. Access to digital services that work	3.69 (2.07, 6.71)	< 0.0001
7. Digital services that suit individual needs	4.18 (2.52, 7.15)	< 0.0001

Table 4.13 Multivariate of RBPM with e-HL domains (Firth's logistic regression)

Predictor Variables	Adjusted odds ratio (95% Confidence interval)	P-values
1.Using technology to process health information	2.45 (0.71, 8.78)	0.16
2. Understanding health concepts and language	0.58 (0.22, 1.60)	0.29
3. Ability to actively engage with digital services	0.84 (0.33, 2.15)	0.72
4. Feel safe and in control	1.13 (0.49, 2.73)	0.78
5. Motivated to engage with digital services	0.50 (0.15, 1.73)	0.27
6. Access to digital services that work	1.14 (0.35, 3.78)	0.83
7. Digital services that suit individual needs	4.49 (1.65, 13.28)	0.003

Figure 4.1 Ranking of participants' interaction preferences with health care providers regarding their hypertension management (1 denotes the most preferred and 6 is the least preferred)



Chapter 5 Discussion

Telemonitoring of blood pressure (BP) is a remote patient monitoring strategy that improves BP control and patient engagement in their own health. The objective of this dissertation was to understand the factors that impact remote monitoring of BP from the patients' perspective using a mixed-method approach. The central hypothesis of this dissertation was that engagement in remote monitoring of BP is associated with patient's characteristics, technology behaviors, and electronic health literacy (e-HL) status.

e-HL is defined as the skills, knowledge, and resources required to successfully engage in any digital health services (1). This dissertation utilized the e-HL framework (e-HLF) which is a conceptual framework on e-HL developed with the input from various stakeholders including patients with chronic diseases, health professionals, health informatics professionals, computer experts, and public health researchers. The e-HLF captured the important aspects of e-HL in seven domains: 1. Using technology to process health information, 2. Understanding health concepts and language, 3. Ability to actively engage with digital services, 4. Feel safe and in control, 5. Motivated to engage with digital services, 6. Access to digital services that work, and 7. Digital services that suit individual needs. A corresponding 35-item assessment tool called the e-HL questionnaire (eHLQ) was developed from the e-HLF encapsulating the factors in the seven domains (2) to measure a person' e-HL. BP telemonitoring as a digital service needs an individual to have adequate e-HL to effectively participate. It is therefore important to assess patients' e-HL alongside their engagement in BP telemonitoring.

This dissertation was categorized into five chapters. Chapter 1 provided a review of the literature on hypertension control by engaging the patients through technology. The review specifically included 1. analysis of current literature on various technologies including telemonitoring of BP, the concept and impact of e-HL as it relates to BP telemonitoring, 2. the mixed-methods research advantage, and 3. identification of gaps in our knowledge regarding BP telemonitoring. Chapters Two, Three, and Four presented three separate papers with different aims and each analysis contributed to the overall objective of the study. Although the statistical analyses were conducted separately and reported in these chapters, together the chapters aimed to assess the patient-related factors associated with engagement in BP telemonitoring. The first study in Chapter 2 predicted smartphone and tablet use in achieving health goals and communicating with healthcare providers via SMS text messaging among people with hypertension within a nationally representative Health Information National Trends Survey (HINTS) data (3). The second study in Chapter 3 determined facilitators and barriers to telemonitoring of BP using the electronic health literacy framework (e-HLF) (1). In Chapter 4, the third study identified predictors of participation in BP telemonitoring using an online survey of people with hypertension.

This last chapter builds on the results and conclusions of the previous three chapters and provides an overall understanding of factors to improve patient engagement in BP telemonitoring. Specifically, this chapter comprises five sections. First, presentation of the gaps in past BP telemonitoring studies and how the previous three chapters addressed the identified gaps. Second, the summary of findings. Third, the overall findings across the chapters compared to past BP telemonitoring studies. Fourth, discussion of the implication of these studies for hypertension control care practice and health system policy along with future research directions. Lastly, the limitations of this dissertation study.

5.1 Gap in Current BP Telemonitoring Studies

As discussed in the first chapter, BP telemonitoring is currently the readiest implementable solution among the various digital health strategies for hypertension control (4). There are various challenges limiting its adoption among patients with hypertension. These challenges which included, for example, poor electronic health literacy (skills required to operate the technology), lack of access to adequate electronic infrastructure (e.g., internet, mobile devices, computers), lack of affordable digital systems (e.g., BP monitors), ignorance of the importance of cardiovascular risks detection and control, non-user-friendly technology interfaces, etc. have been reported in the literature (5–15). However, these studies on BP telemonitoring are seldom based on any theoretical framework or concurrent assessment of patients' e-HL which is an important resource required by an individual to be able to engage in BP telemonitoring. The few studies that used theoretical framework used the technology acceptance model (TAM) (16–18) which is based on a person's perception of usefulness and ease of use of a technology. Generally, the TAM was effective in predicting a person's intention or actual use of technology based on the ease of use and usefulness of the said technology. However, TAM does not provide information on factors such as the person's knowledge of their disease condition, whether they have access to suitable technology or quantitative assessment of their e-HL status. The BP telemonitoring studies that assessed e-HL utilized the electronic health literacy scale (eHEALS) (9,19) which focuses on patients' ability to use the internet to find health information. This application of e-HL to telemonitoring of BP is limited because it is centered only on a person's ability to find, evaluate, and use health information from the internet and does not account for active engagement with digital health services such as BP telemonitoring. Thus, these limitations provide an opportunity to use a new e-HLF (1). The e-HLF provides both a theorical framework and the corresponding assessment tool: the e-HL questionnaire (eHLQ) (2) for evaluation of e-HL status. The robustness of the e-HLF in terms of content and its development process makes it a suitable framework to explore in the study of BP telemonitoring. This dissertation is to our knowledge the first application of e-HLF to study factors that impact BP telemonitoring among patients with hypertension. The e-HLF is shown in Figure 1.2.

A second limitation of previous studies on patient-related factors that impact BP telemonitoring is related to the approach in the studies. Elucidation of patient-related factors has been mainly through BP telemonitoring effectiveness and intervention studies (7,8,10,12,15,20). This approach has made it difficult to account for the prevalence of BP telemonitoring among people with hypertension in the real world outside the research and clinic settings as well as quantitatively predict the factors that enhance BP telemonitoring participation. The available studies on BP telemonitoring also lack the advantage of a mixed-methods research approach which leverages on both qualitative and quantitative data to enrich the understanding of these patient-related factors that impact BP telemonitoring.

To fully understand the factors that impact telemonitoring of BP from the patient's perspective, this dissertation first leveraged the nationally representative Health Information Trends Survey (HINTS) data to assess mHealth use among people with hypertension in communicating with their healthcare providers achieving health goals. The lessons from this first study were added to the second and third studies. We then used the e-HLF to assess patients' experiences and predict factors impacting BP telemonitoring using mixed-methods and survey research in the second and third studies, respectively.

5.2 Summary of findings across the three studies

Predictors of mHealth use. In Chapter 2, the study used a weighted sample of people with hypertension from 2017 and 2018 HINTS cycles 1 and 2 data to assess the use of smartphone and tablet in communicating with healthcare providers via SMS text messaging and achieving their health goals. This dependent variable is not specifically telemonitoring of BP, but it is theoretically and pragmatically relevant because telemonitoring of BP involves remote communication with healthcare provider which could be done through SMS text messaging. Telemonitoring of BP can also be done through health apps on patients' smartphones and tablets thus providing a means of achieving health goals. The findings from this first study (21) showed that using SMS text messaging communication with a healthcare professional is positively associated with prior electronic communication with the healthcare provider and ownership of a wellness app. The odds of achieving health-related goals with tablet or smartphone declined significantly with older age and ownership of basic cellphones. Increase in the odds of achieving health-related goals with tablet or smartphone was associated with being a woman, being married, having wellness app, using devices other than smartphones or tablet to monitor health, and making health treatment decisions and discussing with a provider with the help of a tablet or smartphone.

These findings suggest that patients who are already engaging in some electronic usage for their health are more likely to achieve health goals and communicate with their healthcare provider via SMS text messages using mHealth. These findings are relevant to BP telemonitoring because mHealth devices like smartphones and tablets can be used in BP telemonitoring in both communication with healthcare providers and keeping track of BP target goals. Previous studies have identified the effectiveness of SMS text messaging between patients and providers in achieving better BP control (22–25) but not in the light of predictors of its use. Also, previous studies on achieving health goals with smartphones or tablets found similar negative association with decreasing age (26,27) and positive association with having wellness app like our study. Unlike our study, they found employment and health status to be associated with achieving health goals with smartphones or tablets (26) while did not find such association. Moreover, these studies were not done in the context of BP telemonitoring. Knowing that smartphone and tablet use to communicate with healthcare providers via SMS text messaging or achieve health goals could be associated with patients' demographics such as age, and technology behavior such as prior electronic communication with provider is helpful. This is because such knowledge will help health systems to offer BP telemonitoring programs accounting for example, patients' age and preferred remote communication methods leading to greater use of BP telemonitoring.

Facilitators and barriers to BP telemonitoring. In Chapter 3, the study used a convenience sample of patients with hypertension from Michigan Medicine to explore facilitators and barriers to BP telemonitoring. Participants had either already used a BP telemonitoring program or not. The e-HLF was the theoretical framework for this exploration as well as the quantification of the patients' e-HL status. Joint display was used to show the mixed-methods results and conclusions. In this second study involving 21 patients with hypertension, we identified five major themes including knowledge, motivation, skills, health systems, and patient behaviors as facilitators and/or barriers to BP telemonitoring. The patients participating in BP telemonitoring had higher e-HL compared to those not participating. The mixed-methods results showed concordance between patients' e-HL quantitively derived status and their expressed ability to actively engage in BP monitoring and management through digital services. However, there was discordance between the patients' quantitively derived e-HL status and their expressed use of technology to process health information; understanding of health concepts; sense of security of health information; motivation; and access to digital services that work and suits their individual needs.

Our findings are similar to previous studies that reported that patients' knowledge, skills, motivation, behaviors and the health system could decrease and/or increase engagement with remote monitoring services (20,28–32). Knowing the facilitators and barriers to BP telemonitoring from the patients' perspective will help healthcare professionals to promote the facilitators and mitigate the barriers, thus improving BP telemonitoring engagement. Though we could not find comparator studies for our mixed-method results, a significant takeaway from the concordance and discordance findings is the importance of always confirming the patients' self-assessed knowledge and capabilities in any health management engagement by direct interaction with a healthcare provider. This is essential in BP telemonitoring to ensure appropriate BP telemonitoring technique resulting in accurate and reliable measurements and interpretation.

Predictors of BP telemonitoring participation. In Chapter 4, the study utilized a cross-sectional, national survey of 507 patients with hypertension selected using a quota rubric (age and education) from a Qualtrics® survey panel. The study assessed the predictors of BP telemonitoring participation in the context of patients' demographics, technology behavior and e-HL. The survey was developed with insight from study 1 in that it included patient-provider communication preferences and BP telemonitoring specific questions. As well, study 2 showed a relationship between e-HL and engagement with BP telemonitoring and so the Chapter 4 survey provided the opportunity to test that relationship at the national level.

The prevalence of participation in BP telemonitoring in this convenience quota sample was 11.8%. The significant predictors of participation in BP telemonitoring included awareness of BP telemonitoring, sharing health information electronically with healthcare providers, and having access to digital services that suit individual patient needs (e-HL domain 7 item). The patients' most preferred electronic communication method with their healthcare provider was phone calls. The most common reasons for not participating in BP telemonitoring were because their healthcare provider did not request them to do so and the patient's lack of awareness of BP telemonitoring. These results are the first findings to consider factors that predict this health behavior in a large sample.

Though there are no direct comparator previous studies to predictors of BP telemonitoring, a review on impact of telemedicine in COVID-19 pandemic (33) noted patient awareness as an essential factor in adoption of electronic health services similar to our study. Our findings on the sharing health information as a predictor of BP telemonitoring participation is confirmed by previous study which found that prior electronic communication with healthcare provider increases the probability of engaging in SMS text communication (21). In other words, having engaged in a particular behavior increases the chances of engaging in a similar behavior. Tailoring of technological interventions to individual patients has been found to improve engagement in previous studies (34–37) which is similar to our findings on providing patients with technology that suit them. Creation of awareness of BP telemonitoring programs and providing tailored BP telemonitoring services through the patients' preferred electronic communication method will help to increase BP telemonitoring engagement.

Overall findings. Collectively, the findings from the three studies show that participation in BP telemonitoring will increase with the consideration of the following factors: patients' characteristics such as age and education; prior technology use and behavior such as electronic communication with the doctor or doctor's office; knowledge including awareness of BP telemonitoring programs; motivation including recommendation from healthcare provider; and access to suitable technology for hypertension management. The results showed a positive relationship between patients' e-HL status and ability to actively engage in BP monitoring and management through digital services.

5.3 Study Methods compared to Past BP Telemonitoring Studies

The methods used in the three studies utilized innovative approaches including the use of weighted sample of nationally representative data of people with hypertension, the use of e-HLF mixed-methods research to understand patient-related factors impacting BP telemonitoring, and survey research comparing those who use and do not use telemonitoring of BP. These approaches have not been investigated in previous studies. The following paragraphs explain these approaches in relation to previous studies.

Predictors of mHealth use. Most studies on SMS text messaging communication between healthcare providers and people with hypertension are intervention studies that focus on the effectiveness of SMS text messaging (22–25). Our study specifically identified factors associated with SMS text messaging communication with healthcare providers to be prior electronic communication with the provider and use of health apps. While previous HINTS data studies on predictors of smartphone and tablet use to achieve health goals have generally focused on just adults regardless of diseases conditions (26,27), our study is specifically focused on people with hypertension. Though we found similar factors associated between the use of mHealth to achieve health goals and patients' characteristics such as age as reported in the previous studies, our study uniquely applies to people with hypertension. Also, the HINTS weighted sampling and our complex sampling design analyses makes it possible to generalize findings to people with hypertension in the United States.

Facilitators and barriers to BP telemonitoring. Facilitators and barriers to BP telemonitoring have been largely studied in the context of general technology adoption and without consideration of e-HL (20,29,38). Our findings of major themes including knowledge, motivation, skills, health systems, and patient behaviors as facilitators and/or barriers to BP telemonitoring are similar to findings in previous studies. However, our incorporation of e-HLF to arrive at these findings has not been done before. This framework was useful because it considers the individual's knowledge and abilities (domains 1 and 2), the health systems responsibilities (domains 6 and 7), and the interaction between the individual and the health systems (domains 3, 4, and 5) in accounting for a patient's e-HL status. Thus, it provided a robust structural foundation for the study.

As well, the mixed-methods approach of comparing the quantitatively assessed patients' e-HL with their qualitatively expressed themes is the first of its kind in BP telemonitoring studies. These results are particularly important because it provided an extended understanding of BP telemonitoring themes in the context of e-HL that either method (qualitative or quantitative) could not have provided. Specifically drawing our attention to be cautious in depending solely on patients' self-assessment tools for clinical decision making.

Predictors of BP telemonitoring participation. Factors influencing BP telemonitoring from patients' perspective have been largely determined qualitatively

(8,10,12,20) and less quantitatively (9) in previous studies. Moreover, very few BP telemonitoring studies consider patients' e-HL assessment (9,19). It was difficult to find comparison for our findings from previous studies because our study is uniquely focused on current BP telemonitoring participation and not willingness or readiness to participate reported in previous studies (9,39). Our study is also the first to our knowledge to incorporate e-HL using the e-HLF in assessing predictors of BP telemonitoring participation in hypertension management. The next section discusses the implications of these findings on health policy, science, and healthcare practice.

5.4 Implications and Future Research

This dissertation is one of the first studies to specifically assess BP telemonitoring in the context of three primary types of predictors including patients' characteristics, technology behaviors, and e-HL that impact participation in this health behavior. Some significant implications have emerged from the findings of this dissertation and can be considered at policy and practice levels.

First, the three important policy takeaways are in the provision of BP telemonitoring infrastructure, reimbursement for healthcare providers of BP telemonitoring, and insurance coverage for patients. For any service to benefit the intended patients, the infrastructure for the service must be made available and accessible. With the knowledge of the advantages of BP telemonitoring, policy makers in the health system should invest in the resources needed to help ensure that telemonitoring of BP is widely adopted. These include secure and dedicated remote BP monitoring technology and adequate technical support systems. For example, the patient needs a BP monitoring machine, a compatible mobile phone or computer with an internet or cellular service for remote communication with the healthcare provider. We found that the patients who were already involved in electronic communication with their healthcare providers were more likely to participate in BP telemonitoring. Having a home BP device would go a long way in increasing access to BP telemonitoring services for the patients. Adequate technical support may include having dedicated staff to monitor the telemonitoring records and respond to patients' technical challenges or questions in record time. The technical support system may include computer experts and health professionals working in tandem to ensure glitch-free telemonitoring experience for the patients.

This infrastructure should then be supported by an adequate reimbursement policy for healthcare providers of the BP telemonitoring services. One of the critical factors affecting BP telemonitoring participation from our study is a lack of patient awareness of such services. Further, a recommendation from a healthcare provider has an influence on using such systems. We believe that when these services are made available and considered payable services, healthcare providers can help to ensure their patients get all the benefits therein. The reimbursement of phone- and video-based health services made it possible for patients to receive health care during the COVID-19 pandemic (40). The advantages of that access to healthcare even in quarantine situations cannot be overemphasized. This same policy should be extended to BP telemonitoring, as it is convenient, easy, and saves time and space for the patients and healthcare providers.

Second, this dissertation offers three significant implications for hypertension care including personalization of BP telemonitoring service, integrating BP telemonitoring into routine care, and teamwork among healthcare providers. We found that patients were more likely to participate in BP telemonitoring when they have access to services that suit their individual needs. These needs include the frequency and timing of BP measurement, mode of remote transmission of BP measurement, as well as type of feedback to patients. Understanding the electronic health literacy of patients by knowing their current technology use could be a means to recommend digital services. Personalization of BP telemonitoring services would also help in ensuring that only required data is obtained from the patient, reducing effort and time spent in reviewing unnecessary data by the healthcare providers.

We also suggest that incorporating BP telemonitoring into routine healthcare will increase its awareness among patients as an available option of care to pursue. This integration into routine care could be done in a way that a patient's BP telemonitoring record is accessible to all their healthcare providers at every point in time. This will enhance teamwork among the healthcare providers and ensure improved coordinated care for patients. From our study findings, the majority of BP telemonitoring services were provided by doctors and nurses. We believe that including other healthcare providers, such as the pharmacists, will not only lessen the burden of the telemonitoring service on doctors but will also foster teamwork among the healthcare providers. Each healthcare practice should take advantage of all the manpower they have available to provide maximum quality care for their patients with hypertension.

For future research, two directions can be pursued to expand the results of this dissertation. First, the real-world association of BP telemonitoring services with BP control is needed. Most of the current studies on the relationship between BP telemonitoring and BP control are intervention studies with limited generalizability. Investigation of the effect of BP telemonitoring on BP control in routine care will help build a stronger case for its effectiveness in BP management and would drive policy towards infrastructure provision and reimbursement.

Second, designing an e-HL assessment tool that could uniquely apply to people with hypertension and related cardiovascular diseases could help capture the full essence of electronic literacy needs of this patient population. Currently, the e-HL assessment tools available are non-specific to hypertension and so patients may not be responding to the assessment questions in the context of their hypertension management. This is usually one of the limitations of using these tools in disease-specific conditions. Exploring the relationship between BP telemonitoring services and hypertension-specific e-HL assessment tool will provide a better understanding of what pertains to people with hypertension than a general assessment tool can offer.

5.5 Limitations

Just like other studies, this dissertation has some limitations which can be categorized into design, data collection tool, and data collection methods. First, the design limitations include cross-sectional study designs and convenience sampling. The cross-sectional design used in Chapters 2 and 4 is a limitation because it cannot provide causal inferences for the outcome variables. However, the robustness of our analytical approach still provides a reasonable estimate of the relationship for the factors identified. The convenience sampling used in Chapter 3 is a limitation because the findings are the opinions of the participants who responded from experiences unique to them. Still, these were people with hypertension with and without experience of using BP telemonitoring and, hence, their perspectives are important. Also, it is not feasible to interview all the people with hypertension before impactful inference can be made in hypertension healthcare.

Second, our data collection tool posed some limitations. For example, we could not account for BP control in Chapter 2 because the secondary HINTS data had no such variable.

However, we were able to add the BP control variable in our own survey used in Chapter 4. The e-HL assessment tool (eHLQ) was not hypertension-specific and may not have captured all patients' characteristics such as the social and cultural characteristics that may affect e-HL. Nevertheless, the tools still provide insightful findings regarding patient experiences. Future studies should aim for disease context specific tools that account for every aspect of human lives.

Third, the use of self-reported data across chapters 2, 3, and 4 is subjective instead of objective. However, patient-reported data is an important consideration in any disease management and cannot be jettisoned. The collection of data through the online method in Chapters 3 and 4 may have biased our sample in favor of those with higher e-HL. However, BP telemonitoring being a technology service makes it reasonable to use such data collection method.

5.6 Conclusion

BP telemonitoring is an emerging BP management digital service that improves BP control. Patient-related factors influencing BP telemonitoring participation are significantly associated with patient demographics, technology behavior and access to technology services. Policy makers could support the broad development of BP telemonitoring infrastructures and reimbursement for the services. BP telemonitoring services should be personalized by providing patients with suitable telemonitoring infrastructures and technical support to maximize individual benefits.

5.7 References

1. Norgaard O, Furstrand D, Klokker L, Karnoe A, Batterham R, Kayser L, et al. Knowledge Management & E-Learning The e-health literacy framework: A conceptual framework for characterizing e-health users and their interaction with e- health systems. Knowl Manag E-Learning. 2015;7(74):522–40.
2. Kayser L, Karnoe A, Furstrand D, Batterham R, Christensen KB, Elsworth G, et al. A multidimensional tool based on the eHealth Literacy Framework: Development and initial validity testing of the eHealth Literacy Questionnaire (eHLQ). J Med Internet Res. 2018;20(2):1–10.
3. Institute NC. Health Information National Trends Survey 5 (HINTS 5) Cycle 2 Methodology Report. 2018;5(July). Available from: https://hints.cancer.gov/data/methodology-reports.aspx
4. Padwal R, Wood PW. Digital Health Approaches for the Assessment and Optimisation of Hypertension Care Provision. Can J Cardiol [Internet]. 2021;37(5):711–21. Available from: https://doi.org/10.1016/j.cjca.2020.12.009
5. Parati G, Dolan E, McManus RJ, Omboni S. Home blood pressure telemonitoring in the 21st century. J Clin Hypertens. 2018;20(7):1128–32.
6. Chirra M, Marsili L, Wattley L, Sokol LL, Keeling E, Maule S, et al. Telemedicine in Neurological Disorders: Opportunities and Challenges. Telemed e-Health. 2019;25(7):541–50.
7. Aquino M, Griffith J, Vattaparambil T, Munce S, Hladunewich M, Seto E. Patients' and Providers' Perspectives on and Needs of Telemonitoring to Support Clinical Management and Self-care of People at High Risk for Preeclampsia: Qualitative Study. JMIR Hum

Factors. 2022;9(1):1–9.

8. Hanley J, Ure J, Pagliari C, Sheikh A, McKinstry B. Experiences of patients and professionals participating in the HITS home blood pressure telemonitoring trial: A qualitative study. BMJ Open. 2013;3(5):1–10.

9. Sin DYE, Guo X, Yong DWW, Qiu TY, Moey PKS, Falk MR, et al. Assessment of willingness to Telemonitoring interventions in patients with type 2 diabetes and/or hypertension in the public primary healthcare setting. BMC Med Inform Decis Mak. 2020;20(1):1–11.

10. Ware P, Shah A, Ross HJ, Logan AG, Segal P, Cafazzo JA, et al. Challenges of Telemonitoring Programs for Complex Chronic Conditions: Randomized Controlled Trial with an Embedded Qualitative Study. J Med Internet Res. 2022;24(1):1–16.

11. Foster M V., Sethares KA. Facilitators and barriers to the adoption of telehealth in older adults: An integrative review. CIN - Comput Informatics Nurs. 2014;32(11):523–33.

12. Koopman RJ, Wakefield BJ, Johanning JL, Keplinger LE, Kruse RL, Bomar M, et al. Implementing home blood glucose and blood pressure telemonitoring in primary care practices for patients with diabetes: Lessons learned. Telemed e-Health. 2014;20(3):253–60.

13. Citoni B, Figliuzzi I, Presta V, Volpe M, Tocci G. Home Blood Pressure and Telemedicine: A Modern Approach for Managing Hypertension During and After COVID-19 Pandemic. High Blood Press Cardiovasc Prev [Internet]. 2022;29(1):1–14. Available from: https://doi.org/10.1007/s40292-021-00492-4

14. Wood PW, Boulanger P, Padwal RS. Home Blood Pressure Telemonitoring: Rationale for Use, Required Elements, and Barriers to Implementation in Canada. Can J Cardiol

[Internet]. 2017;33(5):619–25. Available from: http://dx.doi.org/10.1016/j.cjca.2016.12.018

15. Baratta J, Brown-Johnson C, Safaeinili N, Rosas LG, Palaniappan L, Winget M, et al. Patient and Health Professional Perceptions of Telemonitoring for Hypertension Management: Qualitative Study. JMIR Form Res. 2022;6(6).

16. Abdullah A, Liew SM, Hanafi NS, Ng CJ, Lai PSM, Chia YC, et al. What influences patients' acceptance of a blood pressure telemonitoring service in primary care? A qualitative study. Patient Prefer Adherence. 2016;10:99–106.

17. Portz JD, Bayliss EA, Bull S, Boxer RS, Bekelman DB, Gleason K, et al. Using the Technology Acceptance Model to Explore User Experience, Intent to Use, and Use Behavior of a Patient Portal Among Older Adults With Multiple Chronic Conditions: Descriptive Qualitative Study. J Med Internet Res [Internet]. 2019;21(4):e11604. Available from: https://www.jmir.org/2019/4/e11604/

18. Dou K, Yu P, Deng N, Liu F, Guan Y, Li Z, et al. Patients' Acceptance of Smartphone Health Technology for Chronic Disease Management: A Theoretical Model and Empirical Test. JMIR mHealth uHealth [Internet]. 2017 Dec 6;5(12):e177. Available from: https://mhealth.jmir.org/2017/12/e177/

19. Wang S, Leung M, Leung SY, Han J, Leung W, Hui E, et al. Safety, Feasibility, and Acceptability of Telemedicine for Hypertension in Primary Care: A Proof-of-concept and Pilot Randomized Controlled Trial (SATE-HT). J Med Syst. 2023;47(1).

20. Grant S, Hodgkinson J, Schwartz C, Bradburn P, Franssen M, Hobbs FDR, et al. Using mHealth for the management of hypertension in UK primary care: An embedded qualitative study of the TASMINH4 randomised controlled trial. Br J Gen Pract.

2019;69(686):E612–20.

21. Eze CE, West BT, Dorsch MP, Coe AB, Lester CA, Buis LR, et al. Predictors of Smartphone and Tablet Use among Patients with Hypertension: Secondary Analysis of Health Information National Trends Survey Data. J Med Internet Res. 2022;24(1):1–23.

22. Hacking D, Haricharan HJ, Brittain K, Lau YK, Cassidy T, Heap M. Hypertension Health Promotion via Text Messaging at a Community Health Center in South Africa: A Mixed Methods Study. JMIR mHealth uHealth [Internet]. 2016 Mar 10;4(1):e22–e22. Available from: https://pubmed.ncbi.nlm.nih.gov/26964505

23. Vargas G, Cajita MI, Whitehouse E, Han HR. Use of short messaging service for hypertension management: A systematic review. J Cardiovasc Nurs. 2017;32(3):260–70.

24. Buis L, Hirzel L, Dawood RM, Dawood KL, Nichols LP, Artinian NT, et al. Text Messaging to Improve Hypertension Medication Adherence in African Americans From Primary Care and Emergency Department Settings: Results From Two Randomized Feasibility Studies. JMIR mHealth uHealth [Internet]. 2017 Feb 1;5(2):e9–e9. Available from: https://pubmed.ncbi.nlm.nih.gov/28148474

25. Zhai P, Hayat K, Ji W, Li Q, Shi L, Atif N, et al. Efficacy of text messaging and personal consultation by pharmacy students among adults with hypertension: Randomized controlled trial. J Med Internet Res. 2020;22(5).

26. Mahmood A, Kedia S, Wyant DK, Ahn SN, Bhuyan SS. Use of mobile health applications for health-promoting behavior among individuals with chronic medical conditions. Digit Heal. 2019;5:1–17.

27. Bhuyan SS, Lu N, Chandak A, Kim H, Wyant D, Bhatt J, et al. Use of Mobile Health Applications for Health-Seeking Behavior Among US Adults. J Med Syst. 2016;40(6).

28. Walker RC, Tong A, Howard K, Palmer SC. Patient expectations and experiences of remote monitoring for chronic diseases: Systematic review and thematic synthesis of qualitative studies. Int J Med Inform [Internet]. 2019;124(January):78–85. Available from: https://doi.org/10.1016/j.ijmedinf.2019.01.013

29. Palacholla RS, Fischer N, Coleman A, Agboola S, Kirley K, Felsted J, et al. Provider-And patient-related barriers to and facilitators of digital health technology adoption for hypertension management: Scoping review. J Med Internet Res. 2019;21(3):1–12.

30. Paterick TE, Patel N, Tajik J, Chandrasekaran K. Improving health outcomes through Patient education and Partnerships with patients. Proc (Bayl Univ Med Cent). 2017;30(1):112–3.

31. McCarron TL, Noseworthy T, Moffat K, Wilkinson G, Zelinsky S, White D, et al. Understanding the motivations of patients: A co-designed project to understand the factors behind patient engagement. Heal Expect. 2019;22(4):709–20.

32. Price-Haywood EG, Harden-Barrios J, Ulep R, Luo Q. EHealth Literacy: Patient Engagement in Identifying Strategies to Encourage Use of Patient Portals Among Older Adults. Popul Health Manag. 2017;20(6):486–94.

33. Omboni S, Padwal RS, Alessa T, Benczúr B, Green BB. Europe PMC Funders Group The worldwide impact of telemedicine during COVID-19 : current evidence and recommendations for the future. Connect Heal. 2022;1:7–35.

34. Rezai LS, Torenvliet G, Burns CM. Increasing Patient Adherence to Home Health-Monitoring Systems. Proc Int Symp Hum Factors Ergon Heal Care. 2014;3(1):8–14.

35. de Ridder M, Kim J, Jing Y, Khadra M, Nanan R. A systematic review on incentive-driven mobile health technology: As used in diabetes management. J Telemed Telecare.

2017;23(1):26–35.

36. Scherrenberg M, Marinus N, Giallauria F, Falter M, Kemps H, Wilhelm M, et al. The need for long-term personalized management of frail CVD patients by rehabilitation and telemonitoring: A framework. Trends Cardiovasc Med. 2022;(xxxx).

37. Khalid A, Dong Q, Chuluunbaatar E, Haldane V, Durrani H, Wei X. Implementation Science Perspectives on Implementing Telemedicine Interventions for Hypertension or Diabetes Management: Scoping Review. J Med Internet Res. 2023;25:e42134.

38. Mileski M, Kruse CS, Catalani J, Haderer T. Adopting Telemedicine for the Self-Management of Hypertension: Systematic Review. JMIR Med Informatics. 2017;5(4):e41.

39. Kalańska-Łukasik B, Gładyś A, Jadczyk T, Gruz-Kwapisz M, Wojakowski W, Kowalska M. Readiness for Telemedical Services in Patients With Cardiovascular Diseases: Cross-sectional Study. JMIR Form Res. 2022;6(10):1–9.

40. Kichloo A, Albosta M, Dettloff K, Wani F, El-Amir Z, Singh J, et al. Telemedicine, the current COVID-19 pandemic and the future: a narrative review and perspectives moving forward in the USA. Fam Med community Heal. 2020;8(3):1–9.

Appendix A: Demographics-only Model with Design-adjusted Estimates of Odds Ratios for achieving Health-related Goals with the help of Tablet or Smartphone among the Hypertensive Population

		Sample size = 3,045 Estimated Population size = 183,285,150		
Predictor	Category	Odds Ratio (95% CI)	SE	*P*-value
[a]**Age groups (yrs)**				
	35-49	0.36 (0.155, 0.831)	0.428	.025
	50-64	0.14 (0.058, 0.353)	0.462	<.001
	65-74	0.10 (0.037, 0.270)	0.506	<.001
	75+	0.07 (0.024, 0.180)	0.514	<.001
[b]**Gender**				
	Female	1.69 (1.198, 2.371)	0.174	.006
[c]**Education levels**				
	High Sch grad	1.38 (0.611, 3.115)	0.415	.446
	Some college	1.80 (0.789, 4.104)	0.420	.176
	College grad or more	1.75 (0.736, 4.169)	0.443	.218

		Sample size = 3,045 Estimated Population size = 183,285,150		
Predictor	Category	Odds Ratio (95% CI)	SE	*P*-value
[d]**Race/Ethnicity**				

Predictor	Category	Odds Ratio (95% CI)	SE	*P*-value
	Non-Hispanic Black or African American	1.27 (0.762, 2.115)	0.260	.370
	Hispanic	0.75 (0.366, 1.526)	0.364	.432
	Non-Hispanic Asian	2.17 (0.840, 5.592)	0.484	.124
	Non-Hispanic Other	1.68 (0.626, 4.483)	0.502	.315
[e]**Marital status**				
	Married	2.41 (1.413, 4.120)	0.273	.004
	Previously married	2.11 (1.178, 3.783)	0.298	.019
[f]**House-hold yearly income**				
	<$20,000	0.57 (0.292, 1.107)	0.340	.110
	$20,000 to <$35,000	0.39 (0.212, 0.722)	0.312	.006
	$35,000 to <$50,000	0.50 (0.255, 0.990)	0.345	.058
	$50,000 to <$75,000	0.60 (0.382, 0.936)	0.228	.034
[g]**Employment status**				
	Employed	1.17 (0.804, 1.715)	0.193	.414
[h]**Smoked at least 100 cigarettes**				
	No	1.10 (0.711, 1.716)	0.223	.661
[i]**Health status**				
	Very good	1.07 (0.620, 1.859)	0.280	.802
	Good	0.93 (0.528, 1.643)	0.290	.808
BMI				
		1.01 (0.985, 1.037)	0.013	.432
[j]**Diabetes**				
	Yes	1.07 (0.701, 1.623)	0.214	.766
		Sample size = 3,045 Estimated Population size =183,285,150		

[j]**Heart condition**				
	Yes	1.05 (0.523, 2.106)	0.355	.893
[j]**Depression**				
	Yes	0.95 (0.662, 1.361)	0.183	.779

[a-j]Reference categories for categorical predictors.
[a] =18-34yrs; [b] =Male; [c] =Less than high school; [d] =Non-Hispanic White; [e] =Never married; [f] =$75,000 or more; [g] =Unemployed; [h] =Yes response; [i] =Fair; [j] =No response

Appendix B: Demographics-only Model with Design-Adjusted Estimates of Odds Ratios for Sending or Receiving Text Message from Healthcare Provider in the Last 12 Months among the Hypertensive Population

		Sample size = 3,045 Estimated Population size = 183,285,150		
Predictor	Category	Odds Ratio (95% CI)	SE	*P*-value
[a]**Age groups (yrs)**				
	35-49	1.60 (0.646, 3.960)	0.463	.320
	50-64	1.04 (0.434, 2.473)	0.444	.937
	65-74	0.83 (0.324, 2.106)	0.477	.693
	75+	0.60 (0.206, 1.732)	0.543	.353
[b]**Gender**				
	Female	1.22 (0.929, 1.606)	0.140	.165
[c]**Education levels**				
	High Sch grad	0.89 (0.417, 1.895)	0.386	.764
	Some college	1.28 (0.578, 2.837)	0.405	.545
	College grad or more	1.17 (0.475, 2.904)	0.462	.731
[d]**Race/Ethnicity**				
	Non-Hispanic Black or African American	0.94 (0.583, 1.499)	0.241	.783
	Hispanic	0.76 (0.421, 1.371)	0.301	.372
	Non-Hispanic Asian	0.86 (0.358, 2.070)	0.447	.742
	Non-Hispanic Other	1.42 (0.503, 4.010)	0.530	.515
[e]**Marital status**				
	Married	1.54 (0.815, 2.908)	0.324	.197
		Sample size = 3,045 Estimated Population size = 183,285,150		

Predictor	Category	Odds Ratio (95% CI)	SE	*P*-value
[f]**House-hold yearly income**				
	<$20,000	0.26 (0.132, 0.512)	0.346	<.001
	$20,000 to <$35,000	0.35 (0.202, 0.614)	0.283	.001
	$35,000 to <$50,000	0.49 (0.276, 0.881)	0.296	.026
	$50,000 to <$75,000	0.60 (0.409,0.872)	0.193	.014
[g]**Employment status**				
	Employed	0.81 (0.506, 1.284)	0.237	.373
[h]**Smoked at least 100 cigarettes**				
	No	1.12 (0.858, 1.456)	0.135	.419
[i]**Health status**				
	Very good	1.26 (0.660, 2.087)	0.241	.350
	Good	1.17 (0.789, 2.087)	0.226	.494
BMI				
		1.01 (0.984, 1.035)	0.013	.470
[j]**Diabetes**				
	Yes	1.16 (0.852, 1.585)	0.158	.352
[j]**Heart condition**				
	Yes	1.09 (0.743, 1.585)	0.193	.675
[j]**Depression**				
	Yes	1.29 (0.816, 2.036)	0.233	.288

[a-j]Reference categories for categorical predictors.
[a] =18-34yrs; [b] =Male; [c] =Less than high school; [d] =Non-Hispanic White; [e] =Never married; [f] =$75,000 or more; [g] =Unemployed; [h] =Yes response; [i] =Fair; [j] =No response

Appendix C: Semi-structured Interview Questions Guide

Hello, my name is Chinwe Eze, and I am the principal investigator of this research project titled "Facilitators and Barriers to Blood Pressure Telemonitoring: A Mixed Methods Approach". Thank you for taking the time to participate in this interview about your perceptions of facilitators and barriers to technology use in remote monitoring of blood pressure. We aim to learn from your experiences and apply them to improve technology use in blood pressure remote monitoring.

I will be leading this interview and will also be audio-taping this session to make sure that I do not miss your comments. I will also take notes during this interview. After the recording is transcribed, I will delete the recording. Your name will not be tied to your comments, or any reports produced from the interviews.

(Note to Facilitator: Note date and time of interview, interview number)

Interview Questions[a]

All Participants

1. Are you aware of the importance of managing hypertension? Share your thoughts on that.
2. What has your healthcare provider encouraged you to do in order to manage your high blood pressure (BP)?
3. Is your blood pressure under control?
4. People use different strategies to maintain high blood pressure control. Please share with us what you are doing to maintain blood pressure control? (If not controlled, what can you do to achieve control?)
5. What medications are you taking for high blood pressure?
6. How do you monitor your blood pressure? (Frequency, at home, pharmacy, hospital etc.)
7. Do you have access to technology like computers, tablets/mobile devices, smartphones, monitoring devices, wearables, sensors etc. in your home? (Participant to state all that apply)
8. How comfortable are you in using technology? By technology, I mean things like your phone, phone applications, tablets, etc. Are you able to actively use them? How proficient are you on a scale of 1 to 10, 1 being least proficient, 10 being maximally proficient?
9. Do you feel that engaging in technology services (like services offered through electronic health records, phone calls, text messages, health apps etc.) is useful in managing your health?
10. Do you have access to technology that works (access to health information, provider services, health data, health technology) and what is your experience like?

11. Have you used technology for self-monitoring of BP?
12. What type of technology devices have you used in the past for BP self-monitoring and how?
13. What technology device are you currently using for BP self-monitoring and how?
14. Can you tell us what you know about remote blood pressure monitoring? (Facilitator to introduce remote blood pressure monitoring/ Telemonitoring)

For those enrolled in remote blood pressure

15. Tell me about what it was like using remote blood pressure monitoring for blood pressure management.
16. What did you like most about remote blood pressure monitoring for blood pressure management?
17. What did you dislike most about remote blood pressure monitoring for blood pressure management?
18. What would you like to change about remote blood pressure monitoring for blood pressure management?
19. What challenges did/are you have/having with remote blood pressure monitoring for blood pressure management?

For those that declined enrollment

20. Please tell us why you declined to participate in remote blood pressure monitoring for blood pressure management?
21. What would it take to have you participate in remote blood pressure monitoring?
22. Can you think of ways we can make remote blood pressure monitoring or any other technology service for hypertension management something you will want to use? (How do you think it will work best?)

[a] **The following are examples of probing questions that may be asked to further understand the interviewee's responses:** Would you give me an example? Can you say some more about that? Would you explain that further? I am not sure I understand what you are saying. Could you rephrase your answer? How did that come about? Is there anything else?

Appendix D: Survey for Remote Blood Pressure Monitoring: Electronic Health Literacy and Behavioral Factors related to Participation Study

Start of Block: Introduction

Thank you for choosing to participate in this research study titled **“**Remote Blood Pressure Monitoring: Electronic Health Literacy and Behavioral Factors related to Participation**”.** The next page explains the study more fully and lets you know what will happen to the information you provide.

More Information about the Research Study.

Hypertension, also known as high blood pressure, is a disease that requires monitoring. Information from other studies tells us that people with high blood pressure may now monitor their own blood pressure using a blood pressure monitoring device and communicate the measurement with their phone or tablet to their doctor, pharmacist or nurse from the comfort of their homes. This type of **remote blood pressure monitoring** service may be available at your doctor's office.

In this study, you will be asked questions about your high blood pressure and experiences with monitoring it. You will also answer questions about using technology in general to meet your health needs. We want to understand and learn from your experiences with your blood pressure monitoring. If you do not monitor your blood pressure, we still want to learn from you what could be done to help you in managing your hypertension.

We are conducting this research because we want to learn how we can make the benefits of remote blood pressure monitoring reach every patient with hypertension that needs it.

This study may not benefit you directly but may benefit others in the future.

This is an online survey to gather information about you, your blood pressure, and blood pressure monitoring. There are no anticipated risks or discomforts with this survey. No identifiable data will be collected.

You will be compensated the amount you agreed upon before you entered into the survey.

Your participation in this research is entirely voluntary. Even if you decide to participate, you can change your mind and stop at any time. If you choose not to answer any question, you would quit the survey based upon how we set it up.

If you have questions about this research study, you may contact Chinwe Eze, Graduate Student ceeze@med.umich.edu Or Karen B Farris, PhD, Professor kfarris@med.umich.edu The University of Michigan Institutional Review Board Health Sciences and Behavioral Sciences has determined that this study is exempt from IRB oversight. By selecting YES, you agree to participate in the study and you will proceed to complete the online survey.

- ☐ Yes, I consent
- ☐ No, I do not consent

Skip To: End of Block If More Information about the Research Study Remote Blood Pressure Monitoring: Electronic Health Literacy and Behavioral Factors related to Participation... = No, I do not consent

Part 1. This online survey has four parts. In this first part, we ask you questions that we will use to describe who participated in this study. Please continue to part one.

Age What is your age in years?

____

Skip To: End of Block If Condition: What is your age in years?&... Is Less Than 18. Skip To: End of Block.

Age Bracket Please select your age group below

- ☐ less than 50 years
- ☐ 50-74 years
- ☐ 75 years and above

HTN Have you ever been told by a doctor, nurse or another health professional that you have hypertension or high blood pressure?

- ☐ Yes
- ☐ No

Skip To: End of Block If Have you ever been told by a doctor, nurse or another health professional that you have hypertens... = No

HTNMed Are you currently taking any medication prescribed by your doctor, physician assistant or nurse practitioner for the management of your hypertension?

☐ Yes

☐ No

Skip To: End of Block If Are you currently taking any medication prescribed by your doctor, physician assistant or nurse p... = No

What is your gender?

☐ Male

☐ Female

☐ Non-binary / third gender

☐ Transgender male

☐ Transgender female

☐ Prefer not to say

What is your ethnicity?

☐ Hispanic or Latino

☐ Not Hispanic or Latino

What is your race?

- ☐ White
- ☐ Black or African American
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Native Hawaiian or Pacific Islander
- ☐ Other, please tell us your race in the box below

  ____

What is the highest level of education you have completed?

- ☐ Less than High School
- ☐ High School graduate
- ☐ Some College
- ☐ Bachelor's degree
- ☐ Graduate degree and/or Professional degree

What is your marital status?

- ☐ Married
- ☐ Single
- ☐ Divorced
- ☐ Widowed
- ☐ Separated
- ☐ Living as married

How would you describe your general health status?

- ☐ Excellent
- ☐ Very good
- ☐ Good
- ☐ Fair
- ☐ Poor

What is your estimated annual household Income?

- ☐ Less than $20,001
- ☐ $20,001 to $35,000
- ☐ $35,001 to $50,000
- ☐ $50,001 to $75,000
- ☐ $75,001 or more
- ☐ Prefer not to say

History How long have you had hypertension?

- ☐ Less than 1 year
- ☐ 1 year - Less than 2 years
- ☐ 2 years - Less than 3 years
- ☐ 3 years - Less than 4 years
- ☐ 4 years - Less than 5 years
- ☐ 5 years or more

Which of the following other health conditions do you have? (Check all that apply)

- ☐ Heart condition (examples include coronary heart disease or angina, heart failure, heart attack)
- ☐ Diabetes
- ☐ Depression or anxiety
- ☐ Chronic kidney disease
- ☐ Other, please list in the box below

  ____

- ☐ ⊗None

How many different **hypertension** prescription medications do you take every day? Prescription medications are the ones prescribed by your doctor, physician assistant or nurse practitioner. (Please enter a number)

____

How many other prescription medications do you take every day **for other health conditions**? Prescription medications are the ones prescribed by your doctor, physician assistant or nurse practitioner. (Please enter a number)

____

What is the distance from your residence to your healthcare provider's office or hospital?

- ☐ Less than 5 miles
- ☐ Between 5 and 10 miles
- ☐ More than 10 miles

Please select the option that best describes the area where you currently live

- ☐ Urban
- ☐ Suburban
- ☐ Exurban (rural type areas just beyond the suburbs)
- ☐ Rural

Please answer YES or NO to having any of the following technology devices.

	YES	NO
Tablet computer (example iPad, Samsung Galaxy, Nexus, Kindle fire)	☐	☐
Smartphone (example iPhone, Android, Blackberry, or Windows Phone)	☐	☐
Basic cellphone only	☐	☐
Desktop or Laptop Computer	☐	☐

Part 2. This second part of the survey asks questions about your blood pressure and blood pressure monitoring. First, we ask about your blood pressure monitoring at home.

Do you measure your blood pressure routinely at any of the following places? (check all that apply)

- ☐ At home
- ☐ At the pharmacy
- ☐ At the clinic
- ☐ At work
- ☐ Some other place ____
- ☐ ⊗I do not measure my blood pressure routinely

Do you have a home blood pressure monitoring device like a digital blood pressure cuff or manual blood pressure cuff?

- ☐ Yes, and I use it
- ☐ Yes, but I don't use it
- ☐ No

Skip To: No Home BP device If Do you have a home blood pressure monitoring device like a digital blood pressure cuff or manual... = No

Please indicate who paid for your home blood pressure monitoring device

- ☐ I paid for it myself
- ☐ My insurance paid for it
- ☐ It was a gift given to me
- ☐ Other, please explain in the box below

____

Display This Question:
If Do you have a home blood pressure monitoring device like a digital blood pressure cuff or manual... = Yes, and I use it

How often do you measure your blood pressure at home?

- ☐ Never
- ☐ Daily
- ☐ Several times a week
- ☐ Once a week
- ☐ One to three times in a month
- ☐ Once in 3 months
- ☐ Once in 6 months
- ☐ Once in a year

Display This Question:
If Do you have a home blood pressure monitoring device like a digital blood pressure cuff or manual... = Yes, and I use it

How do you keep track of the blood pressure readings/measurements that you take at home?

☐ I write it on a paper

☐ I write it on a calendar

☐ I write on an App on my phone/tablet/computer

☐ I write on Excel sheet or Notepad on my phone/tablet/computer

☐ I don’t keep track of it

☐ Other, please explain in the box below

____

Display This Question:
If Do you have a home blood pressure monitoring device like a digital blood pressure cuff or manual... = Yes, and I use it

Have you ever shared your blood pressure readings/measurements that you took at home with your healthcare provider?

- ☐ Yes, I take them to my doctor visits
- ☐ Yes, my blood pressure device automatically reports them to my doctor
- ☐ Yes, I send them to my doctor by email
- ☐ Yes, I send them to my doctor through the electronic health record/patient portal
- ☐ Yes, I send them to my doctor through text messages
- ☐ No

Display This Question:
If Do you have a home blood pressure monitoring device like a digital blood pressure cuff or manual... = No

Please indicate why you do not have a home blood pressure monitoring device (Check all that apply)

- ☐ I don't think I need it
- ☐ I haven't seen one that works well
- ☐ I cannot afford it
- ☐ My blood pressure is under control
- ☐ Am not sure how to use it/too complicated
- ☐ My doctor measures my blood pressure
- ☐ Other ____

Please rank the order of the ways listed below that you prefer to interact with your healthcare provider about your blood pressure management, where #1 is the most preferred and #6 is the least preferred. (Rank by dragging your most preferred way to the top and it's number will automatically change to #1. Do the same for the rest of your choices.)

______ Email

______ Phone call

______ Text messages (SMS)

______ In-person visit at clinic

______ Electronic health record

______ Video face-to-face visit/Telehealth

End of Block: BP monitoring

Start of Block: Remote BP monitoring

Remote blood pressure monitoring is a newer way to keep control of your blood pressure from home. In remote blood pressure monitoring, you measure your BP at home and send the readings/measurements to your healthcare provider through an electronic means. You may or may not receive feedback from your provider electronically. You still visit the office for problems or yearly check-ups.

Have you ever heard of remote blood pressure monitoring?

☐ Yes

☐ No

Does your healthcare provider or physician office offer remote blood pressure monitoring?

- ☐ Yes
- ☐ No
- ☐ Don't know or unsure

Do you participate in a remote blood pressure monitoring with your healthcare provider or physician office?

- ☐ Yes
- ☐ No

Skip To: How RBP If Do you participate in a remote blood pressure monitoring with your healthcare provider or physici... = Yes
Skip To: Not RBP reasons If Do you participate in a remote blood pressure monitoring with your healthcare provider or physici... = No

How do you electronically send blood pressure readings/measurements that you take at home to your healthcare professional or physician? (check all that apply)

- ☐ Text message(SMS)
- ☐ Email
- ☐ Electronic health record or patient portal
- ☐ Health Apps
- ☐ Phone call
- ☐ My blood pressure device automatically reports them to my doctor

How often do you electronically send blood pressure readings/measurements that you take at home to your healthcare professional or physician ?

☐ Daily

☐ Several times a week

☐ Once a week

☐ One to three times a month

☐ Less than once a month

What type of feedback do you receive when you electronically send your blood pressure readings/measurements that you take at home to your healthcare professional or physician?

☐ None

☐ Readings received/acknowledgement

☐ Interpretation of readings as normal, high or low

☐ Changes in hypertension medication

☐ Changes in frequency of blood pressure monitoring

☐ Other ____

Which of the following healthcare provider(s) is/are involved in your remote blood pressure monitoring? (check all that apply)

- ☐ Doctor
- ☐ Nurse
- ☐ Pharmacist
- ☐ Physician assistant
- ☐ ⊗Don't know or unsure

Display This Question:
If Do you participate in a remote blood pressure monitoring with your healthcare provider or physici... = No

Please indicate the likely reason(s) why you are not participating in remote blood pressure monitoring with your healthcare provider. (Check all that apply)

- ☐ I do not measure my blood pressure
- ☐ I do not have a blood pressure monitoring device
- ☐ My doctor has not asked me to do that
- ☐ I am not aware I can do that
- ☐ My doctor does not offer electronic communication means
- ☐ I do not need to do that
- ☐ My blood pressure is under control
- ☐ My doctor prefers to measure my blood pressure by himself/herself
- ☐ I am too busy to do that
- ☐ I prefer face-to-face human interaction
- ☐ I do not know how to do that/need training
- ☐ I do not have internet access
- ☐ I do not have smartphone/tablet/computer
- ☐ Other, please explain in the box below

____

Display This Question:
If Do you participate in a remote blood pressure monitoring with your healthcare provider or physici... = No

If your healthcare provider or physician offered a remote blood pressure monitoring system or program to you, how likely are you to participate in remote blood pressure monitoring?

- ☐ Very likely
- ☐ Somewhat likely
- ☐ Neither likely nor unlikely
- ☐ Somewhat unlikely
- ☐ Very unlikely

Is your blood pressure under control?

- ☐ Yes
- ☐ No
- ☐ Don't know or unsure

BP numbers What were your blood pressure numbers the last time you measured it at home or had it measured?

Systolic or top number ____

Diastolic or bottom number ____

Which of the following ways do you use to manage or control your blood pressure? (check all that apply)

- ☐ Taking my blood pressure medications as prescribed
- ☐ Exercise
- ☐ Low sodium diet
- ☐ Low carbohydrate diet
- ☐ Adequate hydration with lots of water
- ☐ Adequate sleep
- ☐ Reduction in coffee intake
- ☐ Meditation
- ☐ Breathing exercises
- ☐ Stress reduction
- ☐ Reducing alcohol consumption
- ☐ Periodic health checks
- ☐ ⨂None of the above

☐ Other, please state in the box below

____

Please share in the box below any other comments you have on remote blood pressure monitoring that we have not asked.

____

Part 4 Instruction This fourth part of the online survey is taken from a national survey asking questions on how you prefer to use technology. We will appreciate your answers to the questions.

In the past 12 months, have you used a computer, smartphone, tablet or other electronic means to use email or the internet to communicate with a doctor or doctor's office?

☐ Yes

☐ No

In the past 12 months, have you used a computer, smartphone, tablet or other electronic means to look up medical test results?

- ☐ Yes
- ☐ No

On your tablet or smartphone, do you have any app related to health and wellness?

- ☐ Yes
- ☐ No

Has your tablet or smartphone helped you keep track on health-related goal, such as quitting smoking, losing weight, or physical activity?

- ☐ Yes
- ☐ No

Has your tablet or smartphone helped you make a decision about how to treat an illness or condition?

- ☐ Yes
- ☐ No

Has your tablet or smartphone helped you in discussions with your health care provider?

- ☐ Yes
- ☐ No

Have you shared health information from either an electronic monitoring device or smartphone with a health professional within the last 12 months?

- ☐ Yes
- ☐ No

Have you sent or received a text message(SMS) from a doctor or other health care professional within the last 12 months?

- ☐ Yes
- ☐ No

Please share in the box below any other comments you have on technology use that we have not asked.

Appendix E: Electronic Health Literacy Questionnaire User Agreement

Swinburne University of Technology

QUESTIONNAIRE LICENCE AGREEMENT

Information Schedule	
Parties	
Swinburne	**SWINBURNE UNIVERSITY OF TECHNOLOGY** (ABN: 13 628 586 699) a body politic and corporate established under the Swinburne University of Technology Act 2010 (Vic) of John Street, Hawthorn in the State of Victoria, Australia
Licensee	**The Party identified in Item 1 below**

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A. Swinburne is the owner of the Intellectual Property Rights in the Licensed Material.

B. The Licensee seeks a licence of the Licensed Material.

C. Swinburne has agreed to grant the licence sought on the basis set out in this Agreement.

Date

Date of Agreement	means the date on which the last of the parties signs this Agreement

Details

Item No	Identifier	Detail

1	**Licensee**	**Name:**	**The Regents of The University of Michigan A Michigan Constitutional Corporation - TIN: 38-6006309**
		Address:	**7071 Wolverine Tower, 3003 S. State Street, Ann Arbor, MI 48109-1287, USA**
		Authorised Officer	**Procurement Agent James Kozich**
		Email:	**jamesjko@umich.edu**
		Phone:	**734-615-0515**
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3	**Commencement Date**	means 14 days following the Date of Agreement.	
4	**Term**	means the duration identified in **Item 4** of the **Schedule**, which commences on the Commencement Date.	
5	**Licence Fee**	Means, where applicable, the fee identified in **Item 2** of the **Schedule** and payable by the Licensee during the Term.	

Execution

Swinburne	**SIGNED** for and on behalf of	)	
	SWINBURNE UNIVERSITY	)	
	OF TECHNOLOGY in the	)	....
	presence of:	)	
			....
	Date signed:		
	...../...../.........		Name of signatory
			....
			Title of signatory

	.... Signature of witness	
Licensee	**SIGNED** for and on behalf of **LICENSEE** in the presence of: Date signed: ...../...../..........	))) ....) .... Name of signatory .... Title of signatory
	.... Signature of witness	

General Terms

This section of the Agreement sets out the General Terms applicable to this Questionnaire Licence Agreement. The signed Information Schedule constitutes an acceptance by the Parties of these General Terms and all other parts of this Agreement.

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5.1.2 Licensee must provide a copy of the forward and backward translations to Swinburne for approval at least 60 days before Licensee proposes to administer the Questionnaire (**Administration Date**) to allow sufficient time for review of documents by Swinburne, preparation of the final translation and local validation of the Questionnaire, and finalisation as described in **Annexure A.**

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6. Licence Fee

6.1 The Licensee will pay to Swinburne the Licence Fee at the times and in the manner set out in **Item 2** of the **Schedule** during the Term.

6.2 Except as set forth in **clause 5.3**, any Licence Fee specified in **Item 2** of the **Schedule** is payable upfront in a single payment, which must be made on or before the Commencement Date.

6.3 By agreement with Swinburne, the Licensee may pay the Licence Fee payable for each year of the Term annually in advance in each year of the Term. The first payment must be paid on or before the Commencement Date, and thereafter must be paid on or before each anniversary date of the Commencement Date during the Term.

6.4 The Licence Fee is exclusive of GST. If the Licensee is an Australian entity, then GST is imposed on any supply made under this Agreement, the recipient of the taxable supply must pay to the supplier an additional amount equal to the GST payable on the taxable supply. Subject to the recipient receiving a tax invoice of the supply, payment of the GST must be made at the same time as payment for the taxable supply.

6.5 Swinburne reserves the right to revise the Licence Fee for:

6.5.1 any use of the Questionnaire in excess of the Number of Authorised Implementations specified under **Item 3** (Approved Purpose) in the **Schedule**; or

6.5.2 any subsequent extension of this Agreement.

7. Obligations of Licensee

7.1 The Licensee undertakes to use the Licensed Materials only in accordance with the Licence.

7.2 The Licensee must ensure that the Questionnaire is only used for the Purpose, and unless permission is granted in **Item 6** of the **Schedule,** not modify or translate the Questionnaire, without the express written approval of Swinburne.

7.3 The Licensee will itself administer the Questionnaire. The Licensee acknowledges and agrees that it must implement the Questionnaire in a manner that ensures Swinburne may readily audit (at Swinburne's sole discretion) the monitoring, calculation and reporting by the Licensee of usage of the Questionnaire.

7.4 Other than as provided in clause 4.1, the Licensee must not, and must not allow or cause any other person to:

7.4.1 reproduce, communicate or copy the Questionnaire by any means or in any form;

7.4.2 give, license, sub-license, lease, assign, transfer, distribute, disseminate, disclose, or publish the Questionnaire in any form to any other person or attempt to do any of these acts without the written authority of Swinburne;

7.4.3 reverse engineer the Questionnaire; or

7.4.4 alter, change, remove or obscure any notices or other indications (including but not limited to copyright notices) as to ownership of the Questionnaire.

7.5 The Licensee must provide to Swinburne de-identified information (eg age, country and language) about the person to whom the Questionnaire was administered in a locked Excel or other standard database as agreed with Swinburne.

7.6 The Questionnaire consists of separate individual scales that measure separate aspects of health literacy. The Licensee may use the individual scales as long as the Licensee ensures that each selected scale contains all the questions within that scale and the questions are in the exact order as in the Questionnaire. The Licensee must ensure the scales are scored as prescribed to ensure interpretations of the data are consistent with the development and psychometric studies. The Licensee undertakes to ensure that it will not reveal or disclose the individual scales in any publications made by the Licensee.

7.7 The Licensee undertakes to keep secret and protect the confidential nature of all information and documentation provided to it, learnt by it or to which it has or has had access, arising out of or in connection with any aspect of the negotiation or performance of this Agreement including, without limitation, the terms of this Agreement, the Licence Fee, and the Questionnaire ("Confidential Information"). To this end the Licensee must not use, disclose or in any way communicate to any other person the details of any Confidential Information without the prior written consent of Swinburne.

8. Warranties and Limitation of Liability

8.1 The Licensee agrees that, to the extent permitted by Australian law, all warranties (including implied warranties), other than express warranties given in this Agreement, in respect of the subject matter of this Agreement are excluded and of no effect. Where the exclusion of a given implied warranty would be void or unenforceable, the Licensee agrees that Swinburne's liability for a breach of such warranty will be limited, at Swinburne's discretion to the re-supply of the Questionnaire or the payment of the cost of the re-supply of the Questionnaire.

8.2 For the avoidance of doubt, the Licensee agrees that it uses the Questionnaire entirely at its own risk, and Swinburne does not warrant that the Questionnaire is suitable for any particular purpose, or that the Questionnaire will function or perform in a particular manner, or that the Licensee will derive any particular result or outcome from its use of the Questionnaire.

8.3 The Licensee agrees that Swinburne's aggregate liability for all causes of action against Swinburne, whether contractual, tortious or otherwise, will not exceed the aggregate of Licence Fees paid by the Licensee as at the date on which the first such cause of action arose. Swinburne will not be liable to the Licensee for any indirect or consequential losses, damages, costs and/or expenses incurred or sustained by the Licensee under, or as a result of exercising rights in, this Agreement (including as a result of any negligence by Swinburne), and in particular will not be liable for any loss of revenue or profits, loss of data, loss of goodwill or failure to realise an anticipated saving or benefit.

8.4 The Licensee agrees to indemnify Swinburne from and against liability and all loss and damage of any kind whatsoever caused directly or indirectly by any claim or action against Swinburne arising directly or indirectly out of the Licensee's use of the Questionnaire or any breach by the Licensee of the terms and conditions of this Agreement.

9. Termination by Swinburne

9.1 If Licensee violates or fails to perform any material term of this Agreement, then Swinburne may give written notice of the default (**Notice of Default**) to Licensee. If Licensee does not remedy the default within thirty (30) days after the effective date of the Notice of Default (**Period to Cure**), then Swinburne may terminate this Agreement and the Licence by a second written notice (**Notice of Termination**) to Licensee.

9.2 If Swinburne sends a Notice of Termination to Licensee, then this Agreement automatically terminates on the date specified in the Notice of Termination.

9.3 Termination does not relieve Licensee of its obligation to pay any monies (if any) owed at the time of the date of termination and does not impair any accrued right of Swinburne.

9.4 Upon termination of this Agreement, all licenses granted under this Agreement will terminate, and the Licensee must immediately cease all use of the Questionnaire.

10. Termination By Licensee

10.1 Licensee has the right at any time to terminate this Agreement by giving sixty (60) days written notice to Swinburne.

10.2 Any termination in accordance with clause **Error! Reference source not found.** does n ot:

10.2.1 relieve the Licensee of any obligation or liability accrued prior to termination.

10.2.2 rescind anything done by Licensee or any payments made to Swinburne prior to the date of termination.

10.2.3 Termination does not affect in any manner any rights of Swinburne arising under this Agreement prior to termination.

11. General

11.1 Interpretation

The following rules apply unless the

context requires otherwise:

11.1.1 words denoting the singular include the plural and vice versa;

11.1.2 words denoting natural persons include corporations and vice versa;

11.1.3 words denoting any gender include all genders;

11.1.4 headings are for convenience only and do not affect interpretation;

11.1.5 reference to any Party to this Agreement or any other relevant agreement or document includes that Party's successors and permitted assigns;

11.1.6 reference to any document or agreement is deemed to include references to such document or agreement as amended, novated, supplemented, varied or replaced from time to time;

11.1.7 references to any legislation or to any provision of any legislation include any modification or re-enactment of such legislation or any legislative provisions substituted for, and all legislation and statutory instruments issued under, such legislation; and

11.1.8 any reference to "GST", "recipient", "supplier", "supply", "tax invoice" and "taxable supply" has the meaning given to those expressions in the A New Tax System (Goods and Services Tax) Act 1999.

11.2 **No partnerships:** This Agreement does not create a partnership, agency, fiduciary or other relationship, except the relationship of contracting parties. No Party is liable for the acts or omission of any other Party, save as set out in this Agreement.

11.3 **Assignment:** The Licensee must not assign, sub-contract, or transfer any of its rights or obligations under this Agreement to any person without the prior written consent of Swinburne. Such consent must not be unreasonably withheld.

11.4 **Severability:** If a clause or part of a clause can be read in a way that makes it illegal, unenforceable or invalid, but can also be read in a way that makes it legal, enforceable and valid, it must be read in the latter way. If any clause or part of a clause is illegal, unenforceable or invalid, that clause or part is to be treated as removed from this Agreement, but the rest of this Agreement is not affected and all other provisions will remain in full force and effect.

11.5 **Governing Law:** This Agreement shall be governed by the laws of Victoria, Australia. Each Party submits to the non-exclusive jurisdiction of the courts of that place.

11.6 **Several Obligations:** Each Party's obligations and liabilities under this Agreement are several and not joint or joint and several.

11.7 **No Waiver:** Any failure by a Party to compel performance by the other Party of any of the terms and conditions of this Agreement will not constitute a waiver of those terms or conditions or diminish the rights arising from their breach.

11.8 **Counterparts:** This Agreement may be executed in any number of counterparts, each counterpart is an original but the counterparts together are one and the same agreement. This Agreement is binding on the Parties on the exchange of counterparts. A copy of a counterpart sent by electronic transmission –

11.8.1 must be treated as an original counterpart;

11.8.2 is sufficient evidence of the execution of the original; and

11.8.3 may be produced in evidence for all purposes in place of the original.

11.9 **Signatories:** The signatories to this Agreement warrant that they have the authority to enter into this agreement on behalf of the party they are stated to represent.

11.10 **Variation:** This Agreement may only be varied in writing, signed by all Parties.

11.11 **No representation:** A Party shall not represent that another Party or any of their staff in any way endorse, support or approve of, any products, services, Intellectual Property or business of the representing party unless that other Party has given its express written consent to such representation.

11.12 **Entire Understanding:** This Agreement-

11.12.1 is the entire understanding between the Parties on everything connected with the subject matter of this Agreement; and

11.12.2 supersedes any prior agreement or understanding on anything connected with that subject matter.

11.13 **Contra Proferentem:** This Agreement or any part of this Agreement is not to be construed against a Party merely because that Party was responsible for preparing it.

11.14 **Execution:** This Agreement is null and void unless it is executed by all parties.

12. Notices

Any notice given under this Agreement:

12.1 must be in writing and signed by a person authorised by the sender;

12.2 must be delivered to the intended recipient by post or by hand or fax or email to the address or fax number or email address set out in the Information Schedule;

12.3 will be taken to be duly given or made:

12.3.1 in the case of delivery in person, when delivered;

12.3.2 in the case of delivery by post, five Business Days after the date of posting unless it has been received earlier;

12.3.3 in the case of fax, on receipt by the sender of a transmission control report from the dispatching machine; and

12.3.4 if transmitted electronically, upon actual receipt by the addressee provided that the sender does not receive notification of invalid email delivery address or other transmission error. In the case where the sender receives a transmission error report, the sender must re-send the notice by one of the other means by hand, post or fax;

but if the result is that a notice would be taken to be given or made on a day which is not a Business Day, or is later than 4.00pm (local time), it will be taken to have been duly given or made on the next

Business Day.

Glossary	
Agreement	means this agreement including this Glossary, the Information Schedule, the General Terms, all Schedules and Annexures to this agreement, and any amendment to it in writing.
Annexure	means an annexure to this Agreement.
Business Day	means a day that is not a Saturday, Sunday or any other day which is a public holiday or a bank holiday in the place where an act is to be performed or a payment is to be made.
General Terms	means the general terms described as such in this Agreement.
Glossary	means this glossary.
Information Schedule	means the Schedule at the start of this Agreement that details the key information relevant to this Agreement.
Intellectual Property Rights	means all rights resulting from intellectual activity whether capable of protection by statute, common law or in equity and including copyright, discoveries, inventions, patent rights, registered and unregistered trade marks, design rights, circuit layouts and plant varieties, know-how and all rights and interests of a like nature, together with any and all documentation relating to such rights and interests for the intellectual property specified in Item 3 of the Information Schedule.
Item	means an item in the Information Schedule.

Licence	has the meaning set forth in clause 1 of this Agreement.
Parties	means the parties to this Agreement and their respective successors and permitted assigns, and **"Party"** means any one of them.
Purpose	means the manner of use permitted under this License specified in Item 3 of the Schedule.
Questionnaire	means the health literacy questionnaire as specified in Item 1 of the Schedule.
Schedule	means a schedule to this Agreement.
Territory	means the territorial limits of this Licence specified in Item 5 of the Schedule.

Schedule

Licence Number: E2002IA

Item 1 – The Questionnaire	eHLQ – the health literacy questionnaire developed by Richard Osborne, Roy Batterham, Lars Kayser, Ole Norgaard, Dorthe Furstrand Lauritzen, Astrid Karnoe Knudsen, Karl Bang Christensen and more fully described in "A Multidimensional Tool Based on the eHealth Literacy Framework: Development and Initial Validity Testing of the eHealth Literacy Questionnaire (eHLQ)" doi:10.2196/jmir.8371

Item 2 – Licence Fee	
	Waived (for the duration of the Term)

Item 3 – Approved Purpose	
Purpose	Use of the eHLQ in the English Language for the project "Understanding Patient-related Factors that Impact Technology Use in Telemonitoring of Hypertension"
Number of Authorised Implementations	530
Project Start Date	1st July 2020
Project End Date	31st December 2022

Item 4 – Duration of Licence	
	2.5 years

Item 5 – Territory	
	USA

Item 6 – Cultural Adaptation and/or Translation Rights	
	[*The Licensee does not have a right to prepare or obtain a cultural adaptation of the Questionnaire*] [*The Licensee does not have a right to obtain a translation of the Questionnaire*]
Language of Translation	[***N/A***]

The following Questions must be completed within 3 months before the end of the Term. The response to the questions should not exceed one side of an A4 page.

1) Please provide information on the particular purposes for which the questionnaires have been administered in the past 12 months?

2) What challenges (if any) have you encountered in the administration and collection of responses to the questionnaires in the last 12 months?

3) What benefits have accrued through the administration of the questionnaires in the past 12 months? (this may include but not limited to new interventions, re-alignment of practices, input to strategic plans and policy, presentation to stakeholders and broader audiences, publications etc)

4) Did the questionnaire serve your specific needs and purpose? Do you have any suggestions on ways in which the questionnaires may better serve your specific requirements