Advancing Digital Health Equity in a Safety-Net Health System: Identifying Barriers, Evaluating Training, and Assessing Impact on Diabetes Outcomes

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Abstract

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Digital health technology, including patient portal use and telehealth visits, has been increasingly utilized across healthcare settings, transforming how individuals access healthcare and contributing to improved quality of care. However, there are differences in which types of patients use digital health technology, stemming from multi-level factors at the structural, contextual, and individual levels. Without better evidence, improved methodology, and proactive interventions to reduce inequity and promote equity, these disparities will persist as the digital divide widens. This dissertation is centered on the experience of individuals at San Francisco Health Network, an urban safety-net health system. Across three papers, I employ novel qualitative and quantitative methods to address critical questions about marginalized populations and digital health technology use, thereby filling gaps in the literature and advancing digital health equity.

In the first paper, I employ mixed methods to examine fundamental skill and usability barriers to digital health technology use. Notably, I highlight critical gaps in digital literacy,

particularly in device navigation and processing complex tasks, that prevent effective use of these tools, and the need for usability-driven improvements to reduce digital barriers. The second paper uses a zero-inflated negative-binomial generalized linear mixed model to evaluate the impact of person-centered digital training on patient portal uptake and use, considering sociodemographic factors, clinical characteristics, and digital engagement. I identify that patients who participated in tailored training saw a 91% relative increase in average monthly portal users, compared to a 12% relative increase among those who received basic digital support only. More specifically, the basic digital support program especially benefited Spanish-speakers who demonstrated an 80% increase in login counts, although the tailored training significantly benefited participants with low baseline engagement and resulted in a fivefold increase in login frequency compared to pre-intervention rates. The final paper leverages the widespread adoption of digital health technology and remote care engagement in health systems and uses a linear mixed-effects model to examine how combined in-person and remote care utilization patterns impact longitudinal changes in A1c control, and whether these patterns differ across key sociodemographic factors. I found that multiple remote and in-person care utilization patterns were associated with modest but clinically meaningful differences in glycemic control. Specifically, the degree of A1c improvement followed a clear gradient across care patterns, with the least improvement among patients with little or no care and progressively greater gains as remote and in-person modalities were combined, underscoring the value of hybrid engagement for chronic disease management. However, these associations varied by sociodemographic characteristics, revealing disparities in access, adoption, and effectiveness of in-person and remote engagement across patient groups.

Together, these papers outline the growing issue of disparities in digital health technology use and pinpoint solutions and evidence to support accessibility and equitable use. These papers highlight the skills needed to use digital health technology effectively, the role of digital skills training in promoting the use of these tools, and the benefits of engaging in care remotely on patient health outcomes. However, a common thread across all these papers is the persistent presence of disparities and barriers among marginalized populations, and how the influence of these barriers extends beyond disengagement with digital health technology but also affects health outcomes. In my concluding chapter, I summarize these findings and suggest areas for future research. As digital health technology becomes more widely adopted in healthcare delivery, and the risk of disproportionate uptake and use of digital health technology becomes more pronounced for marginalized populations, this dissertation provides a strong scientific framework through which new strategies to reduce disparities, and the digital divide can be developed. These results will inform healthcare systems about innovative and equitable interventions and strategies to reduce inequity in digital health technology uptake and use and promote equity.

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List of Abbreviations

A/U: Assisted/Unsuccessful

CCI: Charlson Comorbidity Index

CI: Confidence Interval, at the 95th percentile

Col: Column

EHR: Electronic Health Record

HCD: Human-Centered Design

HCI: Human-Computer Interaction

IQR: Interquartile Range

IRR: Incidence Rate Ratio

Indep: Independent

NH: Non-Hispanic

nSES: Neighborhood Socioeconomic Status

OR: Odds Ratio

SD: Standard Deviation

SFHN: San Francisco Health Network

UHC HRSA: UnitedHealth Group—HRSA Uninsured Plan

Dissertation Definitions

For the purpose of this research, we will apply the following definitions:

Digital Health Technology: The application of information and communication technology into healthcare. This includes telehealth (video or phone visits), the patient portal, and all the actions individuals can do within the patient portal (secure messaging, requesting medication refills, scheduling appointments, viewing labs and visit summaries).

Digital divide: The gap between individuals who have access to modern information and communication technology and those who do not. This includes physical and socioeconomic access, as well as skills and knowledge needed to use the technology effectively.

Digital equity: The concept that everyone has equal access to and opportunities to use technology for personal and social well-being, but particularly, for health. Achieving digital equity includes addressing access, opportunity, skills, knowledge, and resources necessary.

MyChart: The patient portal application supported by Epic and currently offered/used among individuals at the San Francisco Health Network.

Race and ethnicity: A social construct that denotes groups of individuals based on shared cultural heritage or social identity, but functions as a proxy variable in digital equity research, due to race and ethnicity often being linked to broader social experiences such as historical marginalization or racism. In this study, race and ethnicity are proxy variables to indirectly capture the influence of underlying (and otherwise unmeasured) social determinants on an individual's digital health technology uptake and use.

Remote care engagement: Use of personal devices (such as a landline or cell phone) to engage in care remotely, regardless of whether the action requires navigating a digital interface (i.e., calling the clinic with a health concern is considered remote care engagement, but not digital health technology use). This term encompasses digital health technology but is broader in its inclusion of engagement activities that are considered virtual or remote, not just digital.

Chapter 1: Introduction

Digital health tools have become deeply embedded in how healthcare is delivered across the United States[1–5]. The patient portal, secure messaging, and telehealth encounters are tools that offer new avenues for accessing care, communicating with providers, reviewing visit notes and lab results, coordinating services, and managing chronic conditions[6–14]. These advancements in healthcare delivery are particularly promising as they have the potential to address disparities in healthcare access and patient health outcomes[7–9,11–13,15]. Yet, as these tools have become more integrated into routine care, longstanding inequities regarding who can and does use them remain a pressing concern[4,16]. Research has consistently shown that disparities in the use of digital health tools continue to exist by race and ethnicity, age, preferred language, sex, digital literacy, health status, and socioeconomic status, highlighting how technological advancements risk further exacerbating existing inequities in access to and engagement in care for marginalized communities[11,12,15–28]. Despite these concerns, there is limited research and interventions designed to advance digital health equity[4,11,29–32].

Much of what is currently known about digital health disparities has been gleaned from self-reported data or survey-based assessments[33–35]. These studies have consistently identified patterns of lower engagement among older adults, individuals with lower income and educational attainment, non-English speakers, and racial and ethnic minority groups[11,15–18,20,21,23,25–27]. Digital literacy, both in general and in health-specific contexts, has also emerged as a key predictor of engagement[11,12,15,16,18,19,22,24,26,28]. However, objective usage and self-reported metrics overlook human-computer interaction abilities and digital skills, and less attention has been paid to identifying the tangible, fundamental, task-specific skills and abilities required to navigate and interact with these tools effectively[33–36]. These skills may range from accurately finding or using a web browser or other device applications to recognizing clickable elements and credential entry[36]. To truly understand and address disparities in digital health technology use, studies must isolate the tangible skills and actions that are foundational to accessing digital health technology and how a lack of these skills might play a significant role in limiting uptake and use of digital health technology for marginalized populations.

It is also essential to identify the usability barriers that play a critical role in preventing individuals from successfully engaging with these tools to drive human-centered design strategies that better engage and are responsive to users with varying levels of digital proficiency[22,32,37–39]. Numerous examples cite poorly designed interfaces, unclear navigation paths, and accessibility issues that negatively impact use by creating unnecessary friction and discouraging continued use[19,22,38–40]. This is particularly important as individuals from marginalized communities are less often represented in usability studies, limiting our understanding of the specific challenges they face when navigating these tools and hindering the development of equitable interventions to build the skills essential to improve uptake of digital health technology[30,31]. As adoption of digital health technology becomes more embedded in healthcare delivery, reducing usability barriers is more critical than ever to ensure a more equitable distribution of the benefits of digital health technology.

Despite skill and usability barriers that may exacerbate disparities in digital health technology use, evidence has shown that providing multimodal and audio-visual digital training is supported by patients and is associated with improved use[41–43]. Trainings that offer technical support and hands-on practice/guidance navigating these tools may alleviate some of the digital proficiency challenges patients face, particularly among those who face greater barriers to digital use[41–43]. This suggests that training among populations with marginalized identities can be beneficial; nonetheless, better evidence is needed to evaluate the effect of digital training programs separately from other core drivers of use, such as sociodemographic factors, clinical characteristics, and self-reported digital confidence. Measuring the impact of a patient portal support program that differentiates these and identifies which patients benefit the most from digital training can inform scalable strategies to advance digital health equity.

Especially in the post-COVID-19 era, widespread adoption of digital health technology in healthcare delivery and training programs offer expanded opportunities to engage in care and may contribute to increased use of digital health technology and other remote modalities[3,11,13]. Research studies focusing on chronic disease management have yielded robust evidence supporting digital and remote care modalities for enhancing patient-provider communication, improving patient satisfaction, promoting better understanding of care plans, and encouraging increased patient engagement[3,8,10–13]. Despite this, longitudinal evidence examining how remote care in the context of in-person care affects health outcomes such as glycemic control among individuals with diabetes is lacking[4,44,45]. Measuring the impact of combined in-person and remote care patterns is especially pivotal as research has shown that significant disparities in digital engagement persist, particularly among populations who face disproportionate burdens of chronic disease and poor patient health outcomes[4,16].

To address these research gaps, I use mixed methods and mixed-effects model approaches to advance digital equity over three papers. The objectives of these papers are as follows:

1. To identify the skill and usability barriers to using digital health tools among older patients in a safety-net health system.

2. To assess the effectiveness of digital support interventions on patient portal use in a safety-net health system, considering socioeconomic characteristics, clinical factors, and digital self-confidence.
3. To measure the effect of remote care engagement patterns on subsequent A1c levels among patients in a safety-net health system.

To achieve these objectives, I use secondary data from a large, urban safety-net health system in San Francisco, the San Francisco Health Network (SFHN). SFHN includes 14 community-based primary care clinics and serves a racially and ethnically diverse patient population of about 60,000 patients, most of whom are enrolled in Medicaid or citywide insurance plans. The SFHN patient population is primarily non-white (80%), 45% do not identify English as their primary language (35% prefer Spanish and over 10% prefer Cantonese exclusively), and more than half report barriers to accessing and using digital health technology[46,47]. Prior work by researchers at SFHN indicates that many patients in this health system are highly interested in communicating with providers electronically, with over 70% expressing interest in this option. However, a decade of research at SFHN indicates many barriers to the use of digital health technology exist among this population, particularly concerning uptake and use[16,19,48,49]. Efforts to reduce barriers have included engaging patients in training opportunities to use digital health technologies and user-driven approaches to project design and iteration[41,50]. I use a variety of techniques to undertake my research objectives and further the work that has been ongoing at SFHN to reduce digital inequities.

Chapter 2

Title: Identifying Skill and Usability Barriers to Digital Health Tool Use among Patients in Safety Net Clinics: A Mixed Methods Study

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Abstract:

Background**:** Despite the benefits of digital health tools, individuals often face barriers because of the digital divide that hinders adoption. Identifying the fundamental user skills required to effectively navigate these tools and the usability barriers that prevent use is essential to addressing disparities in use.

Objective**:** To identify the skill and usability barriers to using digital health tools.

Methods**:** This study included patients aged ≥50 who speak English, Spanish, or Cantonese and receive care at an urban safety-net health system in the US. Participants completed a survey examining sociodemographic characteristics and digital health tool use and were observed and video recorded as they navigated four digital healthcare tasks: (1) launch a video visit, (2) visit a health website through a URL, (3) log in to the patient portal, and (4) sign up for a patient portal account. Participants who could not independently perform the tasks received additional support. Tasks were conducted in English, while instructions and additional assistance were provided in each participant's preferred language. Kruskal-Wallis, Chi-squared, and Fisher's exact tests examined the association between key participant demographics and the ability to complete each task independently. Thematic coding was used to identify key skills needed to use the digital tools effectively and determine usability barriers. Chi-squared and Fisher's exact tests examined the association between themes and the ability to complete the task independently.

Results**:** Of the 64 participants, 52-74% of participants completed the digital tasks independently (Task 1: 72%, Task 2: 52%, Task 3: 74%, Task 4: 71%). Independent task completion varied by age, race and ethnicity, language preference, education, internet access, and patient portal enrollment. Older age, minoritized races and ethnicities, non-English language preference, lower educational attainment, access to data only or no internet access, and lack of a portal account were associated with a higher likelihood of requiring assistance or being unsuccessful at completing each task (P's≤.05). Video observations revealed keyboard navigation, device skills, and human-computer interaction skills as the foundational skills required to navigate the digital tasks. Chi-squared and Fisher's exact tests indicated significant associations between these skills and the ability to complete each digital task independently (P's≤.04). Qualitative codes further identified learnability and operability difficulties for each task that presented key usability barriers for individuals, ranging from hard-to-detect errors that led to repeated mistakes to confusion with where to put information and how to proceed.

Conclusion**:** This study identified the foundational skills needed, as well as the learnability and operability issues related to using digital health tools effectively, which are underspecified in the literature. Focusing on a diverse sample from a safety net healthcare setting underscored the importance of these foundational skills for individuals from marginalized communities who face digital exclusion.

INTRODUCTION

The electronic health records, the patient portal, and telemedicine (often referred to as digital health tools) have increased opportunities for individuals to engage more directly in their care. Access to these tools enables appointment scheduling, medication refills, and communication with healthcare providers, reducing some of the accessibility burdens of face-to-face interactions[6]. These tools have also been linked to improved clinical outcomes among individuals with chronic disease[7–9,11,14,51]. However, there are documented differences in use among marginalized populations who may face individual and systemic barriers that hinder adoption[16,17,19,46]. Previous research has demonstrated different rates of digital health tool use among individuals and groups from minoritized racial and ethnic backgrounds (including those who prefer languages other than English), age groups, and genders, as well as differences in use for those that report barriers to broadband internet, devices, or data (e.g., due to cost)[11,16–21,52]. In particular, older adults, especially those with non-English language preferences or who identify as a racial or ethnic minority, experience large disparities in digital health tool adoption as a result of steep disparities in device, internet, or data access[12,18,21]. These known barriers create a "digital divide" that may be exacerbated in healthcare settings that rapidly expand and rely on digital health tools in routine practice, particularly those who serve low-income, diverse racial and ethnic populations[12,16,20,22].

To address these barriers for a vulnerable population, there is a need for pragmatic research rooted in identifying and understanding digital literacy skills and user needs[31,32,53]. There is a growing literature that documents core self-reported digital literacy skills needed to access digital tools; yet, the tangible, fundamental user skills required to effectively navigate these tools have not been well-defined[33–36]. Core self-reported digital literacy skills refer to a user's perceived ability to or confidence perform general digital tasks, such as sending emails or using search engines, while fundamental user skills are the observable, tangible, task-specific abilities required to navigate and interact with a particular system—such as accurately finding/using a web browser or other device applications or recognizing clickable elements[34–36]. To identify the tangible actions and behaviors that are foundational to accessing digital health tools and can serve as barriers to individuals with low digital literacy skills, self-reported skills must also be paired with observational data. To our knowledge, there have been no studies evaluating the tangible, foundational digital skills individuals need to be able to use digital health tools, particularly in marginalized communities that are disproportionately impacted by the digital divide.

It is also important to identify usability barriers that prevent individuals from successfully interacting with digital tools and contribute to disparities in digital health tool uptake and use[22,32,37–39]. Poorly designed interfaces, unclear navigation paths, and accessibility issues disproportionately impact individuals with limited digital literacy, disabilities, or language barriers[19,22,38–40]. These usability challenges may create unnecessary friction, discourage continued engagement, and deter patients from using digital health tools to engage in continuity of care. Moreover, individuals from marginalized communities are also less often represented in usability studies, limiting our understanding of the specific challenges they face when navigating these tools and hindering the development of equitable interventions to build the skills essential to improve uptake of digital health tools[30,31]. Pragmatic human-centered research rooted in identifying usability barriers for marginalized populations, using representative sampling within healthcare systems outside of academic medical centers, may reveal key themes to improve user experience and mitigate disparities.

To address these gaps, we conducted a mixed-methods study among multilingual older adults receiving care at an urban safety-net health system in San Francisco, CA, to identify the skill and usability barriers to using digital health tools. By using observational data of participants interacting with real-world digital health tools, we focused on qualitative identification of skills and usability barriers mapped to existing frameworks. We then compared these qualitatively developed skills/barriers to the observed completion rates of digital health tasks (such as completing log-in to a patient portal) to pinpoint the fundamental skills necessary to complete each digital health task independently and the usability barriers many individuals face when navigating these tasks. We also examined task completion rates overall and by key sociodemographic characteristics to assess disparities in task completion success.

METHODS

Study Setting

This study was conducted within San Francisco Health Network (SFHN), San Francisco County's safety-net health system encompassing 14 community-based primary care clinics. SFHN serves a racially and ethnically diverse patient population of about 60,000 patients, most of whom are enrolled in Medicaid or citywide insurance plans. The SFHN patient population is primarily non-white (80%), 45% do not identify English as their primary language (35% prefer Spanish and over 10% prefer Cantonese exclusively), and more than half report barriers to accessing and using digital health technology[46,47].

Recruitment and Participation

Eligible study participants receive primary care at an SFHN clinic, are aged 50 years or older, speak English, Spanish, or Cantonese as their primary language, and do not have a cognitive or behavioral impairment that would preclude them from providing informed consent or completing the digital tasks. We focused on adults aged 50 years or older, given the prevalence of digital barriers within this population. Between April 2023 to June 2024, individuals at SFHN meeting these inclusion criteria were recruited by the study team over the phone after receiving prior approval from their primary care providers.

Study team members recruited 101 eligible patients who completed a participant questionnaire and performed the digital tasks. A subsample of 64 participants provided written consent to record their progress through each digital task for this study. Participants were compensated $20 for completing the questionnaire and $40 for completing up to 4 digital tasks while observed. The study was approved by the UCSF IRB (#22-36493).

Data Collection

The participant questionnaire, conducted in the participant's preferred language, included items eliciting information on individual age, sex, race, ethnicity, preferred language, comfortability speaking English, and educational attainment; and questions about device preference, having access to a device with video capability, type of internet access, and current enrollment in the SFHN patient portal. Questionnaires were administered in person or via phone by study staff. All video observations were conducted in person. See Appendix A for questions from the participant questionnaire included in this analysis.

After completing the questionnaire, participants were asked to use their preferred digital device if on hand, or if not, to choose a device provided by the research team that they felt comfortable using to complete the digital task assessment (either an Android smartphone, an iPad, a windows laptop, or a Macbook). Participants were filmed as they attempted four digital tasks that simulated the necessary skills and actions required to use digital health technology effectively: (1) launching a video visit, (2) going to a specific health website, (3) signing in to a patient portal emulator using a dummy account, and (4) signing up for a patient portal account via emulator. These tasks were selected due to their importance for engaging with digital health tools. While digital health tools have become more inclusive in recent years and offer the ability to switch between English and Spanish (and sometimes other languages) on the platform itself, many elements of those digital tools (such as automated text messages or notifications and prompts) are often unavailable in languages besides English, so to replicate that experience, the platforms participants navigated to complete each task were in English only. Further details about the steps involved in each of the tasks, including instructional handouts, are detailed in Appendix B.

Participants were asked to independently complete each task following a set of written instructions in their preferred language; if they were unsuccessful after two attempts, research staff provided a standardized instructional handout or video, followed by language-concordant verbal, tailored assistance if necessary. After each step of assistance, participants were asked to try the task again; if unsuccessful again, the research staff proceeded to the next level of assistance. Participants were deemed unsuccessful if they were unable to complete the task after receiving tailored 1-on-1 assistance. The level of assistance provided was logged by the research team member conducting the assessment. For accuracy, a second team member reviewed video recordings and assigned their score. If the two scores differed, discrepancies were addressed via team discussion.

The participant questionnaire, written task instructions, and assistance from the research staff were conducted in the participant's preferred language, as determined during recruitment. The questionnaire and instructions were translated into Spanish and Cantonese by research staff proficient in the respective languages.

Analysis

Qualitative Analysis

For the qualitative analysis, framework analysis, a matrix-based method that allows for systematic comparison of themes across cases while retaining case context, was employed to identify both the fundamental skills required of users and the usability barriers that prevent successful use. First, we watched a subsample of video observations to gain a comprehensive understanding of the participants' experiences and behaviors across the digital tasks. This initial stage helped to identify recurrent ideas, patterns, and areas of interest (keyboard skills, typing skills, and navigation skills). We then developed a thematic framework to guide our analysis by generating a priori coding categories guided by the research question ("What are the specific and foundational skills a user needs to successfully use digital health tools?" and "What are the usability barriers of these tools?") and the existing literature about digital literacy and usability[37,40,54–56]. We categorized qualitative codes according to the level of digital literacy they reflected and distinguished them as novice or advanced, where appropriate. This categorization was informed by van Deursen, Helsper, and Eynon's digital literacy framework and modified to appropriately reflect the skills pertinent to using digital health tools rather than the internet in general[36]. This framework differentiates operational, formal, informational, and strategic digital skills, which capture the range of competencies needed to use digital tools effectively[36]. We primarily focused on operational and formal skills, such as device handling, typing, and navigating digital interfaces, which were most relevant to the tasks in our study. Novice-level skills included novice keyboard skills and novice device skills, which were observed as operational inability or skill gaps when performing a task. Advanced-level skills included advanced typing and advanced device skills—skills that encompassed strategic problem-solving abilities, such as troubleshooting errors and intuitive device understanding. We also mapped the predetermined coding categories of learnability (the capability of digital health tools to enable the user to learn their application) and operability (the capability of digital health tools to enable the user to operate and control them) to challenges associated with completing digital tasks due to usability issues[56]. We also employed an inductive coding approach to allow codes emerge from the analysis to limit a priori bias. Inductive and deductive coding ensured that both anticipated and novel insights were captured.

Next, we compiled and organized the codes in a structured matrix format, which enabled us to summarize and compare the nature and context of responses, while preserving the richness of the video observations. Each row represented an individual participant, and each column presented the themes associated with a specific task (see Appendix C and D). As a calibration step, three independent coders watched a sample of the videos and created a templated summary for each task in the matrix tool. This was used to assess the template and confirm that the domains are intuitive, identify any missing or incorrectly labeled domains, clarify any issues, and ensure consistency in content, style, and organization across coders. During this process, actions that supported or deviated from these predicted codes led to additional codes, iteratively expanding upon and updating the codebook to include relevant concepts. The percent agreement for the first 15 participants was 91%, after which the three coders split the remaining recordings.

Quantitative Analysis

For the quantitative component, survey responses were first exported from RedCap for preliminary descriptive summaries, focusing on the variables of age, sex, race and ethnicity, preferred language, educational attainment, device with video capability, source of internet access, and enrollment in the SFHN patient portal. These sociodemographic characteristics comprised our covariates for analysis.

Our primary quantitative outcome variable was task completion, which was measured as whether a participant independently performed the task with simple written instructions, performed the task after receiving standard assistance (i.e., detailed handout, video tutorial), performed the task after receiving tailored assistance (i.e., verbal instructions, 1:1 help), or was unsuccessful. For analyses, we dichotomized this outcome, categorized as performing independently vs. requiring any support/unsuccessful. This cut point was chosen as it represents the key distinctions between a user demonstrating fundamental skills and those requiring further assistance or training. Because of technical issues (e.g., malfunctioning cameras or recording failures) and participants occasionally declining tasks they found too difficult, the number of video recordings varies slightly across tasks, as individuals with no video recording were treated as missing data and removed from the analysis for that task.

We conducted Kruskal-Wallis tests, Chi-squared tests of independence, and Fisher's exact tests to determine the significance between each sociodemographic characteristic with the task completion outcome. The Kruskal-Wallis test was employed to test the association between age as a continuous variable and task completion. Fisher's exact tests were used when expected cell counts were <5. R version 4.3.3 was used to conduct analyses.

Comparison of Qualitative Findings and Quantitative Data

To assess the relationship between identified themes and task completion, qualitative and quantitative analyses were conducted in parallel using a convergent triangulation design in which the data sets were integrated prior to the combined analysis[57–59]. Key qualitative themes were grouped into higher-order categories to facilitate interpretation. This involved identifying conceptual connections between codes and organizing them into thematic categories. These thematic categories were then converted into categorical variables and incorporated into the quantitative dataset. Triangulating the two types of data supported the identification of findings of the foundational skills necessary to use digital health tools successfully (and conversely, what skill gaps require interventional support). We estimated Chi-squared tests of independence and Fisher's exact tests to determine the significance between each identified skill or skill gap with the task completion outcome. Fisher's exact tests were used when expected cell counts were <5. R version 4.3.3 was used to conduct analyses.

RESULTS

Participant Characteristics

The 64 adults who provided consent to film their digital task completion efforts include 40 males and 24 females. Most spoke English (n=42), followed by Cantonese (n=14) and Spanish (n=8). The median age was 61.9 (range: 51.0-83.4). 81% of participants (n=52) identified as non-White. 53% of participants (n=34) had an educational attainment of high school or less. Participants strongly preferred using their smartphone (86%), with some preferring a desktop or laptop computer (19%) or tablet (14%), and only 2% preferred using a simple cell phone. 91% of participants own a device with video capability. 61% of participants had both Wi-Fi and unlimited data on their smartphones, compared to 23% who used Wi-Fi only, and 11% who had unlimited data only. 66% of participants were enrolled in the patient portal at SFHN. Participant characteristics are displayed in Table 1.

Task Completion

Task completion per task is displayed in Table 2. As shown in Table 2, 46 to 62 participants were filmed completing each of the tasks. Independence was the highest for Task 1 (34/46, 74%) and lowest for Task 2 (31/60, 52%).

Age, race and ethnicity, preferred language, educational attainment, device with video capability, source of internet access, and enrollment in the patient portal were significantly associated with task completion. Participants who were older were more likely to require assistance or be unsuccessful, across all tasks (*P*=.004). Participants who were white were significantly more likely to complete each task independently, compared to other races and ethnicities (*P*<.001). Similarly, preferred language was associated with task completion, with those who prefer Spanish or Cantonese more likely to require assistance or be unsuccessful, compared to those who prefer English (*P*<.001). Participants with a high school education or less were also more likely to struggle to complete the tasks independently and had higher rates of being unsuccessful or requiring assistance (*P*<.001). Access was also significantly associated with task completion, with those who had access to a device with video capability and Wi-Fi more likely to complete tasks individually compared to those without video capability or who rely on data to access the internet (*all P's*≤.05). Individuals already enrolled in the patient portal tended to be more successful and had a higher likelihood of completing each task independently compared to those who were not enrolled in the patient portal or were unsure (*P*<.001).

Video Observations

Thematic findings were grouped into factors, mapped to the overall dimensions of fundamental skills and usability barriers, and reorganized for interpretation. To ease analysis, we decided to separate the codes representing usability barriers from those representing fundamental skills, with several codes representing skills and usability barriers. Figure 1 shows an overview of themes generated during the observational coding process, with sub-categories within each key theme, and separated by fundamental skills and usability barriers.

Fundamental Skills

Video observations revealed that participants exhibited a range of digital skills from novice to advanced. The coding matrix exposed participant behaviors into key themes, including typing skills, navigation skills, and human-computer interaction. Typing skills related to a participant's ability to navigate the keyboard (particularly capitalizing letters and finding special keys) and demonstrating inefficient typing ("hunting" and searching for letters) or advanced typing skills (proficiency with typing, capitalization, and special keys). Navigation skills incorporated inefficient navigation (e.g., extraneous scrolling or tapping on the device), novice device skills (e.g., unfamiliarity with device layout or apps), advanced navigation and device skills (often indicated with minimal scrolling), and continuous progress of the task. Human-computer interaction (HCI) encompasses codes that demonstrate the way participants engage or do not engage with their devices to complete the tasks, ranging from how they respond to prompts, whether they are unsure how to proceed, request assistance, or ineffectively interact with pop-ups/prompts, to having trouble with specific elements of the tasks (e.g., novice URL skills, trouble finding or using a web browser, or novice password skills).

A significant proportion of participants exhibited novice-level digital skills, particularly in typing and navigation. Many participants relied on inefficient typing techniques, such as hunt and peck typing, or relying on using one finger or a stylus to locate and enter subsequent characters. The inability to appropriately capitalize letters or locate and select special characters created significant barriers to completing tasks independently. Similarly, many participants demonstrated navigation inefficiencies. Participants exhibited trouble navigating their device with extraneous and repeated tapping or scrolling, confusion locating specific apps or phone settings, or difficulty using a touchscreen or trackpad. In contrast, participants who demonstrated success at navigating the tasks independently almost exclusively displayed advanced navigation skills and the ability to progress through the tasks continuously without breaks in performance flow.

Many individuals also struggled with more complex HCI actions beyond simply navigating their device or using the keyboard. Common observations included participants not understanding how to proceed through the task due to struggling with fundamental concepts like recognizing common digital icons (e.g., settings icon, close window button, home icon, or back/forward arrows) or clicking the "next" button, having trouble finding or navigating using a web browser (or conceptually understanding what it is), ineffectively interacting with task pop-ups or prompts (e.g., ignoring a pop-up/prompt, choosing the wrong link), and difficulty finding or using the web browser (e.g., not knowing how to select the web browser icon to open a new window, how to proceed once the web browser was open). Individuals also demonstrated "novice" URL and password skills as they struggled with accurate text entry to successfully type in a URL for a website or enter the provided password. Difficulty performing complex tasks despite provided instructions was a common reason participants asked for assistance, often demonstrated without even attempting the task or after several unsuccessful attempts to complete an action.

Table 3 presents the association between typing, navigation, and HCI codes and task performance. Most notably, across the tasks, keyboard skills, navigation skills, and HCI skills showed a significant association between the factor and the ability to complete each task independently. Individuals who demonstrated unfamiliarity with navigating the keyboard, particularly with how to capitalize letters or find special characters, always required assistance or were unsuccessful at completing the digital tasks (all *P's*<.001). Inefficient navigation with extraneous scrolling or tapping of their device was strongly associated with needing assistance or unsuccessfully completing the task, particularly in tasks 1, 2, and 4 which required more complex device navigation to complete the task (all *P's*<.01). Novice device skills, demonstrated by lack of familiarity with one's device, whether it be the layout, finding and using apps, or navigating the trackpad, was significantly associated with requiring assistance or unsuccessfully completing the task (all *P's*<.01). Typing skills (both inefficient typing and advanced typing skills) were not significantly associated with digital task completion. However, we did not test speed to completion.

Beyond navigating one's device, the complexity of digital tasks required several fundamental human-computer interaction skills to complete each task. Displaying confusion or hesitation with how to proceed during a task was a significant barrier for individuals during each task, ranging from not being sure how to move next, confusion over how to navigate barriers that arise, or where to put information (all *P's*≤.02). Individuals also often asked for assistance when stuck on a task, demonstrating the complexity of progressing through a task as a barrier to independently completing a task (all *P's*<.001). In Task 2, the ability to find and use a web browser appropriately and the ability to type in a URL correctly were also significantly associated with being unsuccessful or requiring assistance to complete the task (*P's*<.001). In

Tasks 3 and 4, having trouble with creating a username or password (e.g., not sure how to create one) was associated with needing assistance or unsuccessfully completing the task (*P's*≤.006).

Usability Barriers

Video observations also revealed several barriers to task completion due to usability barriers. The key usability barriers across all the tasks were learnability and operability. Tables 4 and 5 summarize the learnability and operability issues for each task. In Task 1, joining a video visit from a text message and unfamiliarity with system-generated notifications led to hesitation or errors in navigating the log-in prompt (characterized by "confusion/hesitation re: text messages" and "unsure how to proceed"), illustrating learnability barriers to joining video visits, despite the instructions in the text. In addition, individuals often did not select the video link, instead opting to choose an alternative method, such as replying to the text (despite it being a no-reply message) or attempting to join the video visit unsuccessfully. Additionally, once the participant successfully selected the link in the text message, additional pop-ups and links necessary to join the video call confused the participant, resulting in those pop-ups and links being ignored or ineffectively addressed. The operability limitation of this task is that the system did not provide clear enough cues for individuals to correctly select the link to join the video visit, and therefore individuals often did not know which link to select and instead selected the wrong link, either delaying their ability to join a video visit or preventing it all together.

Task 2 was the most difficult for participants, with learnability and operability barriers affecting the ability to complete the task of signing in to the patient portal on a web interface. Many participants displayed misinterpretation of browser suggestions and confusion regarding where to type in the URL (coded as "mistake search bar for URL bar") and the extent to which the URL needs to be complete (categorized as "how to do manual credential entry", many stopped before typing in the complete URL or mistakenly used autofill to create a false URL), illustrating the learnability barriers associated with this task. In addition, individuals often were unsure how to proceed, sometimes selecting irrelevant links or failing to recognize the correct link to continue to the patient portal website. Typing in a URL with multiple characters and capitalizations also proved to be a user burden, as many individuals made small mistakes that led to repeated failures, without indications of where the error is, illustrating the operability barrier in URL design. These mistakes included typos in the URL or using autofill to automatically complete the URL, despite the autofill not matching the provided URL.

Participants struggled with the password aspects of Tasks 3 and 4, further exposing learnability and operability barriers. They often misunderstood the login prompts, illustrating conceptual clarity issues in password duplication or creation for digital tools (categorized as "how to do manual credential entry" and "how to create a password"). The knowledge required to understand and replicate the complexity required for password creation is too steep, resulting in learnability barriers for many users who do not possess the basic level of knowledge necessary to navigate username and password duplication or creation. Additionally, once individuals in Task 4 created a password, they often did not know what to do next to proceed, illustrating the learnability issues of progressing successfully through the steps required to sign in or sign up for a patient portal account. The operability limitation of these tasks is notifications that do not adequately notify the participant of their error and leads to repeated errors (categorized as "generic error notification leads to repeated errors" and "login failed" notification leads to repeated errors"). For example, the activation codes were confusing and led to errors among participants without proper indication. Once prompted that an activation code was needed, many did not know what it was, where to find it, or what to do with it. If they mistyped the activation code, but not the username or password, they'd only receive a "login failed" notification that did not properly indicate where the error occurred.

DISCUSSION

Principal Results

Our study identified the fundamental skills necessary to be able to effectively navigate digital health tasks, found significant disparities in those skills among participants, and established usability issues associated with navigating digital health tools.

Although nearly universal access to digital devices has resulted in increased device ownership and personal use, less than 60% of participants were able to complete more than half of the tasks independently. 16% were unable to complete any tasks independently, indicating a discrepancy between device ownership and ability to navigate these devices effectively, particularly for digital tasks related to healthcare. This data is supported by prior work assessing disparities in digital health tool use[18,19,60].

We expected that typing skills, navigation skills, and HCI skills should be associated with the ability to complete the digital tasks independently, but it was found that only a subset of these factors were associated with task completion, which may be limited by our sample size.

Challenges in Task Completion

More than half the participants were able to complete each task independently, with nearly 75% able to complete Tasks 1, 3, and 4 independently. The task of typing in a URL in Task 2 posed unique barriers and resulted in more participants requiring assistance or being unsuccessful. This is potentially explained by the fact that typing in a complete URL is increasingly uncommon in digital health contexts, where users typically rely on search engines (e.g., searching "SFHN MyChart patient portal" in the search bar), use autocomplete based on browsing history, or access the portal through an app. This is further supported by the fact that many participants struggled to even recognize the URL bar or conceptually understand what was being asked of them during Task 2. Despite this, many informational handouts about the patient portal continue to direct users to type in a specific URL to access the patient portal. These materials should consider providing alternative instructions that align with common user behavior, such as using search terms or app-based access.

Disparities in Task Completion

We anticipated that there would be disparities in task completions based on age, sex, race and ethnicity, preferred language, education, access to a device with video capability, source of internet access, and patient portal enrollment. Older age, minoritized races and ethnicities, preferred languages other than English, low educational attainment, possession of a device without video capability, data as the source of internet access, and not being enrolled in the patient portal contributed significantly to gaps in digital skills. These sociodemographic characteristics were significantly associated with requiring assistance or being unsuccessful, particularly for tasks that involved multiple steps or complex engagement with digital interfaces. This suggests that individuals from these groups may be disproportionately less likely to have the skills required to feel confident and able to complete each task individually. Moreover, Tasks 3 and 4 were more complex, involving reading comprehension and following multiple prompts to enter pertinent text or create a unique password. These elements (such as log in prompts and password creation details) are in English only, which poses obvious barriers to individuals who prefer non-English languages.

Although this study is not sufficiently powered to examine the intersectional vulnerabilities of participants who experience multiple, overlapping socioeconomic disadvantages—factors that may confound their ability to complete digital tasks independently—

there remains a critical need for future research to adopt an inclusive approach to participant recruitment and analysis in usability studies. Specifically, examining how compounded forms of marginalization (e.g., low income, limited education, language barriers, and age-related factors) shape digital engagement is essential for uncovering the full extent of challenges faced by individuals most at risk of digital exclusion. Such efforts are key to informing the design of equitable digital health tools and implementation strategies that promote broader and more effective adoption across diverse populations[22,30–32,61].

Challenges in Digital Proficiency

These results illustrate that the basic foundational skills necessary for successful navigation and use of digital health tools include competency with one's device, such as knowing basic keyboard navigation and how to find appropriate apps or change settings, and navigating complex processes, such as interacting with pop-ups, successfully navigating web browsers, and ability to proceed after each step. Without these basic foundational skills, individuals' ability to successfully use and navigate digital health tools decreases significantly. Strategies for improving digital skills to ensure that individuals have the foundational skills necessary include digital skills workshops and trainings that emphasize hands-on practice with common tasks such as manual text entry, device and keyboard navigation, managing settings, and interacting with complex pop-ups or prompts. Prior studies have found that providing support, such as technical support or digital education, can alleviate some of the digital proficiency challenges many face and promote use of digital health tools, particularly among those who face greater barriers to digital use[41–43]. In addition to providing detailed assistance and training to address the complex barriers faced by those with limited digital literacy, ongoing or repeated support may be necessary, as one-time training or technical help may not be sufficient to overcome persistent technical challenges[43].

Usability Barriers May Impact Digital Task Success

The findings highlight the critical role of learnability and operability challenges across a range of digital health tasks commonly required for digital patient engagement. Participants encountered distinct barriers at each task, verbalizing frustration and making repeated assistance requests. Many of the difficulties were often tied to misunderstandings about how to initiate or complete a task, suggesting that digital inclusion efforts should simplify interfaces, provide clear prompts, and reduce extraneous steps to mitigate the usability issues many participants face.

Learnability issues can lead to a range of negative user experiences, including hesitation and confusion, a greater need for assistance and additional support to complete each task, and low user confidence. Each task required a level of understanding that users might not have to complete the task, resulting in a system that does not equally support users of all backgrounds to adapt and use the system. In addition, there were operability barriers across each task. Particularly, difficulties with clicking the wrong link, making errors without descriptive/specific notifications, or confusing mechanisms to proceed during a task result in a system that does not provide users with the necessary functionalities to allow users of all backgrounds to adapt and use the system. Efforts to improve the clarity of digital task prompts and processes, from simplifying the URL to log-in to the patient portal, to clarifying how to successfully join a video visit from a text/link or how to engage with certain prompts will enhance the learnability and increase the operability of the system and allow users to better engage with and remember how to use the system going forward.

These findings are consistent with prior research identifying digital navigation and account access as common friction points for users with limited digital literacy[18,19]. However, our human-centered design (HCD) approach to this study adds nuance by documenting how these challenges manifest in real time and vary by task complexity. Previous literature often examines digital competence in aggregate, but our task-specific analysis reveals that even users with some experience may struggle with unfamiliar or multi-step processes, particularly when there are long task completion times or confusing interfaces/prompts lead to repeated errors[62,63]. As adoption of digital health tools continues to increase, there are opportunities to utilize HCD approaches to identify usability barriers and align digital health tool design with user needs to ensure a more equitable distribution of digital health tools benefits[40]. This is particularly important as there are numerous examples in which digital tools exacerbate inequities and HCD approaches can help uncover health equity issues that were previously unknown and drive efforts to address those inequities that marginalized populations may feel more acutely that are often considered priorities in research[30,37].

Role of Vendors Addressing Usability Barriers and User-Friendliness

The findings from this study underscore the pressing need for digital health vendors to take a more active role in addressing the usability barriers and skill gaps that disproportionately affect individuals with limited digital skills or who belong to marginalized groups. While health systems increasingly rely on digital platforms to facilitate patient engagement, results demonstrate that foundational usability issues and digital design that is too complex for a broad range of users are common friction points that inhibit successful digital health tool use. These barriers are not merely technical inconveniences; they function as structural barriers that exclude users from accessing care and support. Prior studies have similarly identified usability challenges—such as manual data entry, following procedures to retrieve data (such as appointment details), and understanding medical terminology—as key barriers that prevent equitable use of patient portals among diverse populations[64].

Vendors should adopt HCD principles and co-design strategies that engage diverse users throughout the design process to ensure that digital interfaces are intuitive, accessible, and responsive to users' varying levels of digital proficiency. This includes incorporating plain language, reducing unnecessary steps, improving language functionalities for non-English speakers, and reducing privacy and security complexities that act as a barrier to users with low digital literacy[64]. Vendors must not assume a baseline level of digital literacy and should instead actively test for, design against, and consult patients about learnability, operability, and task complexity barriers in these digital health tools. By treating usability and accessibility as core priorities rather than downstream implementation concerns, vendors can play a pivotal role in promoting digital equity and closing gaps in healthcare access. For example, strict security needs for usernames and passwords (including activation codes and other two-factor authentication) are not “user-friendly”, and while they make sense from a security perspective, they are advanced skills that many users do not understand or have experience with. Issues with complex password creation, entering an activation code, and other two-factor authentication are demonstrated tension points for users from marginalized backgrounds who may have little experience with engaging with strict and complex privacy protocols. Vendors should include patient voices when weighing privacy concerns against usability to ensure that access and usability decisions do not further inequities[37,64].

Limitations

We note several limitations of our study design and findings. We recruited participants from a large urban safety-net health system that serves a diverse population, but our stratified samples based on core sociodemographic characteristics are small, limiting our ability to evaluate disparities in fundamental skills by sociodemographic characteristics. Additionally, the Hawthorne effect may have resulted in participants changing their behavior while completing the digital tasks because they were being observed. While the chosen tasks are essential in accessing and using digital health technology, they may not be representative of specific usability barriers individuals face within the patient portal app itself (such as scheduling an appointment) or may be considered by some as antiquated processes (such as using a URL to access the patient portal). Moreover, despite advances in digital health tool accessibility (translation to multiple languages and apps available on most devices), there are still limitations to digital health tools' ability to be inclusive, resulting in issues that are not strictly due to lack of skill but influenced by language barriers or other sociodemographic barriers. However, results will still provide further direction for future digital inclusion studies.

Implications for Future Research

Future studies should more deeply examine usability issues of digital health tools, evaluating the tools themselves and not just tasks that are related to these tools. Future studies should also explore longitudinal improvements in digital skills following structured training interventions. Evidence has shown that providing multimodal and audio-visual digital training is supported by patients and has been associated with improved use[41,42]. These suggest that training among populations with marginalized identities can be beneficial, yet evidence is needed to assess training implications on digital skills. Additionally, assessing the impact of different instructional approaches—such as interactive tutorials versus guided assistance—could yield insights into optimizing digital literacy education.

Furthermore, there are benefits of improving digital literacy broadly, not only specific to digital health tools and digital health engagement. This study demonstrated that there are disparities in foundational skills that are not specific to digital health tools, so designing collaborations with libraries or continuing education classes could be implementation strategies that can help mitigate the effects of these skill disparities and reduce digital exclusion.

CONCLUSION

By integrating the results of the fundamental skills necessary to use digital health tools and usability barriers to using these tools, this study highlights critical gaps in digital literacy, particularly in device navigation and progressing through complex tasks. This study underscores the importance of usability-driven improvements to reduce digital barriers. By addressing these challenges through targeted interventions, digital accessibility may be enhanced, empowering users to navigate digital environments more effectively. Future work should explore user-tailored interventions aimed at providing individuals with the core fundamental skills necessary to use digital health tools, iterative usability testing to improve the usability of these tools, and personalized support mechanisms to support individuals as they navigate these tools. By systematically identifying and addressing these usability challenges, researchers and developers can create more inclusive digital health solutions that promote equitable healthcare access and improve patient outcomes across all populations.

TABLES AND FIGURES

Table 2.1: Participant Descriptives

Participant Characteristics, N (Col., %)	**Subsample with Video Observations (N=64)**
Age, mean (SD)	61.9 (7.4)
% Male	62.5
Race and Ethnicity (%)	
Non-Hispanic White	12 (18.8)
Non-Hispanic Black or African American	10 (15.6)
Non-Hispanic Asian	21 (32.8)
Non-Hispanic Other or Multiple Races	4 (6.3)
Hispanic or Latinx	16 (25.0)
Decline to Answer	1 (1.6)
Preferred Language (%)	
English	42 (65.6)
Spanish	8 (12.5)
Cantonese	14 (21.9)
Education (%)	
High School (no degree), or less	18 (28.1)
High School degree or GED	16 (25.0)
Some College, or associate's degree	18 (28.1)
Bachelor's Degree, or higher	12 (18.8)
Own Device with Video Capability (%)	
Yes	58 (90.6)
No / Don't know	6 (9.4)
Preferred Device(s) (%)	
Smartphone	55 (85.9)
Desktop or laptop computer	12 (18.8)
Tablet	9 (14.1)
Simple cell phone	1 (1.6)
Internet Access (%)	
Both Wi-Fi and unlimited data on phone	39 (60.9)
Wi-Fi only	15 (23.4)
Unlimited data on phone only	7 (10.9)
Neither / Don't know	3 (4.7)
Enrolled in Patient Portal (%)	
Yes, at SFHN	42 (65.6)
No / Don't know	22 (34.4)

Col.: Column, SD: Standard Deviation

Table 2.2: Task Completion Rates for each Task by Key Sociodemographic Characteristics

	Task 1 N = 46		Task 2 N = 60		Task 3 N = 62		Task 4 N = 61		P-value[a]
N (Col., %)	**Indep.** n = 34 (74)	**A/U** n = 12 (26)	**Indep.** n = 31 (52)	**A/U** n = 29 (48)	**Indep.** n = 44 (71)	**A/U** n = 18 (29)	**Indep.** n = 43 (70)	**A/U** n = 18 (30)	
Age, [mean, (SD)]	60.2 (6.49)	67.2 (7.98)	60.8 (7.68)	62.7 (5.99)	61.1 (7.11)	62.3 (5.75)	60.5 (7.21)	63.5 (5.23)	*P=.004*[b]
% Male	58.82	66.67	64.52	62.07	68.18	44.44	69.77	38.89	*P=.06*
Race and Ethnicity (%)									*P<.001*
NH White	8 (23.5)	1 (8.3)	8 (25.8)	4 (13.8)	12 (27.3)	0 (0)	12 (27.9)	0 (0)	
NH Black or African American	4 (11.8)	3 (25.0)	5 (16.1)	4 (13.8)	8 (18.2)	2 (11.1)	8 (18.6)	2 (11.1)	
NH Asian	10 (29.4)	5 (41.7)	8 (25.8)	10 (34.5)	11 (25.0)	8 (44.4)	11 (25.6)	7 (38.9)	
NH Other or Multiple Races	3 (8.8)	0 (0)	3 (9.7)	1 (3.4)	4 (9.1)	0 (0)	4 (9.3)	0 (0)	
Hispanic or Latinx	9 (26.5)	3 (25.0)	6 (19.4)	10 (34.5)	8 (18.2)	8 (44.4)	7 (16.3)	9 (50.0)	
Preferred Language (%)									*P<.001*
English	23 (67.6)	5 (41.7)	26 (83.9)	13 (43.3)	37 (84.1)	5 (27.8)	36 (83.7)	6 (33.3)	
Spanish	4 (11.8)	2 (16.7)	0 (0)	8 (26.7)	3 (6.8)	5 (27.8)	2 (4.7)	6 (33.3)	
Cantonese	7 (20.6)	5 (41.7)	5 (16.1)	8 (30.0)	4 (9.1)	8 (44.4)	5 (11.6)	6 (33.3)	
Education (%)									*P<.001*
High School degree, GED, or less	16 (47.1)	11 (91.7)	10 (32.3)	22 (75.9)	19 (43.2)	17 (94.4)	16 (37.2)	15 (83.3)	
Some College or higher	18 (52.9)	1 (8.3)	21 (67.7)	7 (24.1)	15 (34.1)	1 (5.6)	27 (62.8)	3 (16.7)	
Own Device with Video Capability (%)									*P=.05*
Yes	34 (100)	9 (75.0)	30 (96.8)	26 (89.7)	40 (90.9)	16 (88.9)	40 (93.0)	15 (83.3)	
No / Don't Know	0 (0)	3 (25.0)	1 (3.2)	3 (10.3)	4 (9.1)	2 (11.1)	3 (7.0)	3 (16.7)	
Internet Access (%)									*P<.001*[c]
Both Wi-Fi and unlimited data	23 (67.6)	5 (41.7)	19 (61.3)	18 (62.1)	28 (63.6)	10 (55.6)	28 (65.1)	9 (50.0)	
Wi-Fi only	8 (23.5)	3 (25.0)	11 (35.5)	2 (6.9)	11 (25.0)	3 (16.7)	10 (23.3)	4 (22.2)	
Unlimited data on phone only	3 (8.8)	1 (8.3)	1 (3.2)	6 (20.7)	5 (11.4)	2 (11.1)	5 (11.6)	2 (11.1)	
Neither / Don't Know	0 (0)	3 (25.0)	0 (0)	3 (10.3)	0 (0)	3 (16.7)	0 (0)	3 (16.7)	
Enrolled in Patient Portal (%)									*P<.001*
Yes, at SFHN	28 (82.4)	3 (25.0)	27 (87.1)	13 (44.8)	33 (75.0)	8 (44.4)	34 (79.1)	7 (38.9)	
No / Don't Know	6 (17.6)	9 (75.0)	4 (12.9)	16 (55.2)	11 (25.0)	10 (55.6)	9 (20.9)	11 (61.1)	

Col.: Column, Indep: Independent, A/U: Assisted/Unsuccessful, SD: Standard Deviation, NH: Non-Hispanic

[a] Chi-square test used to assess differences by sociodemographic characteristic, unless otherwise specified; P<.05 significant

[b] Kruskal-Wallis test used to assess differences by age; P<.05 significant

[c] Fisher's Exact test used to assess differences by internet access; P<.05 significant

Figure 2.1: Qualitative thematic maps for fundamental skills and usability barriers

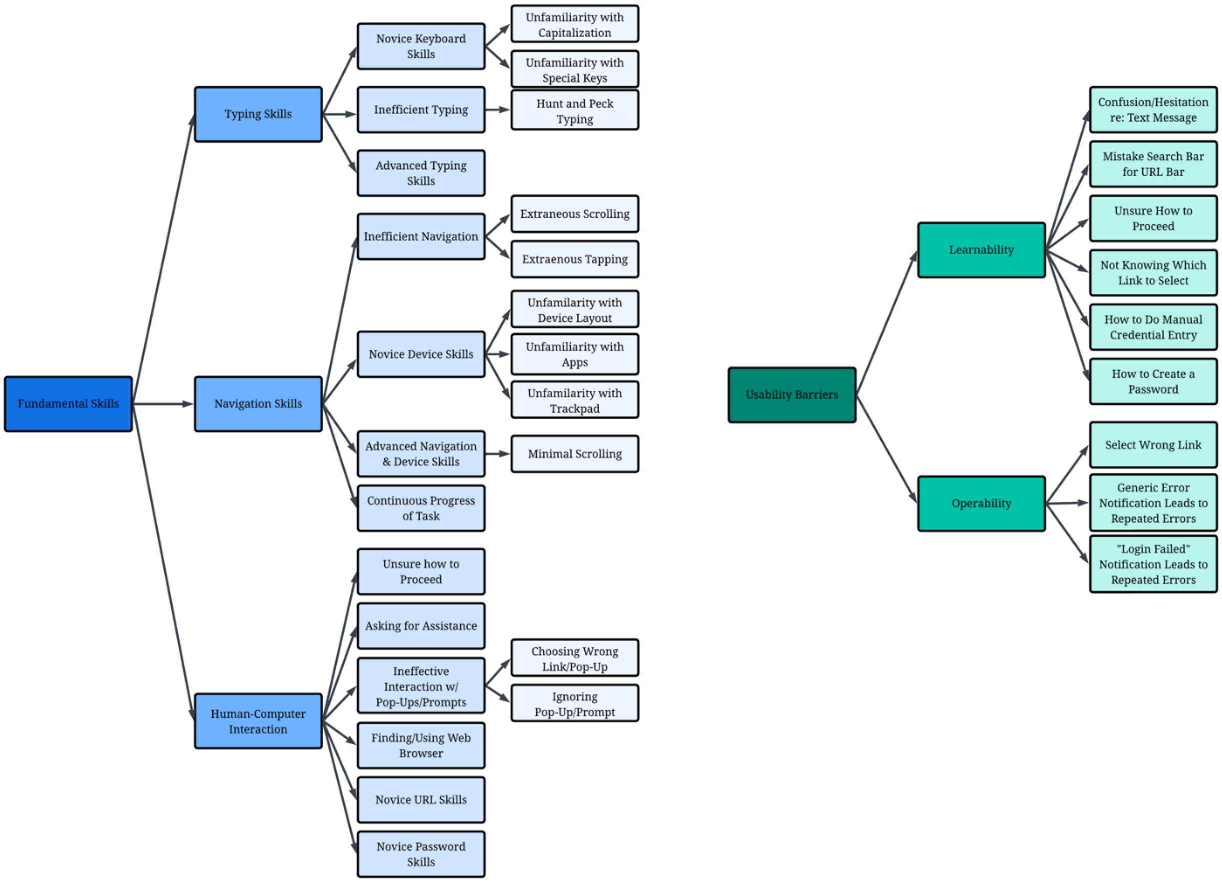


Table 2.3: Association between thematic fundamental skills codes and task completion

	Task	Independent	Assisted/Unsuccessful	***P-value***
Typing Skills				
Inefficient Typing (tasks 2 - 4)	2	24	24	*P=1*
	3	25	17	*P<.001*[a]
	4	28	15	*P=.26*
Novice Keyboard Skills (tasks 2 - 4)	2	0	10	*P<.001*[a]
	3	0	5	*P<.001*[a]
	4	0	7	*P<.001*[a]
Advanced Typing Skills (tasks 2 - 4)	2	5	0	*P=.05*[a]
	3	7	0	*P=.17*[a]
	4	8	0	*P=.09*[a]
Navigation Skills				
Inefficient Navigation	1	4	8	*P=.001*[a]
	2	4	23	*P<.001*
	3	11	9	*P<.001*[a]
	4	11	12	*P=.006*
Novice Device Skills	1	2	10	*P<.001*[a]
	2	2	21	*P<.001*
	3	2	6	*P=.004*[a]
	4	2	7	*P=.002a*
Advanced Navigation & Device Skills	1	28	1	*P<.001*[a]
	2	29	1	*P<.001*
	3	35	4	*P<.001*[a]
	4	33	2	*P<.001*[a]
Continuous Progress of Task	1	22	0	*P<.001*
	2	24	0	*P<.001*
	3	31	0	*P<.001*
	4	23	0	*P<.001*
Human-Computer Interaction				
Unsure How to Proceed	1	7	12	*P<.001*
	2	0	15	*P<.001*
	3	4	6	*P=.02a*
	4	5	11	*P<.001*[a]
Asking for Assistance	1	3	12	*P<.001*[a]
	2	1	19	*P<.001*
	3	7	13	*P<.001*
	4	8	13	*P<.001*
Ineffective Interaction w/ Pop-Ups/ Prompts	1	3	15	*P=.006*
	2	4	11	*P=.04*[a]
	3	8	11	*P=.002*
	4	12	13	*P<.001*[a]
Finding/Using Web Browser (task 2 only)	2	0	13	*P<.001*
Novice URL Skills (task 2 only)	2	3	14	*P<.001*
Novice Password Skills (tasks 3 and 4 only)	3	5	8	*P=.004*[a]
	4	13	13	*P=.006*

Independent and Assisted/Unassisted Columns show the number of participants displaying each qualitative code per task

[a] Indicates Fisher's Exact Test, Chi-Squared Tests of Independence used in all other instances; P<.05 significant

Table 2.4: Examples of learnability usability barriers by task

Learnability			
Task	**Thematic Codes**	**Examples**	**Quotes**
Task 1: Sign In to a Video Visit	Confusion/Hesitation re: Text Messages Unsure How to Proceed Not Knowing Which Link to Select	- Clicking on link to video call from text message requires a level of understanding (to click the link) that users might not have - Results in hesitation to click the link/ignoring text/or replying to no-reply text - Individual ignores necessary prompts for joining video call or selects other incorrect links	"Ok so I have to copy that link and put it on my phone?" "So, I open it, I guess?" "Ok but what does…main menu? What does that look like?"
Task 2: Go To Specific Website	Mistake Search Bar for URL Bar How to Do Manual Credential Entry Unsure How to Proceed Not Knowing Which Link to Select	- Individual types URL into the search bar instead of URL bar - Individual is not sure how to proceed once they type the URL in - Individual does not select the appropriate link or button, instead selects elsewhere	"I don't know how to get to a website" "If I put it up here, it doesn't come down here" (in reference to search bar) "Now I'm stuck"
Task 3: Sign In to the Patient Portal	How to Do Manual Credential Entry Unsure How to Proceed	- Individual does not display the basic level of knowledge for password or username duplication (copying given password/username into account) - Individual stops after typing in password, without clicking enter to continue	"Oh, it says Patient, I'm the patient!" (In response to username being "Patient123" after only entering '123')
Task 4: Sign Up for a Patient Portal Account	How to Create a Password Unsure How to Proceed	- Individual does not display the basic level of knowledge necessary to create a password - Individual does not know how to proceed once they type in a password or username	"Did it accept? Did it accept, or not?" "I don't know what you mean by that" (in response to being instructed to capitalize a letter) "Is that the password? Nothing? I have to create? Invent something?"

Table 2.5. Examples of operability usability barriers by task

Operability			
Task	**Thematic Codes**	**Examples**	**Quotes**
Task 1: Sign In to a Video Visit	Selecting Wrong Link	- Individual clicks on wrong link to join video call	
Task 2: Go To Specific Website	Generic Error Notification Leads to Repeated Errors	- Complexity and length of URL results in errors difficult to discern and correct	(participant mistakenly types forward slash instead of back slash)
Task 3: Sign In to the Patient Portal	Generic Error Notification Leads to Repeated Errors “Login Failed” Notification Leads to Repeated Mistakes	- Activation code causes confusion and leads to error making - “Login failed” notification does not indicate the error, resulting in difficulty correcting username or password errors	“I don’t know [where the activation code is]” “This is the activation code right here?”
Task 4: Sign Up for a Patient Portal Account	Generic Error Notification Leads to Repeated Errors “Login Failed” Notification Leads to Repeated Mistakes	- Activation code causes confusion and leads to error making - “Login failed” notification does not indicate the error, resulting in difficulty correcting username or password errors	“Where do I put [activation code], right here?”

APPENDICES

APPENDIX A. Selected Participant Questionnaire Items

Question	Source
1. What is your birthdate? [MM/DD/YYYY] 2. [If don't know]: About how old are you? [age in years]	Self-developed
3. What terms best express how you describe your gender identity? a. Man b. Woman c. Non-binary d. Transgender e. Other, please specify ________________________ f. Prefer not to answer	Self-developed
4. Are you of Hispanic, Latino, or Spanish origin? a. No, not of Hispanic, Latino, or Spanish origin b. Yes, Mexican, Mexican American, Chicano c. Yes, Puerto Rican d. Yes, Cuban e. Yes, another Hispanic, Latino, or Spanish origin – Please specify, Salvadoran, Dominican, Colombian, Guatemalan, Spaniard, Ecuadorian, etc.	Self-developed
5. What is your race? Mark one or more boxes AND print origins. a. White, please specify: *(for example, German, Irish, English, Italian, Lebanese, Egyptian, etc.)* b. Black or African American, please specify: *(for example, African American, Jamaican, Haitian, Nigerian, Ethiopian, Somali, etc.)* c. American Indian or Alaska Native, please specify: *(for example, Navajo Nation, Blackfeet Tribe, Mayan, Aztec, Native Village of Barrow Inupiat Traditional Government, Nome Eskimo Community, etc.)* d. Chinese e. Filipino f. Asian Indian g. Vietnamese h. Korean i. Japanese j. Other Asian, please specify: *(for example, Pakistani, Cambodian, Hmong, etc.)* k. Native Hawaiian l. Samoan m. Chamorro n. Other Pacific Islander, please specify: *(for example, Tongan, Fijian, Marshallese, etc.)* o. Some other race, please specify:	Self-developed
6. What is the highest grade or level of school you have completed or the highest degree you have received? a. Never Attended/Kindergarten Only; b. 1st Grade; c. 2nd Grade; d. 3rd Grade; e. 4th Grade; f. 5th Grade; g. 6th Grade; h. 7th Grade; i. 8th Grade; j. 9th Grade; k. 10th Grade; l. 11th Grade;	Self-developed

m. 12th Grade, No Diploma; n. High School Graduate; o. GED Or Equivalent; p. Some College, No Degree; q. Associate Degree: Occupational, Technical, Or Vocational Program; r. Associate Degree: Academic Program; s. Bachelor's Degree (Example: BA, AB, BS, BBA); t. Master's Degree (Example: MA, MS, MEng, MEd, MBA); u. Professional School Degree (Example: MD, DDS, DVM, JD); v. Doctoral Degree (Example: PhD, EdD); w. Refused; x. DON'T KNOW	
7. Do you own a phone, tablet, or computer that can do a video call? a. Yes b. No c. Don't know/Not sure d. Decline to state	Developed by Epic Workgroup focused on Digital Exclusion Screening Questions
8. Do you have either Wi-Fi at home or an unlimited data plan (on your phone)? a. Yes, Wi-Fi b. Yes, unlimited data for phone c. Yes, both Wi-Fi and unlimited data for phone d. No e. Don't know / Not sure f. Decline to state	Internally developed at the San Francisco Health Network
9. Are you enrolled in a patient portal (like MyChart) with your primary care provider? [BARRIERS: PATIENT PORTAL] a. Yes, at SFGH b. Yes, at another health system c. No d. Don't know/Not sure e. Decline to state	Self-developed

APPENDIX B. Detailed Descriptions of Digital Tasks.

Each of the tasks were designed by the study team to imitate the actions necessary when joining a telemedicine call from a text message, searching for the patient portal by typing in the URL, creating a unique password for the patient portal, and logging in to the patient portal.

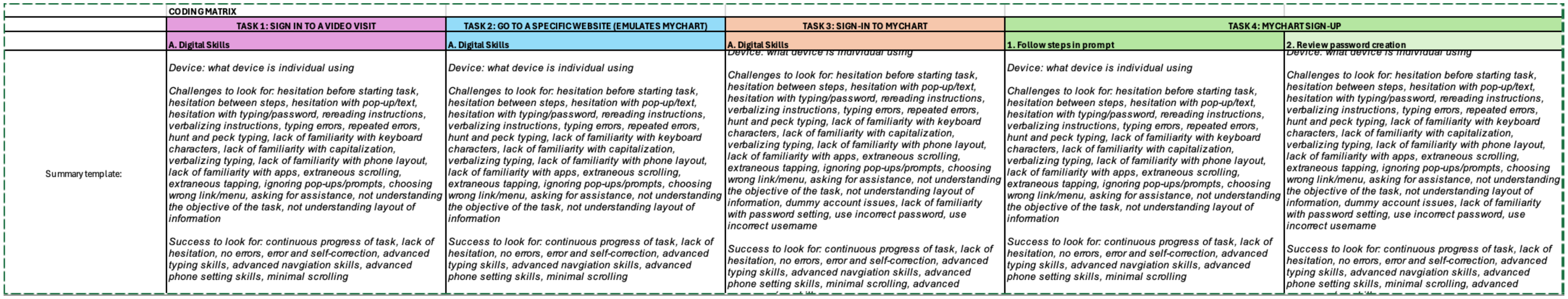
In the *first task (launching a video visit),* the participant received a standardized text message in English from an automated number containing an invitation to join the video visit by clicking the link in the text. Once the participant clicked the link, they followed a series of prompts to successfully join the video visit (e.g., allowing the camera and microphone access).

In the *second task (going to a specific health website),* the participant opened a web browser and typed in the URL for the patient portal website emulator into the URL/address bar.

In the *third task (signing in to a patient portal account via emulator),* the participant entered a provided username and password into the patient portal login fields to mimic logging in to the patient portal.

In the *fourth task (signing up for a patient portal account via emulator)*, participants created a patient portal account by entering an activation code, zip code, and birthdate, and then entering and provided username and creating a unique password for the account.

APPENDIX C. Qualitative Coding Matrix and Codebook



	CODING MATRIX				
	TASK 1: SIGN IN TO A VIDEO VISIT	TASK 2: GO TO A SPECIFIC WEBSITE (EMULATES MYCHART)	TASK 3: SIGN-IN TO MYCHART	TASK 4: MYCHART SIGN-UP	
	A. Digital Skills	A. Digital Skills	A. Digital Skills	1. Follow steps in prompt	2. Review password creation
Summary template:	*Device: what device is individual using* *Challenges to look for: hesitation before starting task, hesitation between steps, hesitation with pop-up/text, hesitation with typing/password, rereading instructions, verbalizing instructions, typing errors, repeated errors, hunt and peck typing, lack of familiarity with keyboard characters, lack of familiarity with capitalization, verbalizing typing, lack of familiarity with phone layout, lack of familiarity with apps, extraneous scrolling, extraneous tapping, ignoring pop-ups/prompts, choosing wrong link/menu, asking for assistance, not understanding the objective of the task, not understanding layout of information* *Success to look for: continuous progress of task, lack of hesitation, no errors, error and self-correction, advanced typing skills, advanced navgiation skills, advanced phone setting skills, minimal scrolling*	*Device: what device is individual using* *Challenges to look for: hesitation before starting task, hesitation between steps, hesitation with pop-up/text, hesitation with typing/password, rereading instructions, verbalizing instructions, typing errors, repeated errors, hunt and peck typing, lack of familiarity with keyboard characters, lack of familiarity with capitalization, verbalizing typing, lack of familiarity with phone layout, lack of familiarity with apps, extraneous scrolling, extraneous tapping, ignoring pop-ups/prompts, choosing wrong link/menu, asking for assistance, not understanding the objective of the task, not understanding layout of information* *Success to look for: continuous progress of task, lack of hesitation, no errors, error and self-correction, advanced typing skills, advanced navgiation skills, advanced phone setting skills, minimal scrolling*	*Device: what device is individual using* *Challenges to look for: hesitation before starting task, hesitation between steps, hesitation with pop-up/text, hesitation with typing/password, rereading instructions, verbalizing instructions, typing errors, repeated errors, hunt and peck typing, lack of familiarity with keyboard characters, lack of familiarity with capitalization, verbalizing typing, lack of familiarity with phone layout, lack of familiarity with apps, extraneous scrolling, extraneous tapping, ignoring pop-ups/prompts, choosing wrong link/menu, asking for assistance, not understanding the objective of the task, not understanding layout of information, dummy account issues, lack of familiarity with password setting, use incorrect password, use incorrect username* *Success to look for: continuous progress of task, lack of hesitation, no errors, error and self-correction, advanced typing skills, advanced navgiation skills, advanced phone setting skills, minimal scrolling, advanced*	*Device: what device is individual using* *Challenges to look for: hesitation before starting task, hesitation between steps, hesitation with pop-up/text, hesitation with typing/password, rereading instructions, verbalizing instructions, typing errors, repeated errors, hunt and peck typing, lack of familiarity with keyboard characters, lack of familiarity with capitalization, verbalizing typing, lack of familiarity with phone layout, lack of familiarity with apps, extraneous scrolling, extraneous tapping, ignoring pop-ups/prompts, choosing wrong link/menu, asking for assistance, not understanding the objective of the task, not understanding layout of information* *Success to look for: continuous progress of task, lack of hesitation, no errors, error and self-correction, advanced typing skills, advanced navgiation skills, advanced phone setting skills, minimal scrolling*	*Device: what device is individual using* *Challenges to look for: hesitation before starting task, hesitation between steps, hesitation with pop-up/text, hesitation with typing/password, rereading instructions, verbalizing instructions, typing errors, repeated errors, hunt and peck typing, lack of familiarity with keyboard characters, lack of familiarity with capitalization, verbalizing typing, lack of familiarity with phone layout, lack of familiarity with apps, extraneous scrolling, extraneous tapping, ignoring pop-ups/prompts, choosing wrong link/menu, asking for assistance, not understanding the objective of the task, not understanding layout of information, dummy account issues, lack of familiarity with password setting, use incorrect password, use incorrect username* *Success to look for: continuous progress of task, lack of hesitation, no errors, error and self-correction, advanced typing skills, advanced navgiation skills, advanced phone setting skills, minimal scrolling, advanced*

Grouping	Code	Definition
Novice Keyboard Skills	Unfamiliarity with capitalization	Individual demonstrates lack of familiarity with capitalization, either by vocalizing it or by not knowing how to do it
	Unfamiliarity with special keys	Individual demonstrates lack of familiarity with keyboard characters, either by vocalizing it or by using the wrong characters
Inefficient Typing	Hunt and peck typing	Individual types with one finger (or with a stylus) at a time, "hunting" for each letter on the keyboard; can also verbalize searching for letters
Advanced typing skills	Advanced typing skills	Individual displays advanced typing skills (intuitive navigation of the keyboard, understanding of capitalization & special keys)
Inefficient Navigation	Extraneous scrolling	Individual scrolls excessively, often too much and past the field or objective they are looking for (also if they scroll incorrectly, such as trying to use the laptop screen as a touchscreen and trying to scroll that way)
	Extraneous tapping	Individual taps their device excessively and maybe arbitrarily trying to click on different things or unsure how to tap (also if they use laptop as a touchscreen and try to tap on monitor)
Novice Device Skills	Unfamiliarity with phone layout (more general)	Individual expresses or demonstrates lack of familiarity with the phone layout, doesn't understand where to go or what to do, how to navigate different steps
	Unfamiliarity with apps (location/what they look like)	Individual expresses or demonstrates lack of familiarity with device applications, such as where they are or how to find them, what they look like, when to use which app, etc.
	Unfamiliarity with trackpad	Individual expresses or demonstrates lack of familiarity with using a trackpad or touchscreen, such as controlling a cursor or how to select items (or using it appropriately, i.e., if a user mistakenly treats the screen of a laptop as a touchscreen)
Advanced Navigation & Device Skills	Minimal scrolling	Individual demonstrates minimal (or lack of excessive) scrolling when completing task
	Advanced phone navigation skills	Individual displays advanced and intuitive navigation skills and understands how to navigate different apps or steps
	Advanced phone setting skills	Individual displays skills adjusting or changing any settings that might be needed

Continuous Progression of Tasks	Continuous progress of task	Individual progresses through task without any breaks in performance flow
Unsure how to proceed	Unsure how to proceed	Individual hesitates between steps/before moving to the next step (i.e., hesitates before pushing enter, double checks their work, etc.)
Asking for Assistance	Asking for assistance	Individual requests assistance with the task, whether or not assistance is provided
Ineffective interaction with Pop-ups/prompts	Choosing wrong link/pop-up/menu	Individual chooses the wrong link, pop-up, or menu during the task
	Ignoring pop-ups/prompts	Individual ignores pop-ups or prompts (or closes them) when they are relevant to completing the task
Finding/Using web browser	Finding/Using web browser	Individual struggles with navigating a web browser, either verbalizes confusion when prompted to use it, expresses hesitation with using a web browser, or navigates in effectively
Novice URL skills	Novice URL skills	Individual does not understand how to type in a URL, either verbally expresses confusion, types it into the wrong place, incorrectly uses autocorrect to finish the URL, or other ineffective URL strategy
Novice password skills	Novice password skills	Individual demonstrates or expresses lack of familiarity with password setting (such as asking questions about it, not sure what to put or how to make a password, etc.)
Learnability	Confusion/Hesitation with text message	Individual hesitates or is confused with the text message, selecting the link, responding to it, ignoring it, etc.; either in action or verbally expresses it
	Mistake search bar for URL bar	Individual types the URL into the search bar and does not know what to do after
	Not knowing which link to select	Individual hesitates with a pop-up or selecting a link, unsure which one to choose or selecting the wrong one
	How to do manual credential entry	Individual uses incorrect username/password/activation code (i.e., their password instead of the dummy password, doesn't type in the full password, etc.)
Operability	Repeated errors	Individual makes repeated errors due to non-specific error or login failed notifications NOTE: specify where the repeated errors occurred and whether notification said "error" or "login failed"

Chapter 3

Title: Impact of Digital Support Interventions on Patient Portal Use Among Patients in an Urban Safety-net Health System

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Abstract:

Objective: To assess the effectiveness of digital support interventions on patient portal use in a safety-net health system.

Materials and Methods: In a 12-month longitudinal study, 286 adult patients from a large, safety-net health system in San Francisco received one-on-one support for patient portal use (basic, or tailored for those who requested in-depth assistance). The primary outcome of change in monthly MyChart login counts was analyzed using a zero-inflated negative binomial mixed-effects model, controlling for age, language, race and ethnicity, comorbidity, and digital confidence.

Results: Average percent of monthly portal users increased from 52 to 71% from pre- to post-intervention period. We observed a 12% relative increase in average monthly portal users following basic support and a 91% relative increase in average monthly users following tailored training. Spanish-speakers benefited particularly from basic support, showing an 80% increase in login counts (IRR=1.8). Participants who received tailored training logged in 85% less frequently at baseline than those with basic support only (IRR=0.15) and showed a fivefold increase in frequency of monthly portal use relative to pre-intervention rates (IRR=4.94).

Discussion: An embedded, multicomponent MyChart support program in a safety-net setting was effective at increasing portal engagement. Basic support was especially effective for Spanish speakers, while tailored support benefited participants with low baseline engagement.

Conclusion: Bilingual digital support and tailored training can substantially improve patient portal use, particularly among underserved populations. Health systems should consider integrating personalized support into care workflows to reduce digital disparities and ensure equitable access to digital health tools.

INTRODUCTION

Patient portals embedded within electronic health records (EHRs) have been associated with more effective and efficient care, enhanced patient-provider communication, and improved health outcomes, particularly for individuals with chronic medical needs. However, there are clear differences between those who experience the benefits of portal use and those who do not[7–12,16,23,65]. Despite strong associations between patient portal use and improved care quality and health outcomes, marginalized populations remain significantly less likely to engage with these tools[11,16,23–25,38,51]. This disparity reflects the broader digital divide, a complex and persistent inequity in access to technologies, connectivity, and/or the skills required to use them effectively, often driven by socioeconomic, linguistic, and educational differences[11,15,16,25,26,48]. Rather than serving as an additional access point to care, patient portals can unintentionally reinforce existing inequities.

Individuals from marginalized groups, including older adults and those who prefer languages other than English, face complex individual-, platform-, and system-level barriers that restrict meaningful engagement and reinforce digital exclusion[12,15,16,24,26,32,48]. Limited access to broadband internet or devices, low digital literacy, and the absence of language-concordant content or intuitive portal design are well-documented contributors[11,24,32]. These challenges are further compounded in safety-net settings that often lack the resources to provide crucial digital support, which is essential for enhancing patient-provider communication and promoting care engagement[11,29]. Addressing these disparities in patient portal use is therefore critical to ensure that digital health tools effectively reach and benefit marginalized populations, especially given the evidence demonstrating that portals impact healthcare access and patient outcomes[11,29,39].

Targeted digital training is a promising strategy to close these gaps. Yet evidence of its effectiveness is mixed[30,39,48]. Prior studies demonstrate short-term improvements in portal uptake following training; however, many do not or are unable to account for confounding factors, such as preexisting digital confidence, health burden, or language preference, that may influence both engagement with the intervention and subsequent portal use. Furthermore, most interventions have been evaluated in academic medical centers, limiting generalizability to community and safety-net settings where patient populations and needs differ substantially[26,30,39]. To advance digital equity, digital interventions must address the skill and support gaps as well as be attuned to the real-world implementation needs of safety-net clinics.

To address these gaps in the evidence base, we applied mixed-effects modeling to evaluate a portal support program implemented in two large safety-net primary care clinics. We sought to estimate the effects of support (either basic or tailored), as well as explore important differences by sociodemographic characteristics, health burden, and self-reported confidence to identify which populations benefit the most. By clarifying when and for whom training is effective, our findings may inform scalable strategies to advance digital health equity.

METHODS

Study Setting

This study was conducted in two high-patient-volume clinics serving 8,000 – 12,000 underserved individuals within the San Francisco Health Network (SFHN), a safety-net health system serving over 60,000 racially and ethnically diverse patients primarily insured through Medicaid[46]. These two clinics provide comprehensive, multidisciplinary health services for their patients, over 85% of whom are non-white, and nearly 40% of the patient population speaks a language other than English[46,47].

Intervention

In this intervention, all study participants were provided with basic MyChart support (basic support) and offered an additional, optional one-on-one digital skills training tailored to their needs and interests (tailored training). In the basic MyChart support intervention, bilingual research staff focused on making sure patients knew what MyChart was, what it offers, and how to access it. Staff approached patients to determine if they had a MyChart account or had heard of MyChart, owned a digital device with MyChart application capability, and the status of their MyChart account. For those who did not know about MyChart, staff provided a brief explanation along with a language-concordant pamphlet highlighting the main MyChart features. For those who were familiar with MyChart, staff confirmed account setup and login credentials or assisted patients with resetting their accounts. Staff also provided additional resources where appropriate, such as recommending places to get devices/internet access or classes at the public library about using digital devices.

For the tailored training, staff asked all patients if they would like more in-depth MyChart training, assistance with their existing account, or any other MyChart support. For those who desired additional tailored training, staff assisted patients with finding the application on their phone, navigating the different features of the portal, and practicing using MyChart. Individualized assistance ranged from downloading the MyChart application to setting up a proxy portal access for their children/family members. Further intervention details are provided in Appendix A. Finally, while full MyChart support and research participation was only available in English and Spanish (matching the MyChart options at the healthcare system), printed informational pamphlets were offered in six languages to all patients in the waiting rooms.

Recruitment and Participation

Between November 2021 and April 2024, MyChart support was available in the waiting rooms of the two clinics during 203 half-day clinic sessions, with each clinic receiving support for a minimum of two morning and two afternoon half-day sessions a week (8:00-11:30 AM or 1:00-4:00 PM). During these sessions, staff approached every individual in the waiting room to offer basic MyChart support, following a specific workflow and script, as well as inquired about their additional tailored training needs. After receiving MyChart support, patients were invited to join the research study evaluating the longer-term impact of the support program, via written informed and HIPAA consent.

Eligible study participants included patients ≥18 years old, English- or Spanish-speaking, and without cognitive or medical barriers. Those who provided consent also completed an additional brief participant questionnaire received $10 payment for their participation. A detailed recruitment flow diagram is shown in Figure 1. All study procedures were approved by UCSF's Institutional Review Board (IRB #21-33711).

Data Sources and Study Period

Data were collected from participant questionnaires and the SFHN electronic health record (EHR). The questionnaire administered post-MyChart support, in English or Spanish, assessed self-reported confidence using the patient portal, race and ethnicity, and preferred language (see Appendix B for the subset of items included in this analysis). For each participant, we captured all MyChart activity from the EHR for six months before and six months after their training date (12-month window; 3,432 person-months).

Outcome

Our outcome was the unique daily MyChart logins, aggregated into monthly intervals for the six months before and after each participant's training date. We modeled MyChart use frequency as a count of logins per month, rather than binary use/non-use, to capture differences in intensity of engagement over time. Multiple logins within the same day were identified as a single event. We excluded activity on the training date to reduce intervention-related bias, and to preserve the full observation window and reduce bias in trajectory modeling, we retained months with no activity.

Key Predictors and Covariates

Primary Predictors

To evaluate the effect of basic support on monthly MyChart logins, the added effect of tailored one-on-one training on MyChart logins, and the differential effect of basic support or tailored training by subgroup, we modeled basic and tailored training separately.

Covariates

Covariates were selected a priori based on existing literature and theoretical relevance to portal engagement. Included sociodemographic variables are age, preferred language (English or Spanish), and race and ethnicity. To address categories with small numbers, race and ethnicity were collapsed into five groups: White or Caucasian, Asian or Pacific Islander, Black or African American, Hispanic/Latino(a), and Other. The Charlson Comorbidity Index captured relative health burden and was dichotomized as 0 versus ≥ 1. Self-reported confidence using MyChart, drawn from the participant questionnaire, was used as a proxy for baseline digital engagement. We also included time, in monthly intervals for the six months pre- and post-intervention, to adjust for natural variance in login rates over time.

Analytic Approach

Anticipating a lack of portal use among a sizable portion of the sample, we specified a zero-inflation regression model. Specifically, we used a zero-inflated negative binomial generalized linear mixed model with random intercepts and random slopes for the pre/post-intervention period to account for individual-level clustering with repeated measures. In brief, this model simultaneously estimated the frequency of portal use over time (using a generalized linear model) while also accounting for the overall probability of remaining a non-user of MyChart both before and after the intervention (zero-inflated model).

In addition, the model adjusted for the covariates outlined above (age, language preference, race and ethnicity, comorbidity burden, and digital confidence), given that they have been previously associated with portal use. Changes in portal use over time were measured using a mean-centered variable for months since training to control for natural trends in portal use over time. We also tested interactions between basic support and consent to training for the added effect of tailored training; basic support and age/language for the effect of basic support by age and language; and basic support, consent to training, and age/language to assess whether the added effect of tailored training differs by age and language. We chose age and language as the key subpopulations for this analysis since there are known differences in portal use by age and language preference in previous work. Moreover, we use these interaction terms to isolate the differential effects of basic support compared to tailored training among these key subpopulations. R version 4.3.3 was used to conduct analyses.

RESULTS

Participant Characteristics

657 of the 2,644 individuals that were approached by project staff accepted basic MyChart support, with a subset of 286 individuals providing informed consent to participate in the research study. Of the 286 participants, 142 accepted tailored training, while the remaining 144 received basic support only. The median age for study participants was 42 years (IQR 32-55), with just under three-quarters women (73%). The population was 67% Hispanic/Latino(a), 10% Black, 10% Asian or Pacific Islander, and 9% White. Similarly, almost half reported a preferred language of Spanish (48%). A quarter of participants had diagnosed comorbidity burden with a CCI score of >=1 (27%). The mean digital confidence score was 8.5± 2.4 (on a 0–10 scale), and 70% of participants were current users of the portal at the time of MyChart support. Those who accepted training were more likely to be older (median age 45 years, P=.007), Spanish-speaking (P<.001), and those without prior MyChart use (P<.001). Details on participant characteristics are provided in Table 1.

Primary Results

The percentage of MyChart users increased from 63 to 82% of participants in the month prior to relative to the month immediately following the intervention (85 to 89% for basic support only, and 41 to 75% for those who opted for tailored training). Across the entire study sample the average percentage of monthly portal users increased from 52 to 71% from pre- to post-intervention period.

Among participants who received only basic support, the percentage with any portal use ranged from 59% (85/144 participants) to 89% (128/144 participants) over the 12-month study period, with peak usage observed in the first month following training (Figure 2). During the pre-intervention period, an average of 69% of basic-support only participants logged in each month, compared to 77% in the post-intervention period—a 12% relative increase in average monthly portal users following basic support. This translates to an average increase of approximately 12 additional participants logging in each month after receiving basic support.

Among participants who received additional tailored training, portal use ranged from 28% (40/142 participants) to 75% (107/142 participants) over the study period. On average, 34% of participants with tailored training logged in each month during the pre-intervention period, increasing to 65% post-intervention—a 91% increase in the average percent of monthly users following the intervention. This corresponds to an average gain of 44 more participants logging in each month after receiving tailored support.

Impact of Digital, Sociodemographic, and Clinical Variables on Portal Use

The regression model results are presented in Table 2, where Incidence Rate Ratio (IRR) represents the ratio of MyChart login counts in one group compared to another, and Odds Ratio (OR) quantifies the likelihood of being a non-user. For both IRR and OR, values greater than 1 indicate a higher rate or likelihood compared to the reference group, while values less than 1 indicate a lower rate or likelihood. Higher reported digital confidence using digital health tools was significantly associated with increased login frequency; for each one-unit increase in digital confidence, the rate of MyChart logins increased 16% on average, holding all other covariates constant (IRR: 1.16, p<.001). Participants with 1 or more comorbidities had higher login counts compared to those with no comorbidities, logging in 57% more per month on average after adjusting for all other covariates (IRR: 1.57, p=.02). Hispanic/Latino participants were less likely to use the portal compared to White participants, logging in approximately 47% less often when controlling for all other factors (IRR: 0.53, p=.03). Similarly, Black or African Americans logged in to the portal about 49% less frequently than White participants, but these results were marginally significant (IRR: 0.51, p=.07). Asian or Pacific Islander race and ethnicity, preferred language, and age were not significantly associated with portal use.

Effect of Intervention on Monthly Portal Use

Receiving basic digital support alone was not associated with a significant overall change in portal login frequency (IRR: 1.13, p=.44). However, a significant interaction effect showed that Spanish speakers experienced greater benefit from the basic support. Specifically, Spanish speakers logged into MyChart 80% more often post-intervention, compared to English speakers (IRR: 1.80, p=.01). The interaction between basic support and age was not significant.

Participants who opted to receive tailored training had significantly lower portal use at baseline compared to those who received basic support only, logging in with an 85% lower rate on average compared to those who opted for basic support only (IRR: 0.15, p<.001). Following the intervention, these participants experienced a nearly fivefold increase in monthly portal use relative to their pre-intervention period, highlighting the strong effect of tailored support (IRR: 4.94, p<.001). While post-intervention usage among the tailored support group remained somewhat lower than among the basic support group, logging into MyChart 36% less frequently, the significant increase in monthly portal use represents a substantial improvement (combined IRR ~ 0.74). Interaction effects by language and age for the tailored group were not statistically significant.

Probability of Remaining a Non-User

The zero-inflation part of the model estimated the likelihood that a participant remains a non-user of the patient portal (i.e., someone who is not expected to log in at all). Participants who did not have an activated MyChart account, whether their account was pending or inactivated, had significantly higher odds of remaining a non-user compared to those with an activated account (OR: 3.2, p<.001). Additionally, participants with lower digital confidence using digital health tools were significantly more likely to be non-users. Specifically, for each one-unit decrease in digital confidence, the odds of being a non-user increased 21% (OR: 1.21, p<.001).

DISCUSSION

We found that the percentage of MyChart users increased from 63 to 82% of study participants in the month prior to relative to the month immediately following the intervention. This demonstrates that an embedded, in-clinic MyChart support program for both English- and Spanish-speaking patients in a safety net setting was effective. This increase in MyChart use was overall but particularly pronounced among Spanish speakers and participants who received in-depth, tailored training, who increased their MyChart use by 80% and almost 500% in the post-intervention period (respectively).

The significant benefit Spanish speakers experienced from the basic support suggests that language-concordant digital or technical support, rather than translating navigation instructions, offers tangible benefits in reaching a group with linguistic barriers to digital engagement[15,16,31]. Studies that expand on and scale language-concordant confidence-building interventions beyond Spanish warrant future exploration. However, significant disparities were evident by race and ethnicity: Hispanic/Latino participants used the portal overall approximately 47% less than White participants, and Black/African American participants logged in about 49% less frequently, though the latter finding was marginally significant. These disparities align with prior studies documenting differences in portal use and persist despite adjustment for age, language preference, comorbidity, and intervention exposure[16,23,38]. This underscores the need for more studies testing targeted outreach and culturally tailored digital health intervention strategies to bridge these enduring gaps in engagement.

The tailored training aspect of the intervention produced the most substantial gains in portal use, particularly among participants who began with low engagement. Though this group started with an 85% lower rate of login compared to those who received basic support, they experienced a nearly fivefold increase in logins post-intervention. While their usage remained moderately lower than those in the basic support group overall, the absolute improvement was notable, suggesting that tailored training can substantially close the digital engagement gap. Our study did not reveal additional effects of tailored training among specific subgroups; however, these results may also be due in part to the fact that our study was not powered sufficiently to detect the nuanced role of tailored training, particularly when stratified by key subpopulations. The results from this study indicate several opportunities for future research. First, larger studies are needed to further assess the effect of basic support and tailored training among key subpopulations to understand who these interventions best suit and to ensure these interventions do not generate intervention-generated inequality. Additionally, future research should evaluate the longer-term effects and sustainability of MyChart support beyond 6 months, as well as the benefits of offering MyChart support regularly and in shorter intervals to address the complex barriers faced by those with limited digital engagement[16,41,43].

The zero-inflation component of the model further revealed factors contributing to non-use. Participants who had not activated their account were over three times more likely to remain non-users. Additionally, lower digital confidence significantly increased the odds of remaining a non-user, reinforcing the critical role of digital self-efficacy in enabling patients to engage with digital health tools . Future studies should expand upon this work to pinpoint the characteristics that most acutely identify persistent non-users and identify the elements of digital support most closely aligned with improving digital confidence and self-efficacy.

Limitations

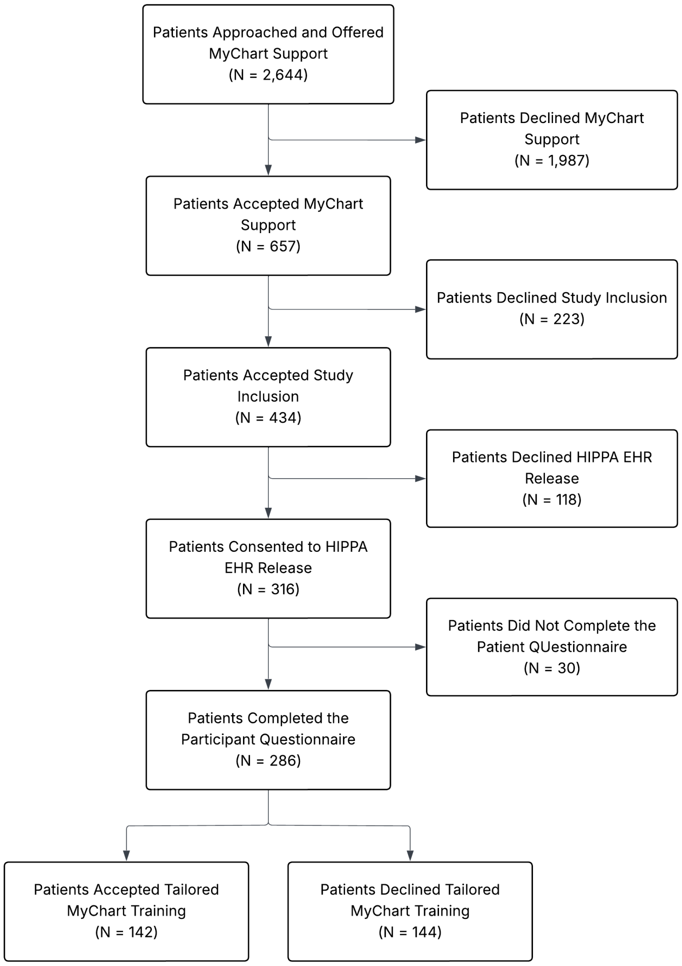
Among the limitations of our study is the relatively small sample, which reduces statistical power to detect the effect of tailored training within subgroups. The training was conducted in a real-world, busy environment—in real time in clinic waiting rooms of a safety net healthcare system. Despite this, our analytic sample captured substantial sociodemographic diversity, including a high percentage of Spanish-speaking participants. Additionally, we were unable to establish the reason for declining training, which limits our ability to further elucidate who is missing from our study and why, and could represent residual confounding; however, these data likely reflect the interest in portal training overall. Finally, although we modeled usage frequency, our study did not assess the specific content or quality of interactions within MyChart (i.e., viewing results, sending messages), which could yield richer insights into meaningful engagement with the patient portal.

Conclusion

This study highlights the critical role of digital support in promoting equitable patient portal engagement. While basic support modestly improved portal use, particularly among Spanish speakers, tailored training led to substantially greater gains, particularly among those with lower baseline engagement. Higher digital confidence and clinical need were associated with more frequent use, while racial and ethnic disparities in portal activity persisted, underscoring ongoing barriers to digital health equity. Additionally, unactivated accounts and low digital confidence were key predictors of non-use. These findings support the integration of bilingual tailored training strategies into clinical workflows and suggest that addressing both structural access and individual capability is essential for ensuring all patients can benefit from digital health tools. Future work should focus on sustaining engagement over time and developing scalable, culturally responsive interventions to close the digital divide in healthcare.

TABLES AND FIGURES

Figure 3.1. Participant Recruitment and Enrollment Flow Chart



The diagram illustrates the number of individuals approached during outreach sessions, those who received real-time MyChart support, and those who consented to participate in the longitudinal study. Study participants could opt in to additional one-on-one digital skills training.

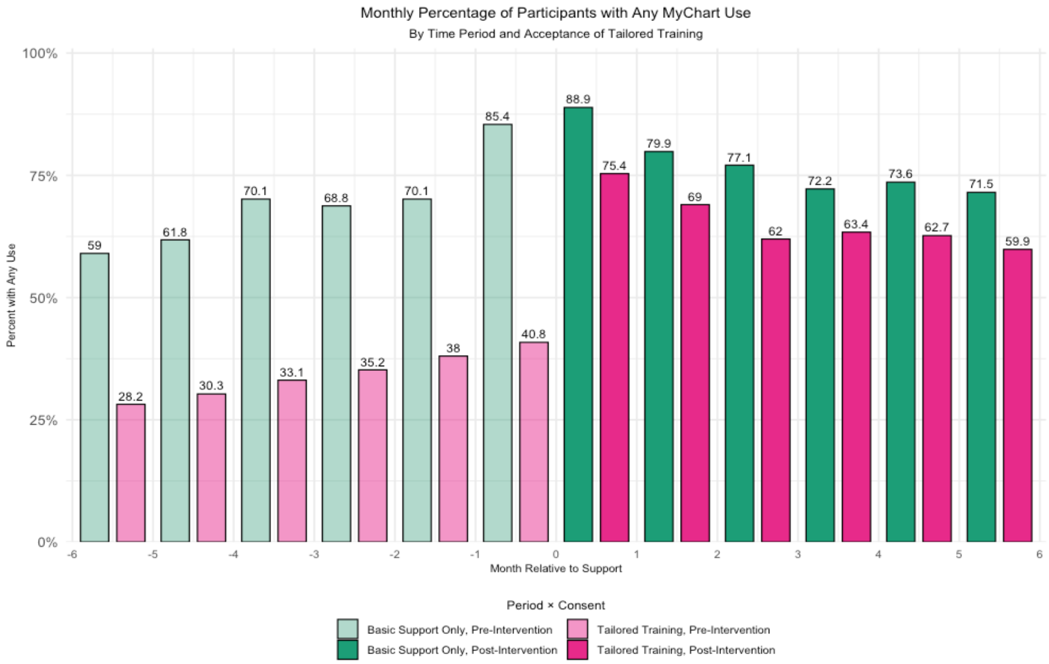
Table 3.1. Baseline Demographic and Clinical Characteristics of Study Participants (N = 286)

	Overall N = 286	Basic Support n = 144	Tailored Training n = 142	P-value
Demographics				
Age (median (IQR))	42 (32 – 55)	40 (30 – 51)	45 (35 – 60)	*P=.007*^{a}
Sex (%)				*P=.07*
Female	112 (77.8)	208 (72.7)	96 (67.6)	
Male	32 (22.2)	78 (27.3)	46 (32.4)	
Race and Ethnicity (%)				*P=.13*
White or Caucasian	14 (9.7)	25 (8.7)	11 (7.7)	
Asian or Pacific Islander	20 (13.9)	29 (10.1)	9 (6.3)	
Black or African American	13 (9.0)	29 (10.1)	16 (11.3)	
Hispanic/Latino(a)	89 (61.8)	191 (66.8)	102 (71.8)	
Other	8 (5.6)	12 (4.2)	4 (2.8)	
Preferred Language (%)				*P<.001*
English	90 (62.5)	149 (52.1)	59 (41.5)	
Spanish	54 (37.5)	137 (47.9)	83 (58.5)	
Comorbidity Burden				
Charlson Comorbidity Index (%)				*P=.13*
0	111 (77.1)	208 (72.7)	97 (68.3)	
1+	33 (22.9)	78 (27.3)	45 (31.7)	
Digital Engagement				
Average Number of MyChart Users (%)				*P<.001*
Baseline	148.3 (51.9%)	99.6 (69.2%)	48.7 (34.3%)	
Post-Intervention	204.1 (71.4%)	111.2 (77.2%)	92.9 (65.4%)	
Active MyChart Account at Baseline	106 (37.1%)	69 (48.0%)	37 (26.1%)	*P<.001*
Confidence (mean (SD))	8.54 (2.4)	8.82 (2.06)	8.25 (2.69)	*P=.09*^{a}

IQR: Interquartile Range, SD: Standard Deviation

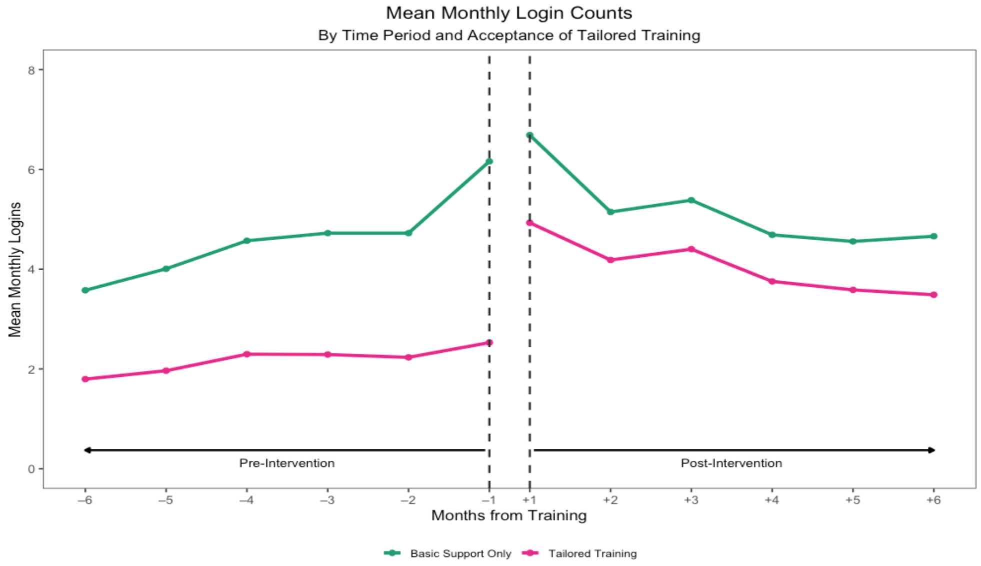
^{a}Indicates Kruskal-Wallis Test, Chi-Squared Tests of Independence used in all other instances; P<.05 significant

Figure 3.2. Monthly Percentage of Participants with Any MyChart Use Before and After Intervention, by Intervention Group



Bars indicate the proportion of participants with ≥1 login per month over the 12-month intervention period by intervention group and aligned by individual training dates (Month 0). Pre- and post-intervention periods each span six months.

Figure 3.3. Average Monthly MyChart Login Counts Before and After Intervention, by Intervention Group



Each point represents the aggregated mean number of logins per month over the 12-month intervention period by intervention group and aligned by individual training dates. Pre- and post-intervention periods each span six months. Logins were capped at 17 per month to reduce the influence of extreme values.

Table 3.2. Rate Ratios of Model Covariates

Zero Inflated Negative Binomial Mixed Model Results			
Rate Ratios (RR) with 95% Confidence Intervals			
Conditional Model	**IRR**	**95% CI**	**P-value[a]**
(Intercept)	3.95	2.17 – 7.20	*P<.001*
Main Effects			
Basic Support Only	1.13	0.81 – 1.57	*P=.47*
Accepted Tailored Training	0.15	0.09 – 0.25	*P<.001*
Spanish Language Preference	0.85	0.49 – 1.49	*P=.58*
Age (centered)	1.00	0.98 – 1.02	*P=.99*
1+ Comorbidity	1.57	1.09 – 2.25	*P=.02*
Digital Confidence (centered)	1.16	1.08 – 1.25	*P<.001*
Race and Ethnicity			
Asian or Pacific Islander	0.62	0.32 – 1.23	*P=.17*
Black or African American	0.53	0.26 – 1.05	*P=.07*
Hispanic/Latino(a)	0.53	0.29 – 0.97	*P=.04*
Other	0.80	0.33 – 1.94	*P=.62*
Time (centered)	0.99	0.97 – 1.00	*P=.06*
Interaction Terms			
Basic Support x Spanish Preferred Language	1.80	1.15 – 2.83	*P<.01*
Basic Support x Age	0.99	0.98 – 1.01	*P=.31*
Accepted Tailored Training x Post-Intervention Period	4.94	3.03 – 8.05	*P<.001*
Accepted Tailored Training x Post-Intervention Period x Spanish Language Preference	0.81	0.49 – 1.33	*P=.40*
Accepted Tailored Training x Post-Intervention Period x Age	1.00	0.98 – 1.02	*P=.92*
Zero Inflation Model	**OR**	**95% CI**	**P-value**
(Intercept)	0.05	0.03 – 0.07	*P<.001*
Low Digital Confidence	1.21	0.77 – 0.89	*P<.001*
MyChart Not Activated	3.20	1.96 – 5.22	*P<.001*

IRR: Incidence Rate Ratio, CI: Confidence Intervals, OR: Odds Ratio

The model accounts for repeated measures via participant-level random effects and includes a separate zero-inflation component

[a] P-values are based on Wald tests using standard errors from the zero-inflated negative binomial mixed model; P<.05 significant

APPENDICES

APPENDIX A. Participant Recruitment Details and Workflow.

Recruitment Setting

The study was conducted at two primary care clinics in the San Francisco Health Network between November 2021 and April 2024. These sites were selected based on high patient volume (8,000–12,000 patients annually) and organizational support for embedded digital health interventions. Study staff coordinated with clinic managers to identify clinic sessions during which digital training could be delivered in the waiting room. Staff were present for a total of 203 half-days (~812 hours) across the two sites where MyChart support and tailored training were embedded into the two clinics.

Clinical Integration and Patient Engagement

Research staff who conducted the multicomponent intervention were bilingual in English and Spanish. Research staff attended clinics with a senior research staff member to observe patient interactions and approaches in the waiting rooms. Research staff observed until they felt comfortable approaching patients on their own.

Embedding the research team within the clinic's daily operations was critical for fostering trust and collaboration with clinic staff. Through consistent relationship building, research staff enhanced their visibility as a reliable source of digital connectivity support, which in turn accelerated referrals of patients interested in MyChart support and training. Team members attended daily morning huddles to coordinate with clinical staff, announce their presence on-site in the waiting rooms, and facilitate any clinic-needed MyChart support. The proactive engagement ensured that both clinic staff and patients were aware of research staff availability in the clinic waiting room and ensured that the program was seen as a trusted resource for promoting digital engagement.

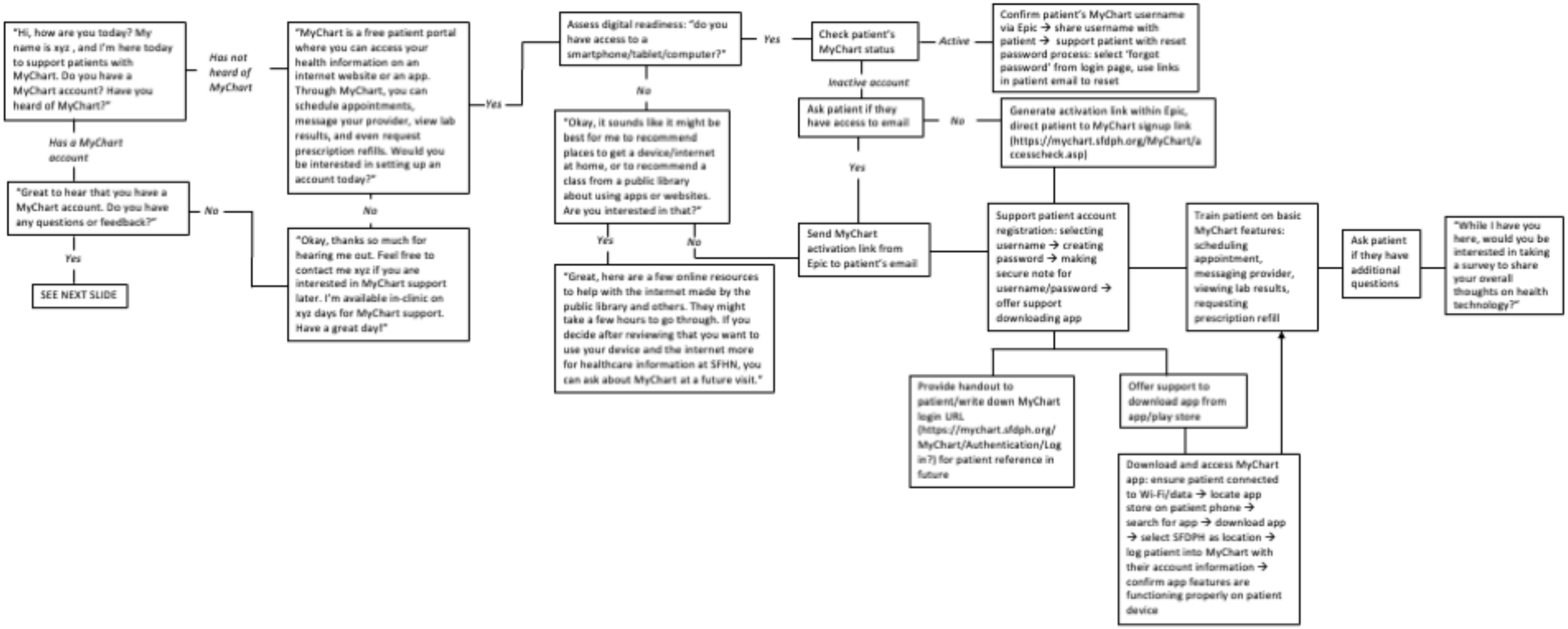
Initial Outreach and Basic MyChart Support

During these sessions, bilingual staff approached every individual in the waiting room to offer MyChart support, following a specific workflow and script that allowed staff to establish if a patient had/had heard of MyChart, owns a digital device with MyChart application capability, and confirm MyChart account status. Study staff approached patients asking if they knew about MyChart, if they did, staff then asked if they had an account and knew how to log-in. Those who did not know about MyChart were provided a brief explanation by the staff if they spoke English or Spanish, otherwise were provided a language-concordant pamphlet highlighting four features of MyChart: managing appointments, sending messages to their doctors, accessing test results and requesting prescription refills or pharmacist visit summaries. Pamphlets were offered in English, Spanish, Chinese, Russian, Tagalog, and Vietnamese. Staff then provided basic technical support to those who needed it, helping patients set up an account, confirming login credentials, or assisting patients with resetting their accounts. All patients had the option to have their login credentials written down for them. Staff were also trained to provide additional resources where appropriate, such as recommending places to get devices/internet access or classes at the public library about using digital devices.

Primary Intervention: Tailored, One-on-One Training

The tailored and individualized training session included demonstrations navigating and using the main features of MyChart (managing appointments, sending messages to their doctors, accessing test results, and requesting prescription refills or pharmacist visit summaries) and addressed any questions the participant had. Assistance ranged from downloading the MyChart application to setting up proxy access for children or family members or creating alternative login methods (such as a login PIN or biometric facial recognition) to remove password barriers.

Workflow detailing the protocol and script staff followed when offering support to patients in the waiting room.



"Hi, how are you today? My name is xyz , and I'm here today to support patients with MyChart. Do you have a MyChart account? Have you heard of MyChart?"

"Great to hear that you have a MyChart account. Do you have any questions or feedback?"

"MyChart is a free patient portal where you can access your health information on an internet website or an app. Through MyChart, you can schedule appointments, message your provider, view lab results, and even request prescription refills. Would you be interested in setting up an account today?"

"Okay, thanks so much for hearing me out. Feel free to contact me xyz if you are interested in MyChart support later. I'm available in-clinic on xyz days for MyChart support. Have a great day!"

Assess digital readiness: "do you have access to a smartphone/tablet/computer?"

"Okay, it sounds like it might be best for me to recommend places to get a device/internet at home, or to recommend a class from a public library about using apps or websites. Are you interested in that?"

"Great, here are a few online resources to help with the internet made by the public library and others. They might take a few hours to go through. If you decide after reviewing that you want to use your device and the internet more for healthcare information at SFHN, you can ask about MyChart at a future visit."

Check patient's MyChart status

Confirm patient's MyChart username via Epic → share username with patient → support patient with reset password process: select 'forgot password' from login page, use links in patient email to reset

Ask patient if they have access to email

Generate activation link within Epic, direct patient to MyChart signup link (https://mychart.sfdph.org/MyChart/accesscheck.asp)

Send MyChart activation link from Epic to patient's email

Support patient account registration: selecting username → creating password → making secure note for username/password → offer support downloading app

Provide handout to patient/write down MyChart login URL (https://mychart.sfdph.org/MyChart/Authentication/Login?) for patient reference in future

Offer support to download app from app/play store

Download and access MyChart app: ensure patient connected to Wi-Fi/data → locate app store on patient phone → search for app → download app → select SFDPH as location → log patient into MyChart with their account information → confirm app features are functioning properly on patient device

Train patient on basic MyChart features: scheduling appointment, messaging provider, viewing lab results, requesting prescription refill

Ask patient if they have additional questions

"While I have you here, would you be interested in taking a survey to share your overall thoughts on health technology?"

APPENDIX B. Selected Participant Questionnaire Items

Question	Source
1. How confident do you feel that you can use a website/app like MyChart to improve your health, with 1 being "Not at all confident" and 10 being "Totally confident"? a. 1 b. 2 c. 3 d. 4 e. 5 f. 6 g. 7 h. 8 i. 9 j. 10	Self-developed
2. What ethnic or racial group do you most identify with? Select all that apply. a. Asian or Pacific Islander b. Black or African American c. White or Caucasian d. American Indian/Native American e. Hispanic/Latino(a) f. Multi-Ethnic g. Other, please specify ________________________ h. Refused	Self-developed
3. What language(s) other than English do you speak at home? [open response]	Self-developed

Chapter 4

Title: Effect of Remote and In-Person Care Utilization Patterns on Glycemic Control in a Safety-Net Health System

Authors: Taylor Rapson, James D. Ralston, Paul Fishman, Kathryn Kemper, Courtney Lyles, Suzinne Pak-Gorstein, Magaly Ramirez, Elaine Khoong

Abstract:

Importance: Telehealth and between-visit interactions (remote care) may help mitigate barriers to diabetes management, yet its impact on glycemic control remains understudied in the post-COVID-19 era, especially among populations facing healthcare disparities. Understanding how patterns of remote and in-person care affect A1c trajectories, and whether these effects differ by key sociodemographic characteristics, is critical for tailoring care delivery and advancing equity.

Objective: To examine the association between remote and in-person care patterns and subsequent A1c, and to assess whether these associations differ by age, race/ethnicity, and preferred language.

Design: Retrospective cohort study of adults with type 2 diabetes (T2DM) from April 2021-March 2023.

Setting: San Francisco Health Network safety-net health system in San Francisco, California.

Participants: A cohort of 6,281 adult patients with current T2DM who were actively engaged in their care and had at least one A1c during the study period.

Exposure(s): Quarterly combined remote and in-person care utilization patterns. Remote engagement was measured as a composite of scheduled and unscheduled telephone/video visits and secure messaging; both remote and in-person care were categorized as none, low/moderate, or high based on the distributions. We then combined remote and in-person categories to create 9 combined care patterns representing different levels of remote and in-person care.

Main Outcome(s) and Measure(s): Our outcome was continuous A1c, log-transformed. Included measures were time, age group, sex, race and ethnicity, preferred language, insurance type, neighborhood SES, diabetes treatment intensity, and Charlson Comorbidity Index.

Results: 82% of patients were aged ≥50, 71% were Asian or Hispanic, and 58% preferred non-English. A greater proportion of care, particularly any remote engagement and high in-person care, was associated with clinically meaningful reductions in A1c (≥5% reduction, P's≤.01). The impact of care patterns on A1c varied by age, race/ethnicity, and language. Patients aged 50-64 with low or moderate remote engagement and high in-person engagement had higher relative A1c compared to those <50 (P=.02). Asian, Black, and Hispanic patients with high remote engagement had higher relative A1c compared to their White counterparts (P's≤.02). Conversely, Chinse and Spanish-speaking patients with high in-person care and no remote engagement had lower relative A1c compared to English speakers (P's≤.03).

Conclusions and Relevance: Distinct combinations of remote and in-person care were associated with differences in glycemic control, overall, with notable variation by age, language, and race/ethnicity. While main effects were favorable for marginalized groups, disparities emerged depending on use of remote/in-person care. These findings suggest potential benefits of hybrid engagement for chronic disease management broadly; still cultural and linguistic factors shape care engagement and effectiveness.

INTRODUCTION

Healthcare delivery has undergone a significant transformation with the integration of remote modalities into routine practice. These include telehealth (scheduled video and/or phone visits) and between-visit interactions (unscheduled telephone visits or secure messaging through the patient portal) [1–5,67]. The adoption of these modalities accelerated with the onset of COVID-19, supported by reimbursement policies that expanded coverage for phone and telehealth services[1–5,67]. These tools afford patients opportunities to engage in their care remotely and are essential components of chronic disease management[7–14].

Despite this growth in access, critical questions remain regarding the effectiveness of remote care relative to traditional in-person care in improving health outcomes among patients with diabetes, particularly in the post-COVID-19 era amid ongoing debate about reimbursement of remote modalities in healthcare[67]. Specifically, the influence of combined in-person and remote care utilization patterns on glycemic control is understudied[4,44,45]. Research has evaluated the effect of telehealth or patient portals on A1c, but few account for multiple types of remote care, including between-visit interactions[9,16,50,68,69]. This question is especially significant as these modalities are integrated into healthcare delivery. There is also little evidence examining whether the increasing reliance on remote healthcare exacerbates health disparities among underserved populations that face barriers to these emerging technologies and experience disproportionate burdens of chronic disease and poor health outcomes[4,16].

To address these gaps in the evidence base, we examined whether care engagement patterns impact glycemic control among adults with diabetes receiving care at a safety-net health system. Specifically, we evaluated how different combinations of remote and in-person care engagement influence A1c and whether sociodemographic characteristics moderate these effects.

Understanding these pathways is essential to informing how remote care should be leveraged to support equitable and effective chronic disease management in safety-net settings.

METHODS

Study Setting and Data Source

We conducted a 2-year retrospective cohort study (April 1, 2021-March 31, 2023) using electronic health record (EHR) data from the San Francisco Health Network (SFHN), a safety-net health system with 14 primary care clinics serving over 60,000 socioeconomically and racially diverse patients, most insured through Medicaid. Approximately 80% of the patient population identifies as non-White, and 45% report Spanish or Chinese as their preferred language[46,47].

We extracted in-person, telephone, and video encounters; secure messaging; and sociodemographic and clinical data from the EHR. Encounters included visits with clinicians (physicians, APPs), nurses, social workers, pharmacists, dietitians, medical assistants, and embedded behavioral health clinicians. This study was approved by the UCSF Institutional Review Board (IRB #20-31253).

Study Sample

We created a cohort of adult patients (aged ≥18 years) with a diagnosis of Type 2 diabetes mellitus (T2DM) empaneled in primary care at the start of the study period. This cohort is further described in a previous study and in the Methodological Appendix[4]. Patients were included in the cohort based on diabetes diagnosis codes from the problem list, inclusion in diabetes registries, elevated HbA1c laboratory results (≥6.5%), and/or diabetes prescriptions. To ensure patients were actively receiving care, we included only those with documented encounters with their primary care or endocrinology teams and at least one HbA1c result during the study period.

Outcome

Our primary outcome was glycemic control, measured using hemoglobin A1c (HbA1c). We identified all HbA1c values recorded during the study period. To account for temporal ordering between care utilization patterns and glycemic outcomes, we aligned each A1c with clinical encounters from the preceding quarter. If multiple A1c values occurred during a quarter, we chose the one closest to the start of that quarter to best approximate the relationship between the exposure and the outcome. We modeled log-transformed A1c rather than nominal values to account for the right-skewed distribution of A1c values.

Exposure

Our exposure was the combined pattern of patient engagement in remote and in-person care. To measure this, we created a categorical variable that integrated patients' volume of remote care and in-person care utilization each quarter. Remote care included telehealth visits (scheduled telephone or video visits) and between-visit interactions (unscheduled telephone or patient portal messages). Between-visit interactions were only included when patient contact occurred and could involve multiple back-and-forth exchanges over a single clinical concern.

Specifically, we categorized remote care engagement as "none", "low/moderate remote care", and "high remote care" based on the distribution of counts for telehealth, unscheduled telephone visits, and patient portal messages. In-person care engagement was similarly categorized as "none", "low/moderate in-person care", and "high in-person care" based on the distributions in the study sample. These categories were then combined to form composite groups (e.g., "High Remote, High In-Person") that capture distinct care utilization patterns. We selected “No Remote, Low/Moderate In-Person Care” as the reference category because it represents traditional engagement through in-person visits only. We measured care utilization patterns in three-month intervals and created a quarterly composite exposure variable to most accurately reflect the 2–3-month window of time where behavior influences A1c.

Covariates

We adjusted for sociodemographic and clinical covariates derived from the EHR. These included age (categorized as <50, 50-64, 65-74, 75+), sex (male/female), race and ethnicity (categorized as Hispanic/Latino(a); non-Hispanic Asian; non-Hispanic Black; non-Hispanic White/Caucasian; or other non-Hispanic races, which included American Indian or Alaska Native, Native Hawaiian or Other Pacific Islander), preferred language (Chinese, English, Spanish, or Other), insurance type (Medicare, Medicaid, Healthy Workers, or Uninsured), and neighborhood socioeconomic status (nSES, in quintiles) based on geocoded residential addresses. Insurance and nSES details are included in the Methodological Appendix.

We adjusted for baseline health status using the Charlson Comorbidity Index (CCI) and diabetes treatment intensity (categorized as diet only, non-insulin medications, or insulin therapy). CCI was modified to exclude diabetes and was dichotomized as 0-2 or 3+ to represent the severity of disease comorbidities. CCI and treatment intensity were extracted from the EHR (Methodological Appendix).

Statistical Analysis

We summarized patient demographic and clinical characteristics. For healthcare utilization, we reported quarterly means and standard deviations of in-person and remote care encounters (overall and by modality, telehealth visits vs. between-visit interactions). We evaluated the association between care patterns and glycemic control using linear mixed-effects models

(LMMs) with random intercepts and slopes to account for within-person correlation over time. We adjusted for covariates and time, including interaction terms between care pattern and age, preferred language, and race and ethnicity. We conducted all analyses using R version 4.5.1.

Handling of Missing A1c Values

Rather than imputing A1c values for quarters in which there is no recorded value, we analyzed only A1c observations preceded by care in the quarter before. This approach reflects clinical practice, where A1c tests are typically ordered following care interactions, and helps reduce bias related to differential monitoring. To evaluate whether A1c availability varied across utilization patterns or patient subgroups, we fit a logistic regression model with the outcome of having an A1c observed per quarter. Predictors included care utilization patterns and the covariates described above.

RESULTS

Participant Characteristics

Table 1 displays the sociodemographic and clinical characteristics for 6,281 patients in our study. Almost half were aged 50-64 years, and just over a quarter were 65-74 years. The cohort was primarily Asian (35%) and Hispanic or Latino (35%); 42% preferred English. Over 70% were covered by Medicaid or Medicare, and 81% resided in neighborhoods with low socioeconomic status. Most patients (60%) were prescribed non-insulin diabetes medication, and almost 90% had a Charlson Comorbidity Score of 0-2. The average number of in-person visits per quarter was 2.1 (SD: 3.6), compared with 2.4 remote encounters per quarter (SD: 3.2). Of remote encounters, 0.5 were scheduled telehealth visits (SD: 1) and 2.0 were between-visit interactions (SD: 2.8).

Care utilization patterns were heterogeneous. Low/moderate remote engagement was most common, representing ~45-50% of patients per quarter (Figure 1). High remote engagement occurred less frequently, ranging from ~20-30% of patients, with a slight decline over time. Quarters with no remote use varied more widely: ~6-10% of patients had no remote engagement, but some in-person care each quarter, whereas ~15-24% of patients had no engagement in either modality ("no remote, no in-person"), a proportion that increased over time.

Patient Characteristics Based on Remote Care Utilization Patterns

The study period resulted in 50,248 person-quarters, where we collapsed care utilization patterns into three overall categories of remote engagement to examine the distribution of sociodemographic and clinical characteristics, which differed depending on the level of remote engagement (Table 2, expanded in Appendix B).

- **No Remote Engagement (29% of person-quarters):** More common among younger adults (<65 years), men, Asian or Hispanic patients, Spanish/Chinese speakers, and those uninsured or enrolled in Healthy Workers Insurance (all P's<.001). These quarters also corresponded to lower comorbidity and lower-intensity diabetes treatment (both P's<.001).
- **Low/Moderate Remote Engagement (48% of person-quarters):** More common among women, Asian patients, Chinese speakers, and individuals with Healthy Workers or no insurance (all P's<.001). This group tended to have lower comorbidity (CCI 0-2) and more frequent use of non-insulin therapy (both P's<.001).
- **High Remote Engagement (23% of person-quarters):** More common among older adults (≥65), women, White/Black/Other race or ethnicity, English speakers, and those

insured through Medicare or Medicaid (all P's<.001). These quarters were characterized by more insulin use and higher comorbidity (both P's<.001).

Impact of Care Utilization Patterns on A1c

Care patterns had differential effects on glycemic control (key results summarized in Figure 2 and Table 3, full results presented in Appendix C). Compared to low or moderate in-person care only (reference category), multiple care patterns were associated with significant relative A1c reductions. High engagement in remote and/or in-person care was associated with relative reductions in A1c the following quarter (95% CIs < 1). In particular, high remote engagement, regardless of in-person engagement, and high in-person engagement with no or low to moderate remote engagement were associated with clinically meaningful reductions in A1c of at least 5% (exponentiated estimates: 0.91-0.95, 95% CIs < 1).

Individuals with moderate levels of care (low to moderate remote and in-person engagement or low to moderate remote care and no in-person care) were associated with 4% relative reductions in glycemic level compared to those with traditional in-person utilization (95% CIs < 1). No engagement in a quarter was not associated with changes in A1c compared to the reference group.

Impact of Sociodemographic and Clinical Characteristics on A1c

A1c varied by sociodemographic and clinical characteristics (Figure 2, Appendix C). Older adults had lower average A1c than patients <50 years old, with those aged 50-64, 65-74, and 75+ averaging 6% lower A1c values (all exponentiated coefficients: 0.94, all 95% CIs < 1). Compared with White patients, Asian and Black patients averaged 6-7% lower A1c (95% CIs < 1), whereas Hispanic/Latino and other races and ethnicities did not differ significantly. Compared to males, female sex was associated with 1% relative reduction in A1c (95% CI: 0.98-

0.99). Insurance status was also associated with glycemic control; Healthy Workers and Medicare coverage were linked to 2% lower A1c levels on average compared to those on Medicaid (both 95% CIs < 1). In contrast, those who were uninsured on average had 2% higher A1c levels (95% CI: 1.01-1.04). Lower nSES status was associated with 1% higher A1c on average (95% CI: 1.0-1.02). Language preference was not associated with changes in A1c.

Patients with higher comorbidity burden (CCI ≥ 3) experienced 4% lower A1c on average, compared to those with low comorbidity (95% CI: 0.95-0.98). Treatment intensity showed the largest effects; non-insulin medications were associated with 12% higher A1cs on average, and insulin with 27% higher A1c compared with diet only (95% CIs > 1).

Interaction Effects of Care Patterns and Sociodemographic Characteristics on A1c

To understand how key sociodemographic characteristics moderated the relationship between care pattern and A1c, we included interaction terms for care utilization pattern by age, race and ethnicity, and preferred language. Exponentiated interaction terms <1 indicate the combined effect of the two predictors is associated with a greater effect than would be expected from the sum of their main effects. Conversely, values >1 indicate attenuation of the combined effect.

Results indicated that care patterns' effects varied across age, race and ethnicity, and preferred language (Figure 2, Appendix C). Patients aged 50-64 with low/moderate remote and high in-person engagement had a slightly smaller A1c reduction than those who were < 50 years, meaning the benefit of this care pattern was slightly attenuated for middle-aged patients than for younger patients (exponentiated coefficient: 1.04, 95% CI: 1.01-1.06). Other age and care utilization patterns were not statistically significant.

Asian, Black, and Hispanic adults with high remote and no or low to moderate in-person care volume experienced smaller reductions in A1c than White patients with the same care patterns (exponentiated coefficients: 1.05-1.06, 95% CIs > 1). Similarly, Asian and Black adults with high remote and high in-person engagement had higher A1c compared to White patients (exponentiated estimates: 1.05 and 1.07 respectively; 95% CIs > 1). with low or moderate remote engagement and low or moderate in-person or no in-person engagement saw smaller reductions in A1c compared to their White counterparts (exponentiated coefficients: 1.05-1.06, 95% CIs > 1). Asian, Black, and other races or ethnicities with low or moderate remote and in-person care patterns had higher A1c compared to White patients in the same care pattern (exponentiated coefficients: 1.05-1.07, 95% CIs > 1). Additionally, Asian, Hispanic, and other races or ethnicities with low to moderate remote care and no in-person care experienced smaller reductions in A1c compared to White patients (exponentiated coefficients: 1.05-1.06, 95% CIs > 1). Asian and Hispanic patients who engaged with high in-person care and no remote care experienced higher A1c levels than White patients (exponentiated coefficients: 1.08-1.12, 95% CIs > 1). Other care utilization patterns by race and ethnicity were not statistically significant.

Language preference also modified the effect of care patterns on A1c. Spanish speakers with no remote care, but high in-person engagement, experienced larger reductions in A1c compared to English speakers (exponentiated coefficient: 0.94, 95% CI: 0.89-0.99). Similarly, following quarters with no remote or in-person engagement, Chinese-speaking patients experienced larger reductions in A1c compared to English speakers (exponentiated coefficients: 95% CI: 0.94-0.99). Other language and care patterns were not statistically significant.

Sensitivity Analysis

The proportion of patients with an A1c result available each quarter ranged from 32-44% (Appendix D). Logistic regression revealed differential availability across care patterns: patients with high remote but no in-person visits had higher odds of A1c capture, while those with no remote but high in-person care had reduced odds compared to the reference group. Greater A1c availability was also associated with insulin treatment, whereas Black and Hispanic patients had lower odds of A1c capture.

DISCUSSION

Effect of Remote Engagement Patterns on A1c

This study shows that engaging in any form of care beyond low-to-moderate in-person visits benefits glycemic control for individuals. This reinforces the principle that continuity and engagement in care are essential for diabetes management[69,70]. Importantly, we captured between-visit interactions to provide a fuller picture of patient care utilization. This modality, which has been underexamined in prior research, is especially relevant in the post-COVID-19 era of digital healthcare engagement and in safety-net settings that may rely more on unscheduled telephone calls and between-visit secure messaging as elements of care, rather than scheduled telehealth visits[4,45,71].

Leveraging this broader definition, we found that varying levels of engagement across multiple modalities were associated with meaningful improvements in glycemic control. The largest reductions in A1c occurred among patients with the highest levels of engagement (high remote, high in-person care, high remote, low/moderate in-person care; no remote, high in-person care), demonstrating 7-8% reductions in relative A1c compared to the reference. These results suggest that high engagement, regardless of modality, drive the biggest improvements in glycemic control. This signals that consistent and frequent touchpoints with the healthcare system and care team are the strongest predictor of improved glycemic control.

Patients who engaged in both remote and in-person care saw additional improvements, even if not as strong as the highest utilizers. Those with hybrid care patterns experienced 4-6% reductions in relative A1c, highlighting the additive benefits of hybrid models of care. Incorporating multiple modalities of care into diabetes management may offer complementary benefits, such as ongoing monitoring and support via remote engagement and more comprehensive management with in-person visits[9,10,50,68].

Those who engaged exclusively with remote care experienced on average 4-5% lower A1c than those with only low or moderate in-person care. Patients who relied only on remote care still achieved relative reductions in A1c, showing that remote modalities can stand on their own as an effective approach to chronic disease management. These results have significant implications for accessibility and reinforce the idea that remote care can achieve positive health outcomes for those who may face barriers to in-person visits such as transportation, work schedules, or mobility issues[72,73]. Compared with prior studies that examined single modalities of care, our results provide evidence that integrating remote care with in-person care can address barriers to traditional models of care and yield improvements in glycemic outcomes[9,10,16,50,68].

Clinical Implications of Remote Engagement

Although we reported relative reductions in A1c, it is important to translate these into absolute changes to gauge clinical significance. The relative reductions in A1c of 4-8% are likely to be clinically meaningful, but the absolute impact depends on the patient's baseline glycemic control. For instance, for an individual with a baseline A1c of 8%, a 4% reduction equates to an absolute decrease of ~.32 points, whereas 8% corresponds to an absolute decrease of ~.64 points.

Here, only the higher end of the effect range crosses the clinical threshold, but even smaller reductions may matter if sustained over time. In practice, these results suggest that the clinical impact of relative improvements of even care patterns with the smallest relative reductions is greatest for those with poorer A1c control, where reductions are both statistically and clinically substantial.

Moreover, our study shows that, particularly among patients with high engagement or hybrid engagement, larger relative reductions in A1c are likely to translate into clinically meaningful improvements. This is especially true for those with high remote engagement and any in-person care, low to moderate remote and high in-person care, and high in-person care with no remote engagement, which demonstrated 7-8% relative reductions in A1c.

Importantly, remote encounters may substitute or augment in-person visits without diminishing effectiveness. Even modest absolute A1c reductions for those with low to moderate remote and no or low/moderate in-person care can translate into meaningful benefits at the population level. For example, a 0.3% absolute reduction sustained across thousands of patients reduces long-term risks of retinopathy, nephropathy, cardiovascular disease, and other complications related to poor diabetes control[9,45,69]. Thus, strategies that expand access to both remote and hybrid care models could generate significant population health gains, even if individual-level improvements appear modest.

Implications for Disparities

Sociodemographic factors influenced both care utilization patterns and outcomes. Older adults, Black, and Asian patients generally had lower A1c levels than younger and White patients, but interaction effects revealed differential *benefits*. Adults aged 50-64 more commonly displayed quarters with low care engagement, yet when they engaged in low-to-moderate remote and high in-person care, the reduction in A1c was attenuated. This attenuation may reflect age-related barriers to using remote modalities, differing treatment goals, or more complex comorbidity profiles that limit the impact of modest increases in engagement on glycemic control.

Asian, Black, and Hispanic patients derived less benefit from high remote engagement compared to White patients with high remote engagement. Moreover, minoritized races and ethnicities with low to moderate remote engagement derived less benefit than White patients. These findings suggest that while main effects were favorable for minoritized groups, disparities emerged depending on the remote/in-person combinations, indicating that expanding access to telehealth and remote interactions alone may not eliminate disparities in healthcare access.

By contrast, Spanish speakers were overrepresented in groups with high in-person engagement and benefited more from high in-person and no remote care than English speakers. These results suggest that Spanish speakers may rely more heavily on in-person care, possibly due to language barriers in digital tools (such as limited remote usability in Spanish) or a greater trust in face-to-face interactions, which reinforces prior literature on language barriers to care. Furthermore, a recent SFHN study highlighted how language-concordant digital skills training particularly benefits Spanish speakers and patients with lower remote engagement, suggesting a possible strategy to reduce disparities in engagement (Rapson T, Naranjo-Arellano M, Ralston JD, et al. Manuscript submitted for publication, 2025). Chinese speakers are also more likely to be low utilizers of care, commonly overrepresented in care patterns with no or low to moderate remote/in-person care. The lower overall engagement among Chinese speakers may reflect that cultural and linguistic differences likely shape how patients access, interact with, and respond to care, and that barriers to remote engagement persist, even as remote options for care expand[27,46,75]. A recent analysis further demonstrates that Chinese (and Spanish) speakers are disproportionately more likely to struggle with specific tasks required to use digital health tools effectively, reinforcing that linguistic and cultural barriers influence how patients access and interact with different modalities and aspects of care (Rapson T, Ramirez M, He S, et al. Manuscript submitted for publication, 2025). Despite the low utilization, Chinese speakers demonstrated relatively greater reductions in A1c following quarters with no care compared to White patients. This highlights a potential risk for disengagement in care among a vulnerable group, and future studies should examine culturally and linguistically equitable strategies to improve access to and engagement in care among Chinese speakers.

Our findings also highlight the structural underpinnings of disparities. Uninsured patients and those insured through Healthy Workers were disproportionately represented in groups with no or low to moderate remote engagement, compared to Medicaid and Medicare patients, who were more likely to have high remote engagement. Compared to Medicaid, uninsured patients had worse glycemic outcomes, while Healthy Workers and Medicare coverage corresponded with better glycemic control. This suggests that insurance coverage is a significant structural factor influencing both how patients engage with remote care and how well they achieve glycemic control[65,76]. Medicaid patients do engage in remote care at high levels, but still face challenges in achieving glycemic improvements, suggesting that access alone is not enough; the support provided through Medicaid might differ from Medicare or employer-based programs like Healthy Workers. Moreover, uninsured patients are doubly disadvantaged—they engage in less remote care and experience worse outcomes. Patients living in low-SES neighborhoods also showed modestly worse glycemic outcomes, underscoring how social and structural determinants continue to shape health trajectories even when individuals are engaged in their care. Our results indicate that insurance coverage and neighborhood socioeconomic status directly shape both digital engagement and healthy equity beyond just patient-level sociodemographic differences, so future studies should investigate how these structural inequities intersect with digital adoption and how reimbursement policies influence remote engagement and access to care.

Transformation of Care Delivery

The COVID-19 pandemic accelerated the integration of remote modalities into routine diabetes management, supported by changes in reimbursement policy and rapid adoption of telehealth platforms[5,44,50,67]. Our findings reinforce that remote care is not simply a stopgap measure but a viable component of chronic disease management. High engagement in remote modalities was associated with glycemic improvements comparable to high engagement in traditional in-person care and better outcomes when compared to only low to moderate in-person engagement. For clinicians and health systems, this provides reassurance that hybrid models of care combine the strengths of multiple modalities and that hybrid care delivery can achieve meaningful clinical outcomes. Furthermore, these findings suggest that expanding hybrid models of care (combining remote and in-person encounters) can yield meaningful benefits in safety-net populations.

In addition, the absence of engagement in either modality was not associated with A1c improvement, underscoring the risks of disengagement and the need for proactive outreach to patients who may be missing care altogether. However, simply increasing remote engagement may not be sufficient. Tailoring engagement strategies to patient characteristics—such as age, race, language preference, and insurance—is necessary to promote equity and to maximize impact. For example, proactive and targeted language-concordant outreach and digital support for Spanish and Chinese speakers in high in-person settings may prove more effective than generic outreach. Examples include ensuring interpreter services are available and assisting with other accessibility features of digital devices (such as updating the patient portal platform language or changing settings for language-concordant translation). These may not only prevent care disengagement for populations who are likely to have less care but may also address disparities in remote engagement. In addition, intervention trials should test whether culturally and linguistically tailored engagement strategies can enhance not only the uptake of remote care, but also equity in diabetes outcomes.

A key implication is that hybrid models of care are effective, but not one-size-fits-all. Especially amid the debate regarding whether telehealth reimbursement strategies should be continued, our study provides empirical evidence that sustained high-level engagement in care, and particularly hybrid engagement, supports improved outcomes[67]. Reimbursing telehealth visits and continuing to support remote care strategies that account for sociodemographic context and patient preferences have the potential to address gaps in care among marginalized populations and produce equitable outcomes.

Importantly, we observed increasing trends of complete disengagement from care per quarter over time, raising concerns that a growing subset of patients is falling through the cracks. These findings underscore the complexity of tailoring diabetes care to patients' cultural, linguistic, and socioeconomic contexts, and suggest that structural inequities—including differences in digital literacy, trust, or communication preferences—may shape engagement in care. Future strategies should explicitly address how to re-engage these patients, potentially through proactive outreach, qualitative assessments clarifying barriers for these patients, and integrated resources that address those barriers and encourage engagement in any and all modalities that suit their needs. Health systems should also track utilization and outcomes by subgroup to monitor whether digital expansion narrows or exacerbates disparities.

Limitations

This study has several limitations. First, as this is an observational study using EHR data, we cannot rule out residual confounding, particularly related to unmeasured factors such as patient motivation, access to devices and internet, and lifestyle factors or social norms that may influence attitude towards diabetes and remote engagement in care. While we adjusted for a range of clinical and sociodemographic covariates, selection into different care modalities is likely non-random and may reflect underlying health engagement, care-seeking behavior, or attitudes toward different care modalities. Secondly, by grouping multiple digital/remote modalities as “remote”, we may obscure important heterogeneity in intensity, content, or quality of the encounters. Similarly, in-person encounters encompass a wide range of visit types that may have heterogeneous effects on outcomes. However, this approach allowed for direct comparisons across groups and our data-driven thresholds for engagement reflect real-world shifts in how safety-net patients may access care. Third, many factors may influence timely A1c results, and we are unable to capture those differences or account for individuals who are excluded from the cohort as a result. Although the proportion of observed A1cs varied somewhat across utilization categories (33–42%), the range was modest and unlikely to meaningfully bias comparisons. Lastly, the generalizability of these findings may be limited to safety-net populations in similar urban settings.

Conclusion

In a large, safety-net cohort of individuals with diabetes followed over multiple quarters, we found that patterns of remote and in-person care were associated with significant relative differences in glycemic control that trend clinically meaningful. Specifically, a greater proportion of remote care was associated with a larger relative reduction in A1c, suggesting potential benefits of remote modalities and underscoring the value of hybrid engagement for chronic disease management. However, these associations varied by sociodemographic characteristics, revealing disparities in access, adoption, and effectiveness across patient groups. As healthcare systems continue to expand hybrid models of care, it is critical to ensure equitable access and effectiveness across diverse populations. Future work should focus on disentangling mechanisms—such as communication frequency, care continuity, and digital literacy—that may mediate the observed effects and evaluate equity-focused interventions to ensure that the digital transformation of care meaningfully advances, rather than undermines, health equity.

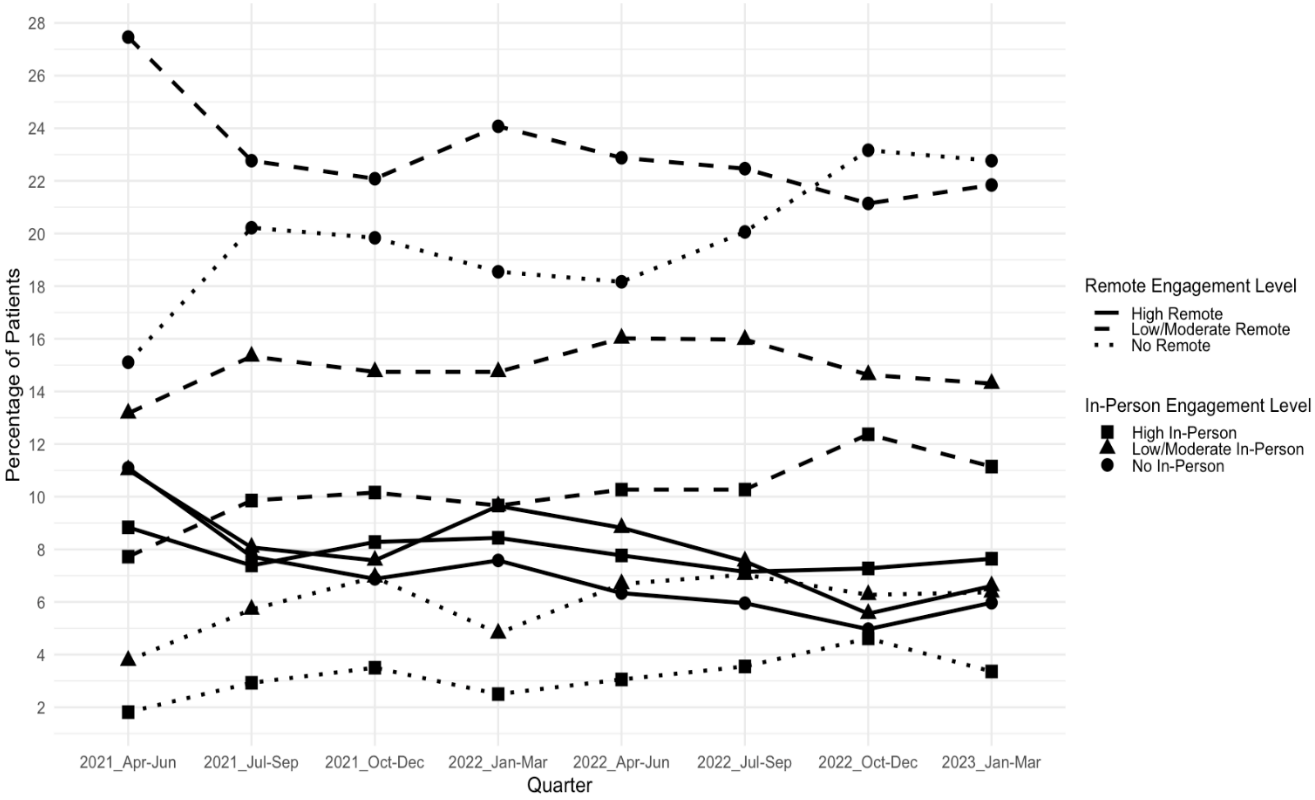
TABLES AND FIGURES

Table 4.1. Demographic and Clinical Characteristics of Patients (N = 6,281)

Characteristic	**N = 6,281**
Sociodemographic Characteristics	
Age Group (%)	
<50	1,125 (18%)
50-64	2,953 (47%)
65-74	1,630 (26%)
75+	573 (9.1%)
Sex (%)	
Male	2,971 (47%)
Female	3,309 (53%)
Race and Ethnicity (%)	
NH White	649 (10%)
NH Asian	2,251 (36%)
NH Black or African American	899 (14%)
Hispanic or Latino	2,181 (35%)
Other	301 (4.8%)
Preferred Language (%)	
English	2,631 (42%)
Spanish	1,789 (28%)
Chinese	1,258 (20%)
Other/Unknown	603 (9.6%)
Insurance (%)	
Medicaid - Medi-Cal/Medicaid/SF Health Plan	2,295 (37%)
Medicare	2,204 (35%)
Uninsured - Patient Pay/Uninsured/Anchor Study/UHC HRSA	845 (13%)
Healthy Workers	937 (15%)
Neighborhood Socioeconomic Status (%)	
Q4-Q5 (Higher nSES)	1,197 (19%)
Q1-Q3 (Lower nSES)	4,960 (81%)
Health-Related Traits	
Treatment Intensity (%)	
Diet Only	1,006 (16%)
Non-Insulin Medication	3,783 (60%)
Insulin	1,492 (24%)
Charlson Comorbidity Index (%)	
0-2	5,483 (87%)
3+	798 (13%)
Care Utilization Per Quarter	
Care Utilization (mean(SD))	
In-Person	2.137 (3.59)
Remote	2.405 (3.18)
Telehealth	0.456 (0.96)
Between-Visit	1.948 (2.78)

NH: Non-Hispanic, SF: San Francisco, UHC HRSA: UnitedHealth Group—HRSA Uninsured Plan, nSES: Neighborhood Socioeconomic Status, SD: Standard Deviation

Figure 4.1. Care Pattern Proportions Over Time



Each point represents the percentage of patients in each care pattern per quarter over the 24-month study period. Line patterns represent the level of remote engagement (no, low/moderate, high) and point shapes indicate the level in-person engagement (no, low/moderate, high) to visualize trends based on composite care patterns but also by remote or in-person modalities.

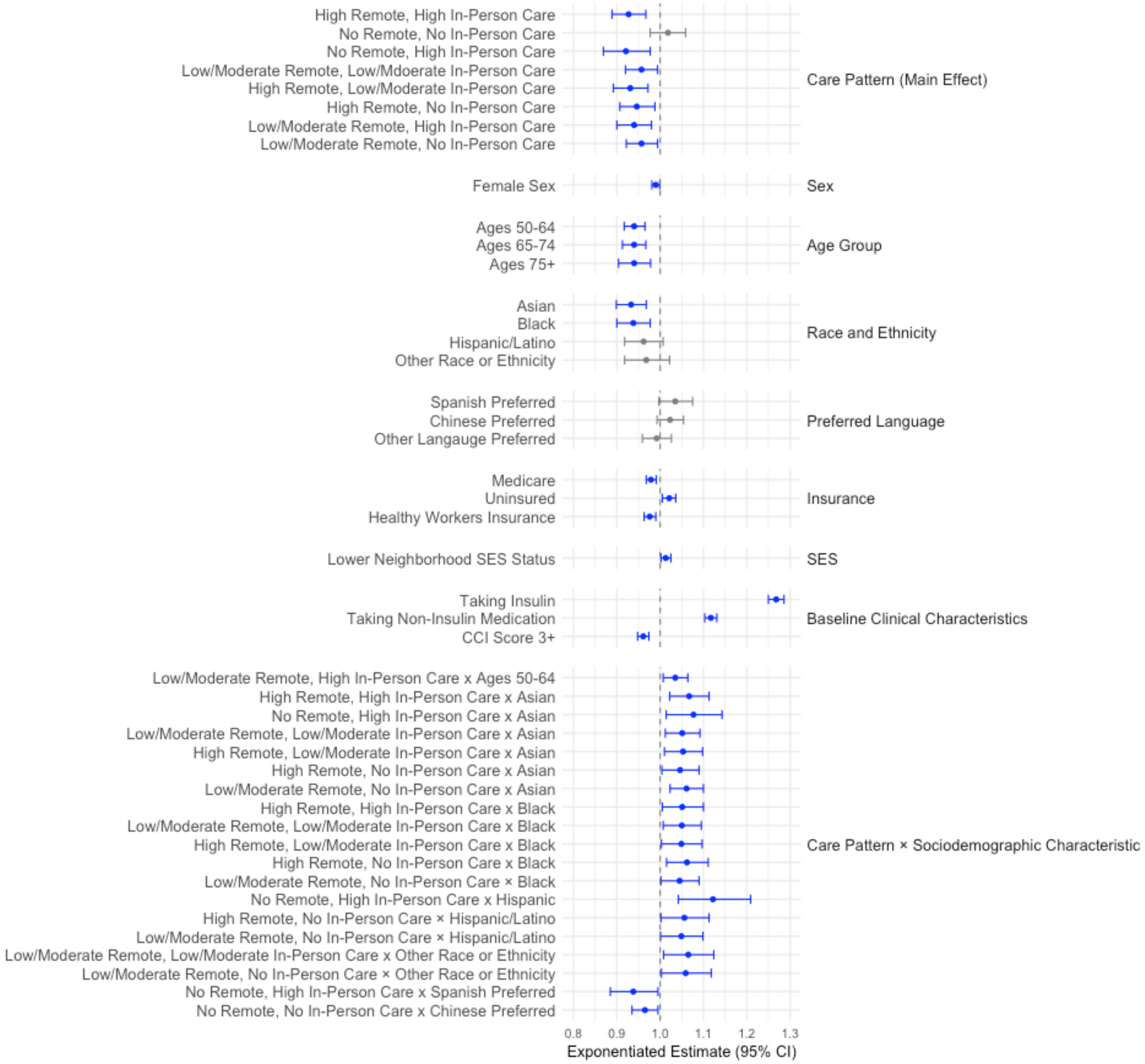
Table 4.2. Patient Characteristics Stratified by Grouped Care Engagement Patterns

Characteristic	Overall N = 50,248	No Remote Engagement N = 14,497	Low/Mod Remote Engagement N = 24,186	High Remote Engagement N = 11,565	P-Value[a]
Age Group					<0.001
<50	9,000 (18%)	2,808 (19%)	4,212 (17%)	1,980 (17%)	
50-64	23,624 (47%)	6,977 (48%)	11,344 (47%)	5,303 (46%)	
65-74	13,040 (26%)	3,564 (25%)	6,386 (26%)	3,090 (27%)	
75+	4,584 (9.1%)	1,148 (7.9%)	2,244 (9.3%)	1,192 (10%)	
Sex					<0.001
Male	23,768 (47%)	7,252 (50%)	11,215 (46%)	5,301 (46%)	
Female	26,472 (53%)	7,242 (50%)	12,967 (54%)	6,263 (54%)	
Race and Ethnicity					<0.001
NH White	5,192 (10%)	1,260 (8.7%)	2,294 (9.5%)	1,638 (14%)	
NH Asian	18,008 (36%)	5,640 (39%)	9,269 (38%)	3,099 (27%)	
NH Black or African American	7,192 (14%)	1,671 (12%)	3,136 (13%)	2,385 (21%)	
Hispanic or Latino	17,448 (35%)	5,184 (36%)	8,443 (35%)	3,821 (33%)	
Other	2,408 (4.8%)	742 (5.1%)	1,044 (4.3%)	622 (5.4%)	
Preferred Language					<0.001
English	21,048 (42%)	5,459 (38%)	9,324 (39%)	6,265 (54%)	
Spanish	14,312 (28%)	4,351 (30%)	7,092 (29%)	2,869 (25%)	
Chinese	10,064 (20%)	3,176 (22%)	5,388 (22%)	1,500 (13%)	
Other/Unknown	4,824 (9.6%)	1,511 (10%)	2,382 (9.8%)	931 (8.1%)	
Treatment Intensity					<0.001
Diet Only	8,048 (16%)	2,801 (19%)	3,794 (16%)	1,453 (13%)	
Non-insulin Medication	30,264 (60%)	9,279 (64%)	14,977 (62%)	6,008 (52%)	
Insulin	11,936 (24%)	2,417 (17%)	5,415 (22%)	4,104 (35%)	
Charlson Comorbidity (CCI) Score					<0.001
0-2	43,864 (87%)	13,113 (90%)	21,421 (89%)	9,330 (81%)	
3+	6,384 (13%)	1,384 (9.5%)	2,765 (11%)	2,235 (19%)	
Insurance Type					<0.001
Medicaid	18,360 (37%)	5,233 (36%)	8,664 (36%)	4,463 (39%)	
Medicare	17,632 (35%)	4,259 (29%)	8,318 (34%)	5,055 (44%)	
Healthy Workers	7,496 (15%)	2,575 (18%)	3,877 (16%)	1,044 (9.0%)	
Uninsured	6,760 (13%)	2,430 (17%)	3,327 (14%)	1,003 (8.7%)	
Neighborhood Socioeconomic Status (nSES)					0.089
Q4-Q5 (Higher SES)	9,576 (19%)	2,671 (19%)	4,663 (20%)	2,242 (20%)	
Q1-Q3 (Lower SES)	39,680 (81%)	11,512 (81%)	19,086 (80%)	9,082 (80%)	

NH: Non-Hispanic, AA: African American, SES: Socioeconomic Status

[a] Chi-Squared Tests of Independence; $P<.05$ significant

Figure 4.2. Associations Between Care Patterns, Sociodemographic and Clinical Characteristics, and Glycemic Control



Each point represents the exponentiated estimate for A1c for each covariate, with bands representing 95% confidence intervals. Blue estimates are statistically significant; grey points are not statistically significant.

Table 4.3. Key Associations Between Care Patterns, Sociodemographic and Clinical Characteristics, and Glycemic Control

Term	Exponentiated Estimate	Lower CI	Upper CI
(Intercept)	7.47	7.18	7.78
Care Pattern			
High Remote, High In-Person Care	0.93	0.89	0.97
High Remote, Low/Moderate In-Person Care	0.93	0.89	0.97
High Remote, No In-Person Care	0.95	0.91	0.99
Low/Moderate Remote, High In-Person Care	0.94	0.90	0.98
Low/Moderate Remote, Low/Moderate In-Person Care	0.96	0.92	0.99
Low/Moderate Remote, No In-Person Care	0.96	0.92	0.99
No Remote, High In-Person Care	0.92	0.87	0.98
No Remote, Low/Mod In-Person Care	Ref		
No Remote, No In-Person Care	1.02	0.98	1.06
Female Sex	0.99	0.98	1.00
Age Group			
< 50	ref		
Ages 50-64	0.94	0.92	0.97
Ages 65-74	0.94	0.91	0.97
Ages 75+	0.94	0.90	0.98
Race and Ethnicity			
Asian	0.93	0.90	0.97
Black	0.94	0.90	0.98
Hispanic/Latino	0.96	0.92	1.01
White	ref		
Other Race or Ethnicity	0.97	0.92	1.02
Preferred Language			
Chinese Preferred	1.02	0.99	1.05
English Preferred	ref		
Spanish Preferred	1.04	1.00	1.08
Other Language Preferred	0.99	0.96	1.03
Insurance			
Medicaid	ref		
Medicare	0.98	0.97	0.99
Uninsured	1.02	1.01	1.04
Healthy Workers Insurance	0.98	0.96	0.99
Treatment Intensity			
Diet Only	ref		
Taking Non-Insulin Medication	1.12	1.10	1.13
Taking Insulin	1.27	1.25	1.29
Charlson Comorbidity Score			
CCI Score 0-2	ref		
CCI Score 3+	0.96	0.95	0.97
Neighborhood Socioeconomic Status			
Q4-Q5 (Higher nSES)	Ref		
Q1-Q3 (Lower nSES)	1.01	1.00	1.03
Interaction Terms of Care Pattern x Age, Race and Ethnicity, Preferred Language			
Age			
Low/Moderate Remote, High In-Person x 50-64	1.04	1.01	1.06
Race and Ethnicity			
High Remote, High In-Person Care x Asian	1.07	1.02	1.11
High Remote, Low/Moderate In-Person Care x Asian	1.05	1.01	1.10
High Remote, No In-Person Care x Asian	1.05	1.00	1.09
Low/Moderate Remote, Low/Moderate In-Person Care x Asian	1.05	1.01	1.09
Low/Moderate Remote, No In-Person Care x Asian	1.06	1.02	1.10
No Remote, High In-Person Care x Asian	1.08	1.01	1.14
High Remote, High In-Person Care x Black	1.05	1.01	1.10

High Remote, Low/Moderate In-Person Care x Black	1.05	1.00	1.10
High Remote, No In-Person Care x Black	1.06	1.02	1.11
Low/Moderate Remote, Low/Moderate In-Person Care x Black	1.05	1.01	1.10
Low/Moderate Remote, No In-Person Care x Black	1.05	1.00	1.09
High Remote, Low/Mod In-Person x Hispanic	1.05	1.00	1.10
High Remote, No In-Person Care x Hispanic/Latino	1.06	1.00	1.11
Low/Moderate Remote, No In-Person Care x Hispanic/Latino	1.05	1.00	1.10
No Remote, High In-Person Care x Hispanic/Latino	1.12	1.04	1.21
Low/Moderate Remote, Low/Moderate In-Person x Other Race/Ethnicity	1.07	1.01	1.12
Low/Moderate Remote, No In-Person Care x Other Race or Ethnicity	1.06	1.00	1.12
Preferred Language			
No Remote, High In-Person Care x Spanish Preferred	0.94	0.89	1.00
No Remote, No In-Person Care x Chinese Preferred	0.97	0.94	1.00

CI: Confidence Interval at 95%, Mod: Moderate, NH: Non-Hispanic

APPENDICES

METHODOLOGICAL APPENDIX

Details on cohort definition and criteria, as described in a prior study[4]

Cohort Inclusion Criteria

1. An active primary care panel patient, defined as:
    a. A primary care clinician listed as primary PCP in Apex, AND
    b. Any in-person, telephone, telehealth, or MyChart encounter with a primary care department since 03/01/2016
2. Patients 18+ years old as of 03/01/2019 3. With diabetes diagnosis based on any of the following criteria:
    a. Having an active diabetes mellitus health maintenance modifier on 3/1/2019
    b. ICD-9/ICD-10 codes on active problem list as of 3/1/2019
        i. ICD-9: '250', '357.2', '362.01', '362.02', '362.03', '362.04', '362.05', '362.06', '362.07', '366.41', '648.00', '648.01', '648.02', '648.03', '648.04'
        ii. ICD-10: 'E10', 'E11', 'E13'
    c. Most-recent A1c test result within 3-year span of 3/1/2016 - 3/1/2019:
        i. HbA1c > 6.5%, or ii. HgA1c < 6.5% with an active diabetes medication on medication list:
            (1) Any non-metformin medication, or
            (2) A combination medication including metformin Medication list: 'acarbose', 'actoplus', 'actos', 'amaryl', 'apidra', 'avandamet', 'avandaryl', 'avandia', 'bydureon', 'byetta', 'chlorpropamide', ‘dapagliflozin’, 'diabeta', 'duetact', ' dulaglutide ', ‘farxiga’, 'glimepiride', 'glipizide', 'glucotrol', 'glucovance', 'glyburide', 'glynase', 'glyset', 'humalog', 'humulin', 'invokamet', 'invokana', 'janumet', 'januvia', 'jardiance', ‘jentadueto', 'juvisync', 'kazano', 'kombiglyze', 'lantus', 'levemir', ‘liraglutide’, 'lispro', 'metaglip', 'metformin' combo, 'nateglinide', 'nesina', 'novolin', 'novolog', 'onglyza', 'oseni', 'pioglitazone', 'prandimet', 'prandin%', 'precose', 'relion', 'repaglinide', 'starlix', 'symlin', 'tanzeum', 'tolazamide', 'tolbutamide', 'tradjenta', ‘trulicity’, 'victoza'

Cohort Exclusion Criteria

1. Diabetes diagnosis specifically for:
    a. Gestational diabetes
    b. Pre-diabetes
    c. Steroid-induced diabetes
2. Health maintenance modifier stating: “Exclude from Diabetes Registry: Does not have Diabetes”
3. No A1c test within the 2-year span of 04/01/2021 – 03/31/2023
4. No in-person, telephone, telehealth, of MyChart encounter with a primary care department between 04/2020-03/31/2021
5. Diabetes diagnosis with a resolved date prior to 04/01/2021

Additional Details about Covariates

Insurance Type/Status

The 4 insurance types are Medicare, Medicaid, Healthy Workers, and Uninsured. Medicare includes dual-eligible Medicare and Medicaid. Medicaid includes Medi-Cal, and SF Health Plan. SF Health Plan is a non-profit Medi-Cal managed care plan that serves low-income residents who qualify for Medi-Cal. Healthy Workers is a San Francisco-specific program that provides health insurance coverage to people working in In-Home Supportive Services, foster care, or other publicly funded roles who do not qualify for traditional Medicaid or employer-sponsored coverage. Uninsured includes patient self-pay or local government safety-net programs such as Anchor Study or UHC HRSA (non-standard coverage streams for uninsured or underinsured patients).

Neighborhood Socioeconomic Status

Neighborhood Socioeconomic status (nSES) is a quintile categorization based on geocoded addresses. nSES is a composite indicator that incorporates the most recent 5-year averages from the American Community Survey data on income, education, poverty, employment, occupation, housing and rent values, applied to US Census tract boundaries. nSES was determined by linking patient addresses from the EHR to census tract[77]. Quintiles of nSES were then created based on the distribution of nSES across US Census tracts of SF Bay Area counties, with the first quintile (Q1) reflecting lowest nSES and the fifth quintile (Q5) reflecting highest nSES US Census tract. We collapsed the quintiles into two categories for lower nSES (Q1 – Q3) and higher nSES (Q4 – Q5).

APPENDIX B. Patient Characteristics by Care Utilization Patterns

Characteristic	**All Person-Quarters** N = 50,248	**No Remote, No In-Person** N = 9,916	**No Remote, Low/Mod In-Person** N = 2,990	**No Remote, High In-Person** N = 1,591	**Low/Mod Remote, No In-Person** N = 11,602	**Low/Mod Remote, Low/Mod In-Person** N = 7,468	**Low/Mod Remote, High In-Person** N = 5,116	**High Remote, No In-Person** N = 3,549	**High Remote, Low/Mod In-Person** N = 4,073	**High Remote, High In-Person** N = 3,943	**P-value**
Age Group											*P<0.001*
<50	9,000 (18%)	2,051 (21%)	460 (15%)	297 (19%)	2,070 (18%)	1,189 (16%)	953 (19%)	636 (18%)	646 (16%)	698 (18%)	
50-64	23,624 (47%)	4,727 (48%)	1,508 (50%)	742 (47%)	5,573 (48%)	3,458 (46%)	2,313 (45%)	1,659 (47%)	1,845 (45%)	1,799 (46%)	
65-74	13,040 (26%)	2,385 (24%)	777 (26%)	402 (25%)	2,999 (26%)	2,055 (28%)	1,332 (26%)	893 (25%)	1,162 (29%)	1,035 (26%)	
75+	4,584 (9.1%)	753 (7.6%)	245 (8.2%)	150 (9.4%)	960 (8.3%)	766 (10%)	518 (10%)	361 (10%)	420 (10%)	411 (10%)	
Sex											*P<0.001*
Male	23,768 (47%)	4,965 (50%)	1,475 (49%)	812 (51%)	5,328 (46%)	3,443 (46%)	2,444 (48%)	1,594 (45%)	1,792 (44%)	1,915 (49%)	
Female	26,472 (53%)	4,950 (50%)	1,514 (51%)	778 (49%)	6,272 (54%)	4,023 (54%)	2,672 (52%)	1,955 (55%)	2,280 (56%)	2,028 (51%)	
Race and Ethnicity											*P<0.001*
NH White	5,192 (10%)	898 (9.1%)	255 (8.5%)	107 (6.7%)	1,204 (10%)	694 (9.3%)	396 (7.7%)	551 (16%)	583 (14%)	504 (13%)	
NH Asian	18,008 (36%)	3,903 (39%)	1,248 (42%)	489 (31%)	5,069 (44%)	2,815 (38%)	1,385 (27%)	1,178 (33%)	1,140 (28%)	781 (20%)	
NH Black or AA	7,192 (14%)	1,156 (12%)	324 (11%)	191 (12%)	1,483 (13%)	1,026 (14%)	627 (12%)	729 (21%)	888 (22%)	768 (19%)	
Hispanic or Latino	17,448 (35%)	3,407 (34%)	1,051 (35%)	726 (46%)	3,354 (29%)	2,619 (35%)	2,470 (48%)	934 (26%)	1,239 (30%)	1,648 (42%)	
Other	2,408 (4.8%)	552 (5.6%)	112 (3.7%)	78 (4.9%)	492 (4.2%)	314 (4.2%)	238 (4.7%)	157 (4.4%)	223 (5.5%)	242 (6.1%)	
Preferred Language											*P<0.001*
English	21,048 (42%)	3,814 (38%)	1,069 (36%)	576 (36%)	4,566 (39%)	2,900 (39%)	1,858 (36%)	1,976 (56%)	2,242 (55%)	2,047 (52%)	
Spanish	14,312 (28%)	2,825 (28%)	875 (29%)	651 (41%)	2,711 (23%)	2,192 (29%)	2,189 (43%)	654 (18%)	894 (22%)	1,321 (34%)	
Chinese	10,064 (20%)	2,275 (23%)	705 (24%)	196 (12%)	3,168 (27%)	1,641 (22%)	579 (11%)	611 (17%)	594 (15%)	295 (7.5%)	
Other/Unknown	4,824 (9.6%)	1,002 (10%)	341 (11%)	168 (11%)	1,157 (10.0%)	735 (9.8%)	490 (9.6%)	308 (8.7%)	343 (8.4%)	280 (7.1%)	
Treatment Intensity											*P<0.001*
Diet only	8,048 (16%)	2,023 (20%)	548 (18%)	230 (14%)	1,914 (16%)	1,227 (16%)	653 (13%)	439 (12%)	623 (15%)	391 (9.9%)	
Insulin	11,936 (24%)	1,549 (16%)	451 (15%)	417 (26%)	2,262 (19%)	1,564 (21%)	1,589 (31%)	1,195 (34%)	1,291 (32%)	1,618 (41%)	
Non-insulin	30,264 (60%)	6,344 (64%)	1,991 (67%)	944 (59%)	7,426 (64%)	4,677 (63%)	2,874 (56%)	1,915 (54%)	2,159 (53%)	1,934 (49%)	
Charlson Comorbidity Index Score											*P<0.001*
0-2	43,864 (87%)	9,056 (91%)	2,690 (90%)	1,367 (86%)	10,464 (90%)	6,599 (88%)	4,358 (85%)	2,926 (82%)	3,357 (82%)	3,047 (77%)	
3+	6,384 (13%)	860 (8.7%)	300 (10%)	224 (14%)	1,138 (9.8%)	869 (12%)	758 (15%)	623 (18%)	716 (18%)	896 (23%)	
Insurance Coverage											*P<0.001*
Medicaid	18,360 (37%)	3,646 (37%)	1,010 (34%)	577 (36%)	4,147 (36%)	2,587 (35%)	1,930 (38%)	1,319 (37%)	1,497 (37%)	1,647 (42%)	
Medicare	17,632 (35%)	2,785 (28%)	967 (32%)	507 (32%)	3,759 (32%)	2,727 (37%)	1,832 (36%)	1,503 (42%)	1,843 (45%)	1,709 (43%)	
Uninsured	6,760 (13%)	1,583 (16%)	504 (17%)	343 (22%)	1,410 (12%)	1,014 (14%)	903 (18%)	309 (8.7%)	327 (8.0%)	367 (9.3%)	
Healthy Workers	7,496 (15%)	1,902 (19%)	509 (17%)	164 (10%)	2,286 (20%)	1,140 (15%)	451 (8.8%)	418 (12%)	406 (10.0%)	220 (5.6%)	
Neighborhood Socioeconomic Status											*P<0.001*
Q4-Q5 (Higher nSES)	9,576 (19%)	1,812 (19%)	591 (20%)	268 (17%)	2,343 (21%)	1,464 (20%)	856 (17%)	746 (21%)	819 (20%)	677 (18%)	
Q1-Q3 (Lower nSES)	39,680 (81%)	7,869 (81%)	2,351 (80%)	1,292 (83%)	9,061 (79%)	5,861 (80%)	4,164 (83%)	2,725 (79%)	3,184 (80%)	3,173 (82%)	

Mod: Moderate, NH: Non-Hispanic, AA: African American, nSES: neighborhood socioeconomic status

APPENDIX C. Associations Between Care Patterns, Sociodemographic and Clinical Characteristics, and Glycemic Control

Term	Exponentiated Estimate	Lower CI	Upper CI
(Intercept)	7.47	7.18	7.78
time	0.99	0.99	0.99
Care Pattern			
High Remote, High In-Person Care	0.93	0.89	0.97
High Remote, Low/Moderate In-Person Care	0.93	0.89	0.97
High Remote, No In-Person Care	0.95	0.91	0.99
Low/Moderate Remote, High In-Person Care	0.94	0.90	0.98
Low/Moderate Remote, Low/Moderate In-Person Care	0.96	0.92	0.99
Low/Moderate Remote, No In-Person Care	0.96	0.92	0.99
No Remote, High In-Person Care	0.92	0.87	0.98
No Remote, Low/Mod In-Person Care	Ref		
No Remote, No In-Person Care	1.02	0.98	1.06
Female Sex	0.99	0.98	1.00
Age Group			
< 50	ref		
Ages 50-64	0.94	0.92	0.97
Ages 65-74	0.94	0.91	0.97
Ages 75+	0.94	0.90	0.98
Race and Ethnicity			
Asian	0.93	0.90	0.97
Black	0.94	0.90	0.98
Hispanic/Latino	0.96	0.92	1.01
White	ref		
Other Race or Ethnicity	0.97	0.92	1.02
Preferred Language			
Chinese Preferred	1.02	0.99	1.05
English Preferred	ref		
Spanish Preferred	1.04	1.00	1.08
Other Language Preferred	0.99	0.96	1.03
Insurance			
Medicaid	ref		
Medicare	0.98	0.97	0.99
Uninsured	1.02	1.01	1.04
Healthy Workers Insurance	0.98	0.96	0.99
Treatment Intensity			
Diet Only	ref		
Taking Non-Insulin Medication	1.12	1.10	1.13
Taking Insulin	1.27	1.25	1.29
Charlson Comorbidity Score			
CCI Score 0-2	ref		
CCI Score 3+	0.96	0.95	0.97
Neighborhood Socioeconomic Status			
Q4-Q5 (Higher nSES)	Ref		
Q1-Q3 (Lower nSES)	1.01	1.00	1.03
Interaction Terms of Care Pattern x Age, Race and Ethnicity, Preferred Language			
Age			
High Remote, High In-Person x 50-64	1.02	0.99	1.05
High Remote, Low/Mod In-Person x 50-64	1.00	0.97	1.03
High Remote, No In-Person x 50-64	1.00	0.97	1.03
Low/Moderate Remote, High In-Person x 50-64	1.04	1.01	1.06
Low/Mod Remote, Low/Mod In-Person x 50-64	1.00	0.98	1.03
Low/Mod Remote, No In-Person x 50-64	1.01	0.99	1.04
No Remote, High In-Person x 50-64	1.01	0.98	1.05
No Remote, No In-Person x 50-64	0.99	0.97	1.02

High Remote, High In-Person x 65-74	1.01	0.98	1.04
High Remote, Low/Mod In-Person x 65-74	1.03	0.99	1.06
High Remote, No In-Person x 65-74	1.01	0.98	1.04
Low/Mod Remote, High In-Person x 65-74	1.03	1.00	1.06
Low/Mod Remote, Low/Mod In-Person x 65-74	1.00	0.97	1.03
Low/Mod Remote, No In-Person x 65-74	1.01	0.98	1.03
No Remote, High In-Person x 65-74	1.00	0.96	1.05
No Remote, No In-Person x 65-74	0.98	0.95	1.01
High Remote, High In-Person x 75+	1.02	0.97	1.06
High Remote, Low/Mod In-Person x 75+	1.03	0.99	1.08
High Remote, No In-Person x 75+	1.03	0.99	1.08
Low/Mod Remote, High In-Person x 75+	1.04	1.00	1.08
Low/Mod Remote, Low/Mod In-Person x 75+	0.99	0.96	1.03
Low/Mod Remote, No In-Person x 75+	1.01	0.97	1.05
No Remote, High In-Person x 75+	0.97	0.92	1.03
No Remote, No In-Person x 75+	0.97	0.93	1.00
Race and Ethnicity			
High Remote, High In-Person Care x Asian	1.07	1.02	1.11
High Remote, Low/Moderate In-Person Care x Asian	1.05	1.01	1.10
High Remote, No In-Person Care x Asian	1.05	1.00	1.09
Low/Mod Remote, High In-Person x Asian	1.04	1.00	1.08
Low/Moderate Remote, Low/Moderate In-Person Care x Asian	1.05	1.01	1.09
Low/Moderate Remote, No In-Person Care x Asian	1.06	1.02	1.10
No Remote, High In-Person Care x Asian	1.08	1.01	1.14
No Remote, No In-Person x Asian	1.04	1.00	1.08
High Remote, High In-Person Care x Black	1.05	1.01	1.10
High Remote, Low/Moderate In-Person Care x Black	1.05	1.00	1.10
High Remote, No In-Person Care x Black	1.06	1.02	1.11
Low/Mod Remote, High In-Person x Black	1.04	0.99	1.09
Low/Moderate Remote, Low/Moderate In-Person Care x Black	1.05	1.01	1.10
Low/Moderate Remote, No In-Person Care x Black	1.05	1.00	1.09
No Remote, High In-Person x Black	1.06	0.99	1.13
No Remote, No In-Person x Black	1.01	0.97	1.06
High Remote, High In-Person x Hispanic	1.04	0.99	1.10
High Remote, Low/Mod In-Person x Hispanic	1.05	1.00	1.10
High Remote, No In-Person Care x Hispanic/Latino	1.06	1.00	1.11
Low/Mod Remote, High In-Person x Hispanic or Latino	1.04	0.98	1.09
Low/Mod Remote, Low/Mod In-Person x Hispanic or Latino	1.03	0.98	1.08
Low/Moderate Remote, No In-Person Care x Hispanic/Latino	1.05	1.00	1.10
No Remote, High In-Person Care x Hispanic	1.12	1.04	1.21
No Remote, No In-Person x Hispanic or Latino	1.04	0.99	1.10
High Remote, High In-Person x Other	1.02	0.97	1.09
High Remote, Low/Mod In-Person x Other	1.03	0.97	1.10
High Remote, No In-Person x Other	1.03	0.97	1.09
Low/Mod Remote, High In-Person x Other	1.00	0.94	1.06
Low/Moderate Remote, Low/Moderate In-Person x Other Race/Ethnicity	1.07	1.01	1.12
Low/Moderate Remote, No In-Person Care x Other Race or Ethnicity	1.06	1.00	1.12
No Remote, High In-Person x Other	1.08	0.99	1.19
No Remote, No In-Person x Other	1.04	0.98	1.10
Preferred Language			
High Remote, High In-Person x Spanish	1.00	0.96	1.04
High Remote, Low/Mod In-Person x Spanish	0.99	0.95	1.03
High Remote, No In-Person x Spanish	0.98	0.94	1.02
Low/Mod Remote, High In-Person x Spanish	0.98	0.94	1.02
Low/Mod Remote, Low/Mod In-Person x Spanish	1.00	0.97	1.04
Low/Mod Remote, No In-Person x Spanish	0.99	0.95	1.03
No Remote, High In-Person Care x Spanish Preferred	0.94	0.89	1.00
No Remote, No In-Person x Spanish	0.99	0.95	1.03
High Remote, High In-Person x Chinese	0.99	0.95	1.03

High Remote, Low/Mod In-Person x Chinese	0.99	0.96	1.03
High Remote, No In-Person x Chinese	1.00	0.97	1.04
Low/Mod Remote, High In-Person x Chinese	0.99	0.95	1.02
Low/Mod Remote, Low/Mod In-Person x Chinese	0.99	0.96	1.02
Low/Mod Remote, No In-Person x Chinese	0.98	0.95	1.01
No Remote, High In-Person x Chinese	1.01	0.96	1.07
No Remote, No In-Person Care x Chinese Preferred	0.97	0.94	1.00
High Remote, High In-Person x Other/Unknown	1.02	0.98	1.06
High Remote, Low/Mod In-Person x Other/Unknown	1.03	0.99	1.07
High Remote, No In-Person x Other/Unknown	1.01	0.97	1.05
Low/Mod Remote, High In-Person x Other/Unknown	1.03	0.99	1.07
Low/Mod Remote, Low/Mod In-Person x Other/Unknown	1.02	0.98	1.05
Low/Mod Remote, No In-Person x 'Other/Unknown	1.01	0.98	1.04
No Remote, High In-Person x Other/Unknown	1.00	0.95	1.06
No Remote, No In-Person x Other/Unknown	0.98	0.95	1.02

CI: Confidence Interval at 95%, Mod: Moderate, NH: Non-Hispanic

APPENDIX D. Sensitivity Analysis for A1c Missingness

Care Pattern	Total Patient Quarters	Total A1c Results	A1c Availability
No Remote, No In-Person	9,916	3,161	31.88 %
No Remote, Low/Mod In-Person	2,990	1,125	37.63 %
No Remote, High In-Person	1,591	534	33.56 %
Low/Mod Remote, No In-Person	11,602	4,554	39.25 %
Low/Mod Remote, Low/Mod In-Person	7,468	2,930	39.23 %
Low/Mod Remote, High In-Person	5,116	1,923	37.59 %
High Remote, No In-Person	3,549	1,550	43.67 %
High Remote, Low/Mod In-Person	4,073	1,682	41.30 %
High Remote, High In-Person	3,943	1,696	43.01 %

term	**Odds Ratio**	**P-Value**
(Intercept)	0.367	P<.001
Care Pattern		
High Remote, High In-Person	1.236	P<.001
High Remote, Low/Mod In-Person	1.198	P<.001
High Remote, No In-Person	1.299	P<.001
Low/Mod Remote, High In-Person	0.973	0.567
Low/Mod Remote, Low/Mod In-Person	1.079	0.094
Low/Mod Remote, No In-Person	1.066	0.136
No Remote, High In-Person	0.823	0.003
No Remote, Low/Mod In-Person	reference	
No Remote, No In-Person	0.791	P<.001
Age Group		
< 50	reference	
50-64	1.106	P<.001
65-74	1.052	0.132
75+	0.932	0.115
Sex		
Male	reference	
Female	0.997	0.876
Race and Ethnicity		
NH Asian	1.115	0.005
NH Black or African American	0.864	P<.001
NH White	reference	
Hispanic or Latino	0.894	0.017
Other	0.916	0.105
Preferred Language		
Chinese	1.204	P<.001
English	reference	
Spanish	1.351	P<.001
Other/Unknown	1.088	0.023
Treatment Intensity		
Diet Only	reference	
Non-Insulin Medication	1.328	P<.001
Insulin	1.679	P<.001
Charlson Comorbidity Score		
0-2	reference	
3+	1.101	0.001
Insurance Coverage		
Medicaid	reference	
Medicare	1.052	0.055
Healthy Workers	1.095	0.003
Uninsured	1.051	0.136
Neighborhood Socioeconomic Status		
Q4-Q5 (Higher SES)	reference	
Q1-Q3 (Lower SES)	0.981	0.422

Chapter 5: Conclusion and Summary

In this dissertation, I present three papers that assess the barriers to digital health technology use, the impact of digital support interventions on patient portal uptake and use, and the effect of remote care engagement patterns on A1c levels among patients with diabetes to inform solutions to reduce digital exclusion and advanced digital equity. As digital health technology and remote care engagement continue to transform how healthcare is accessed, experienced, and delivered, understanding who benefits (who remains digitally excluded) is of paramount importance[4,69]. This research is of particular consequence given that despite years of research and efforts to reduce barriers to digital health technology, disparities in use persist[16,19,27,46,48,49,75]. The findings from this dissertation underscore that while digital tools offer great promise, their full potential is not equitably realized across populations. Together, these papers advance our understanding of the skill-based, structural, and behavioral barriers to digital health engagement in a large, racially and linguistically diverse safety-net population.

In my first paper, I identify core usability and skill-related barriers older adults face when interacting with digital health technology, drawing from in-depth qualitative video observations and task performance and participant questionnaire data. Findings show that challenges such as unfamiliarity with device navigation, low confidence/inability to progress through multistep tasks, and difficulty identifying clickable elements are not rare occurrences but are foundational barriers that significantly impede access and use. In addition, poor interface design and insufficient notification systems (such as explaining where an error logging in happened) create learnability and operability barriers that hinder successful use. These barriers highlight the urgent need for interventions to support individuals with developing these skills, which are not just important for healthcare engagement but also for everyday digital engagement. It also highlights the importance of applying effective design principles, recognized for decades, to enhance the usability of digital tools[78].

My second paper builds on these findings by investigating a person-centered, tailored digital training intervention to support uptake and use of the patient portal among a population with low levels of patient portal engagement. Participants were provided with brief basic digital support/technical assistance or tailored digital training that supported participants in navigating the patient portal and any questions they had about the platform. This paper shows that digital training can meaningfully improve portal engagement. However, this improvement is not uniform across all populations. Basic support showed modest improvements in the number of MyChart users; however, Spanish speakers were significantly more likely to use the patient portal after receiving technical assistance only. The tailored training was particularly beneficial for those with low engagement at baseline; we observed a 90% increase in the number of users after receiving more detailed and person-centered digital training. This study highlights that different types of digital support differentially benefit different groups and suggests that efforts to provide language-concordant, culturally sensitive digital assistance is a viable solution for addressing disparities in digital technology use[15,16,29,38].

The final chapter of my dissertation looks long-term, providing longitudinal evidence linking patterns of combined in-person and remote care engagement (including portal use, telehealth, and secure messaging) with clinical outcomes among patients with diabetes. This is particularly important given the technological advancements in patient-facing digital health tools and when working to reduce inequities in digital engagement. Notably, higher engagement in care—through combined remote and in-person encounters—was associated with statistically significant relative reductions in A1c levels over time. In absolute terms, these reductions ranged from approximately 0.3% to 0.8% depending on baseline A1c and care utilization pattern, meaning that patients with higher starting A1c experienced larger absolute improvements. While the absolute magnitude of change was modest for some, the size of these reductions achieved or approached the threshold considered clinically meaningful, depending on the patient's baseline A1c. This suggests that consistent engagement, particularly when remote care supplements in-person encounters, may meaningfully improve glycemic control and translate into better long-term outcomes. However, there were clear differences in sociodemographic characteristics of patients based on remote care patterns, suggesting persistent disparities in digital health technology use, even among a population actively engaged in their care. These findings affirm the clinical utility of digital modalities for chronic disease management, while also reinforcing prior evidence and concerns about disparities in access and use of digital health technology and remote care engagement[9,10,27,46,69,75].

Collectively, these papers indicate that advancing digital equity requires moving beyond measuring disparities to understanding their roots, whether skill-based, usability-related, or structural; measuring remote care to appropriately identify disparities and examine clinical outcomes; and advocating for policy and reimbursement changes that better support hybrid care. Moreover, these findings emphasize that remote care and digital engagement are not a one-size-fits-all solution and that their differential impacts must be considered. Different communities face different barriers to access and use of digital health tools and similarly have different perceptions of the value of each modality, so future work must examine how individual- and community-level skills, usability challenges, and structural barriers interact to shape which modalities and combinations of engagement are both accessible and effective for different populations.

Building on this understanding of skills and barriers, accurately measuring remote care engagement is critical. To identify disparities and assess clinical impact, remote care should be across multiple modalities—such as telehealth visits, secure messaging, and patient portal use—considering each independently and in combination, rather than as a single overall construct (i.e., total volume of care). Such nuanced measurement can clarify which forms of engagement are most effective for which populations and inform the design and delivery of hybrid care models. Recognizing these distinctions is critical to designing interventions that maximize engagement and clinical benefit across diverse patient groups and underscore that remote tools used to support remote care must be paired with accessible and user-friendly design, robust support infrastructure, and thoughtful integration with in-person care to prevent further marginalization of high-risk populations.

These insights have important policy implications. To promote equitable access and use of digital health tools and engagement in remote care, reimbursement structures and incentives should recognize the value of multiple digital modalities and support interventions that enhance usability, provide patient support, and facilitate hybrid models. Aligning reimbursement, quality metrics, and care delivery standards with equity-focused deployment of digital services can help ensure that digital health innovations improve access and outcomes without exacerbating existing disparities. Policies that reward comprehensive engagement, rather than volume alone or engagement with “billable” appointments; support language-concordant, culturally sensitive digital assistance; and adhere to proven usability principles in the design and dissemination of digital health tools, are essential to creating an inclusive healthcare environment that leverages digital tools to reduce inequities rather than reinforce them.

This dissertation contributes critical empirical evidence to a growing body of research focused on digital health equity. By examining the individual-level skills required to engage with digital tools, evaluating targeted support interventions, and linking patterns of digital care use with clinical outcomes, this work illustrates the multifaceted barriers and opportunities in achieving equitable digital health engagement. As healthcare systems continue to expand digital offerings, these technologies must be developed and deployed in ways that recognize and respond to users' capabilities, contexts, and needs; or at a minimum, adhere to the long-standing usability guidelines proven effective in creating user-friendly digital tools[78]. Efforts to improve digital literacy and skills, design more user-friendly interfaces, and evaluate digital interventions through an equity lens are not only timely—they are foundational to ensuring that innovations in healthcare do not widen existing disparities but rather serve as tools to reduce them.

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2. Rapson T, Naranjo-Arellano M, Ralston JD, Garcia F, Green BB, Gutierrez C, Guzman-Estrada S, Khoong E, Sarkar U, Shin J, Zhou C, Fishman P, Ramirez M, Lyles C. Impact of Digital Support Interventions on Patient Portal Use Among Patients in an Urban Safety-net Health System. Submitted for publication. 2025